Earth's Resources &
Human Impact

How do changes in Earth's system impact our communities and what can we do about it?

OpenSciEd

MIDDLE SCHOOL SCIENCE

TEACHER EDITION

How do changes in Earth's system impact our communities and what can we do about it?

Earth's Resources & Human Impact: Droughts & Floods

OpenSciEd Unit 7.6

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UNIT OVERVIEW

How do changes in Earth's system impact our communities and what can we do about it?

This unit on Earth's resources and human impact begins with students observing news stories and headlines of drought and flood events across the United States. Students figure out that these drought and flood events are not normal and that both kinds of events seem to be related to rising temperatures. This prompts them to develop an initial model to explain how rising temperatures could cause both droughts and floods and leads students to wonder what could cause rising temperatures, too. This initial work sets students up to ask questions related to the query: How do changes in Earth's system impact our communities and what can we do about it?

Students spend the first lesson set gathering evidence for how a change in temperature affects evaporation, precipitation, and other parts of Earth's water system. They use evidence to support a scientific explanation that two climate variables (temperature and precipitation) are changing precipitation patterns in the case sites they investigated. Students apply these ideas to related phenomena—sea ice decline and wildfires—in the Arctic. Students then launch into their questions about rising temperatures in the second lesson set. They analyze data about atmospheric gas concentrations, how gases relate to atmospheric temperature, and how present-day human activities are changing the concentration of those gases. Students develop and use a model of Earth's carbon system to explain how carbon dioxide accumulates in the atmosphere. Students figure out that the rising temperatures are caused by an imbalance in Earth's carbon system.

Students are ready to solve the problem in the final lesson set. While students can define the problem as a carbon imbalance, they realize that obvious solutions, such as eliminating fossil fuel use, are actually much more complicated than at first glance. This motivates students to evaluate different kinds of solutions and how they are implemented in communities. Students work through a systematic evaluation process to consider (1) each solution's potential to solve the carbon imbalance, (2) tradeoffs associated with solutions based on student-identified constraints, and (3) whether the solution in question makes sense for their community's stakeholders.

Through these investigations, students will

- analyze and interpret data that indicate long-term climate variables (temperature and precipitation) are changing in communities,
- develop and use models to explain how changing variables in Earth's water and carbon systems are impacting human communities that depend on those systems,
- construct an explanation for how increased temperatures can cause changes to a community's water resources,
- argue from evidence that rising temperatures result from an imbalance in Earth's carbon system,
- define the problem as an imbalance in Earth's carbon system due to greenhouse gas accumulation, with no easy solutions to quickly fix it,
- evaluate a variety of solutions based on how well they meet the criteria of reducing the carbon imbalance given the many societal constraints students identified, and
- communicate about a community resilience designed to account for stakeholders' needs while also correcting carbon imbalances and adapting to current changes experienced in the community.

Building Toward NGSS Performance Expectations

MS-ESS3-1:
Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes.

MS-ESS3-5:
Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.

MS-ESS3-3:
Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

MS-ESS3-4:
Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

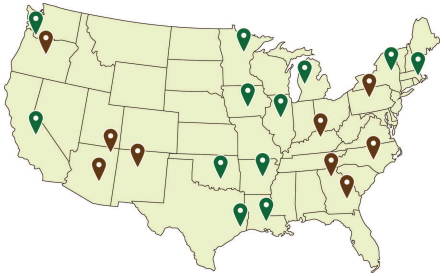
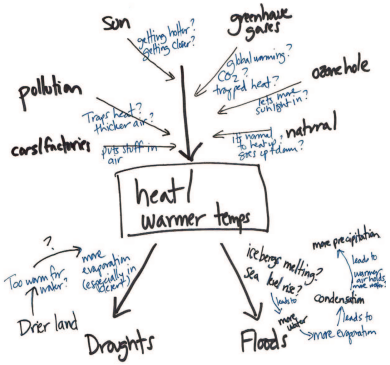
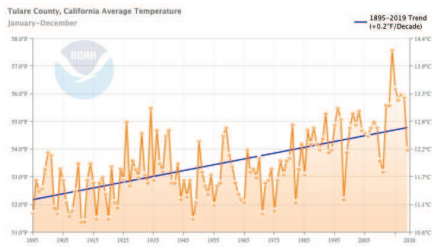
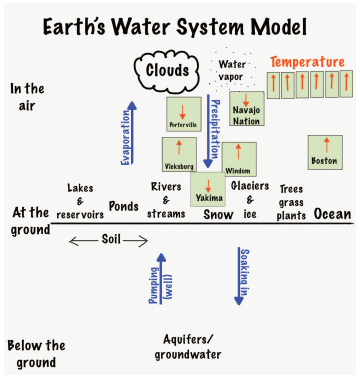
MS-ETS1-2:
Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

UNIT STORYLINE

How students will engage with each of the phenomena

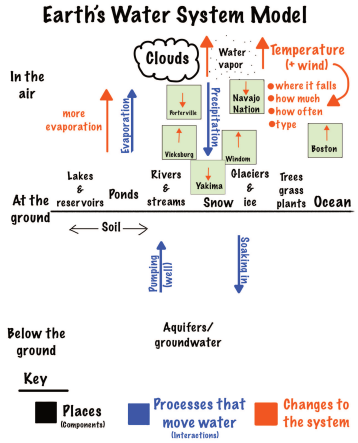
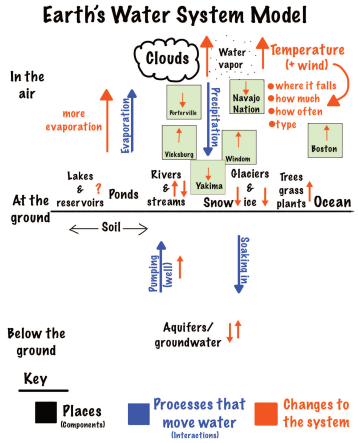
HANDS-ON/ LAB ACTIVITIES | VIDEOS OR IMAGES | DATA SETS | READINGS | COMPUTER INTERACTIVES

Unit Question: How do changes in Earth's system impact our communities and what can we do about it?

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 1 3 days **Why are floods and droughts happening more often?** Anchoring Phenomenon	 *Floods and droughts are increasing across the US and there is a pattern of rising temperatures associated with both.*	We observe two news clips of extreme flood and drought events and share our own water stories. We examine headlines that show a "new normal" of increased floods and droughts and notice a pattern of rising temperatures. We develop an initial model explaining what could be causing warmer temperatures and how warmer temperatures could lead to both droughts and floods. We develop a Driving Question Board (DQB) and brainstorm investigations and sources of data that could help us figure out answers to our questions. We figure out: • Floods and droughts are increasing. • Floods and droughts are linked to a change in precipitation. • Heat waves and warmer temperatures are linked to the increase in floods and droughts.	
LESSON 2 3 days **What would we normally expect for these places and how do we know it's really changing?** Investigation	 *Long-term measurements show that changes in temperature and precipitation are not normal for these places.*	We develop a systems model to describe Earth's water system. We analyze data to determine what is normal and not normal about temperature and precipitation as it relates to floods and droughts. We do this with our community and six case sites in the United States. We figure out: • Earth's freshwater is distributed in the air, at the ground, and below the ground and moves in between these spaces. • Year-to-year variability in precipitation and temperature is a normal pattern. • Data averaged over long periods of time can give us the trends for an area. • Precipitation or heavy storm events show increasing trends in flood areas. • Precipitation, groundwater, and snowpack show decreasing trends in drought areas. • Temperatures are increasing for all of the places we investigated.	

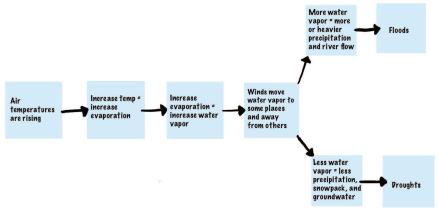
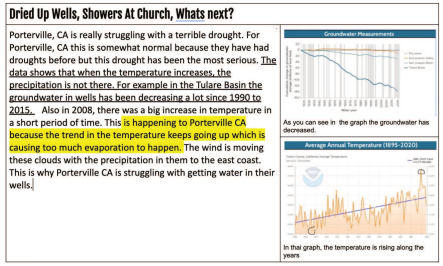
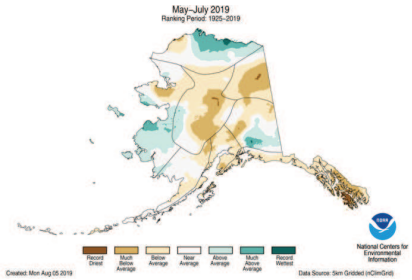
⇓ **Navigation to Next Lesson:** We figured out that increased temperatures seem to be linked to increases in floods and droughts, but we have a lot of questions about what is causing this and where all of the water is coming from or going to. We want to look at more places than just the two places in the videos to help figure out what is happening.

⇓ **Navigation to Next Lesson:** We are wondering if the rise in temperature is related to some places being drier and some places being wetter.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 3 2 days **How would increased temperatures affect evaporation?** Investigation	 *When we warm wet and dry soil at the surface we observe an increase in evaporation. This increases the overall water vapor in the air which does not move around the atmosphere evenly.*	We create bottle setups to test how increased temperatures affect evaporation rates. We also view visualizations of water vapor movement across the US and ocean temperatures in an open system. We figure out: • Increased temperatures lead to increased evaporation rates and more water vapor in the atmosphere. • Evaporation happened in all cases, but more moist conditions had higher evaporation rates than drier conditions. • The amount of water vapor is not the same for every location and winds move the water vapor to different locations. • Drought areas may be getting drier when water vapor moves away from the location, while flood areas may be getting wetter when more water vapor moves toward the location. • Cooler ocean water and landforms may affect how much water vapor gets to a location.	
LESSON 4 1 day **Are rising temperatures affecting anything else in Earth's water system?** Investigation	 *Snow, ice, glaciers, and groundwater are decreasing in many areas, while sea level is rising. Earth's water system is changing.*	We obtain additional scientific and technical information about other components of Earth's water system and how those components are changing as temperatures increase. We conclude that all components and processes in the system have been affected by a temperature rise. We update our model and add an entry to our Progress Tracker. We figure out: • Changes to sources of water affect communities in different ways. • A small change in temperature in the atmosphere can have big changes in Earth's water system.	

⇓ **Navigation to Next Lesson:** We observe that increased temperatures cause an increase in evaporation and water vapor in the air. Winds and ocean temperatures affect the movement of water vapor in the atmosphere explaining more about the location of droughts and floods. We wonder how increased temperatures may be affecting other parts of Earth's water system.

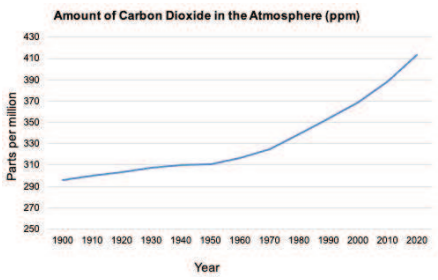
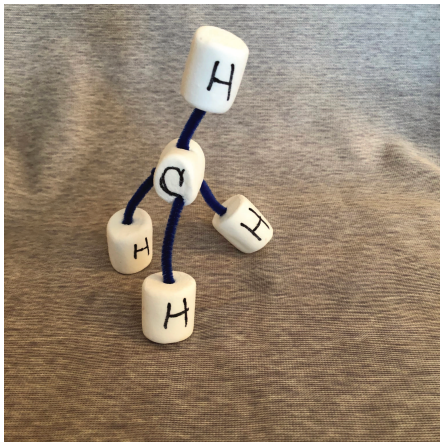
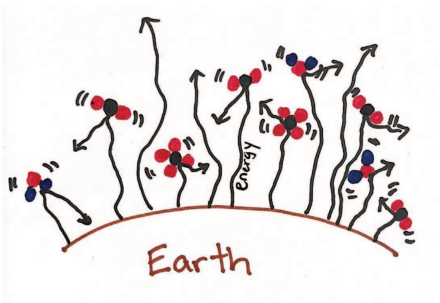
⇓ **Navigation to Next Lesson:** We figure out that a small increase in temperature is having big impacts on all parts of the water system creating different problems for communities. We think we can explain how rising temperatures have led to droughts and floods in our communities.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 5 2 days **How are rising temperatures changing water stories in these communities?** Putting Pieces Together, Problematizing	 *Changes in community water sources can be explained through data and evidence.*	We use our key model ideas from previous lessons to construct explanations, using evidence, about how changes in temperature are having impacts on the water stories in our case site communities. We peer review our explanations and revise them using the feedback from our peers. We figure out: • Small changes in one part of Earth's system can have big impacts on another part. • An increase in temperatures can be used to explain the cause for multiple climate-related phenomena.	
LESSON 6 2 days **How are rising temperatures connected to two seemingly different phenomena?** Putting Pieces Together, Problematizing	 *Changes reported by headlines and by an Alaskan whaler can be explained through the increasing temperatures in Alaska.*	We revisit our Alaskan headlines about wildfires and also learn about another community in Alaska that is experiencing multi-year sea ice loss. We apply our key model ideas in a transfer task to explain how an increase in temperatures is causing both phenomena to occur. We figure out: • An increase in temperatures can cause an increase in both wildfires and a decrease in multi-year sea ice.	

⇓ **Navigation to Next Lesson:** Now that we understand what is causing droughts and floods, we are wondering if we can apply these ideas to another headline we read about in Lesson 1.

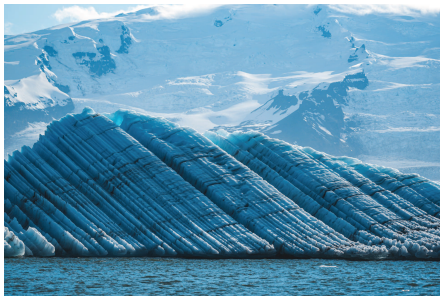
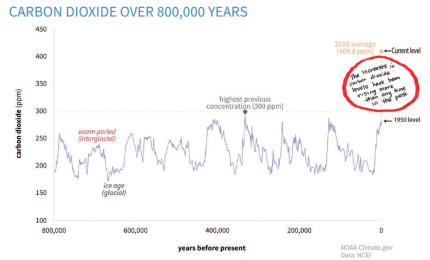
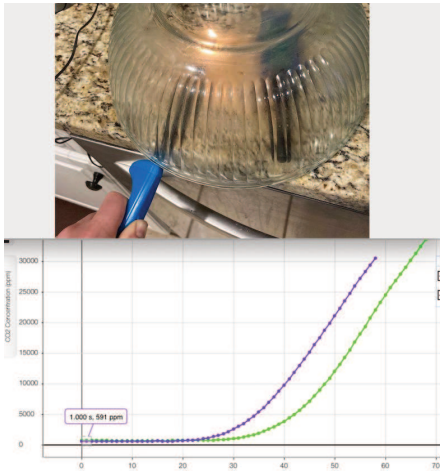
⇓ **Navigation to Next Lesson:** We figured out that the Alaskan claims are caused by rising temperatures. We also believe that the temperatures may continue to rise in the future. After visiting the class model and the Driving Question Board, we realized we still have questions about why the temperatures are increasing, along with what is causing that increase.

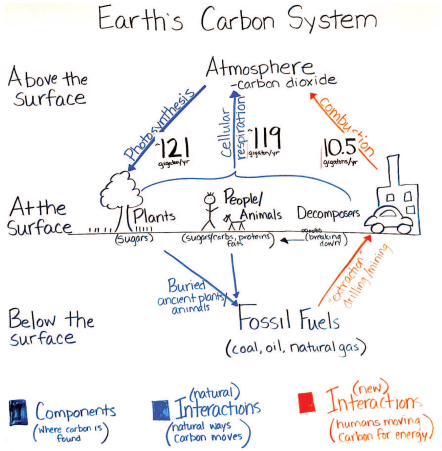
Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 7 1 day **Are there any changes in the air that could be related to rising temperatures?** Investigation	 *The concentration of some atmospheric gases have stayed relatively stable over time, while other gases have increased at an unusual rate.*	We wonder if changes in the air are related to the rise in temperatures. By looking at data, we build our understanding of the meaning of parts per million and figure out how to find the percent change in the quantity of these gases over time. We notice that, while some gases have not changed at all, some have changed very little, and other gases show an unusual increase over the 100-year period. We figure out: • The atmosphere is made from different concentrations of gases. • Some gases have not really changed over time, but some show an unusual increase. • Carbon dioxide and methane are a small percent of the atmosphere but are increasing at a high rate.	**Model Ideas List** • Some gases have not really changed over time, but some show an unusual increase. • Carbon dioxide and methane are a small percent of the atmosphere but are increasing at a high rate.
LESSON 8 2 days **Are changes in carbon dioxide and methane related to or causing temperatures to increase?** Investigation	 *Greenhouse gases absorb and release energy in the atmosphere regulating Earth's temperature.*	We use molecular models to investigate the way molecules move in response to energy transfer. We investigate this idea further using an interactive showing how molecules move when energy is absorbed. Using these ideas and the ideas from a reading, we figure out that because greenhouse gases absorb, vibrate, and release energy, they keep our atmosphere warm. We apply these ideas to what we learned about GHGs increasing in our atmosphere to figure out that increasing GHGs are why temperatures are currently increasing. We figure out: • GHGs are gas molecules in the atmosphere that absorb, vibrate, and release energy back into the atmosphere. This keeps Earth at a livable temperature. • As the amount of GHGs increases in our atmosphere, they cause the atmosphere to get warmer.	

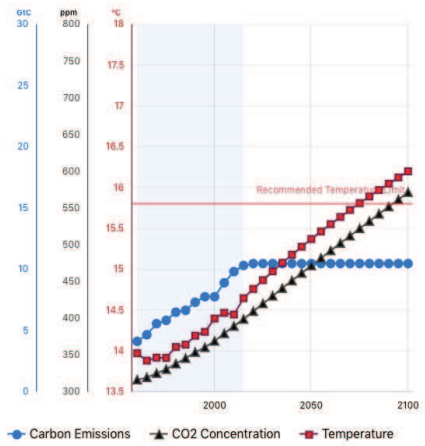
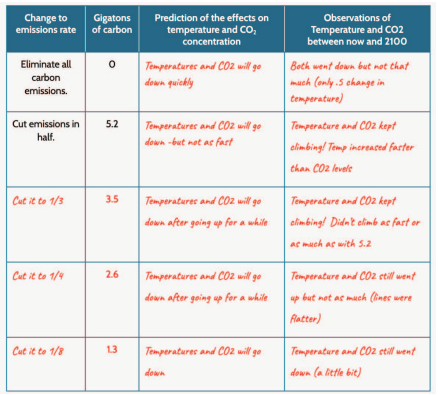
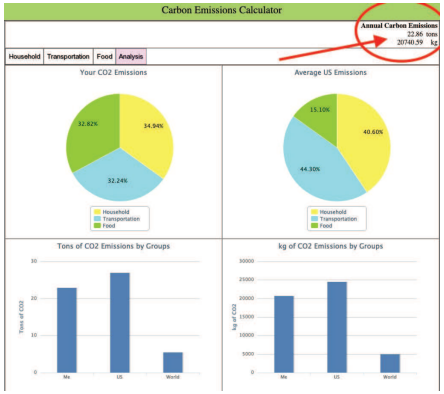
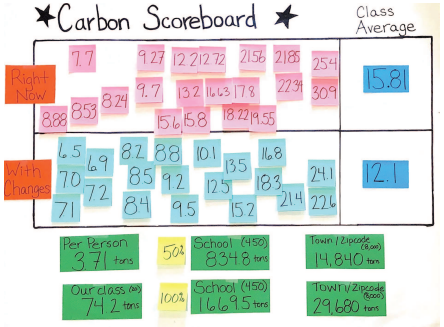
⇓ **Navigation to Next Lesson:** We figure out that carbon dioxide and methane, which make up a small percent of the atmosphere, are increasing at a high rate. Based on these new findings, we wonder if the gases that are rising are related to or causing the temperatures going up.

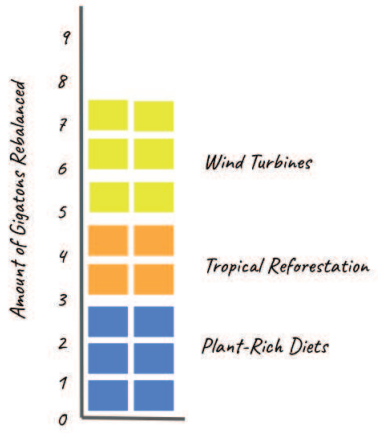
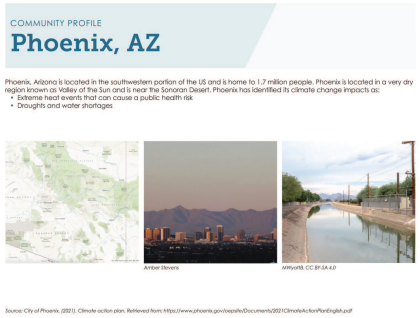
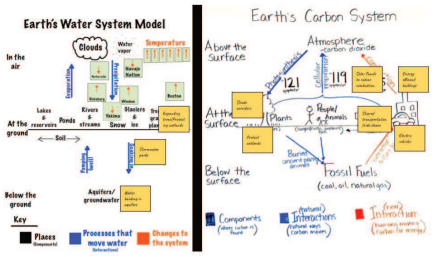
⇓ **Navigation to Next Lesson:** We figure out that increasing GHGs are causing the temperatures to rise, and we wonder if this rise in GHGs is normal.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 9 1 day **Are the changes in the amount of CO2 in the atmosphere part of normal cycles that Earth goes through?** Investigation	 *Ice core samples contain trapped bubbles of gases.*	We carry out an investigation to determine if gas can be trapped in ice. When we figure out it can, we find out more about how scientists use ice core samples from locations on Earth that have very old ice to determine the amounts of carbon dioxide in the air over time. We focus on carbon dioxide because we know that recently it has been rising the most. We figure out: • Levels of CO_2 are increasing at a faster rate than the normal cycles, which means the new levels are out of the normal range. • CO_2 levels over the last 100 years have been rising consistently. • We look back at data from hundreds of thousands of years through analyzing ice core data and find there are cycles, but the last 100 years are not following the normal cycle.	 *Climate.gov*
⇓ Navigation to Next Lesson: We figured out that CO2 levels are increasing at a faster rate than normal cycles. Now we want to know what is different today than in the past that is causing more CO2 to be in the air?			
LESSON 10 2 days **What is happening in the world to cause the sharp rise in CO2?** Investigation	 *Data shows a rapid increase in fossil fuel use, CO2 emissions, and human population in the last two centuries.*	We zoom into the last 200 years of Earth's history to understand what led to a rapid increase in CO_2 emissions. We watch a visualization and read about key innovations in human history that transformed the types of energy used to power our communities. We figure out: • Large deposits of mineral resources (such as "fossil fuels") are used to power our communities and transportation networks, and this use has increased over time. • Population growth increases consumption of resources (per-capita consumption). • A growing population that consumes large amounts of mineral resources is correlated with the rapid increases in CO_2 in Earth's atmosphere.	**Model Ideas List** • Some gases have not really changed over time, but some show an unusual increase. • Carbon dioxide and methane are a small percent of the atmosphere but are increasing at a high rate. • GHGs absorb, vibrate, and release energy back into the atmosphere. • As the amount of GHGs increase in our atmosphere, they cause the atmosphere to get warmer. • CO_2 levels are higher than any time in the past and seem to be increasing really fast outside the normal range. • ↑ population + ↑ mineral resource use = ↑ CO_2 in atmosphere • CO_2 and H_2O (greenhouse gases) are products of the combustion of fossil fuels.
⇓ Navigation to Next Lesson: We are wondering what fossil fuels, which provide us with energy, are made of?			

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 11 1 day **Why could burning fossil fuels create a problem for CO2 in the atmosphere?** Investigation	**Atmosphere** Number on Dice / What to do 1 — Stay in the atmosphere. Carbon dioxide can stay in the atmosphere for as little as 30 years or up to thousands of years. 2 — Stay in the atmosphere. Carbon dioxide can stay in the atmosphere for as little as 30 years or up to thousands of years. 3 — Stay in the atmosphere. Carbon dioxide can stay in the atmosphere for as little as 30 years or up to thousands of years. 4 — Stay in the atmosphere. Carbon dioxide can stay in the atmosphere for as little as 30 years or up to thousands of years. 5 — Go to the plant and animal reservoir. You are used by a plant in photosynthesis and may be eaten by an animal. 6 — Go to the plant and animal reservoir. You are used by a plant in photosynthesis and may be eaten by an animal. *Burning fossil fuels adds CO2 to the atmosphere at a faster rate than is taken out by photosynthesis.*	We modify an Earth's Carbon System model to represent the locations of carbon and processes that move carbon around. We simulate these processes using a kinesthetic activity. We figure out that photosynthesis cannot take up CO_2 at the same rate that burning fuels puts CO_2 in the atmosphere and that this is creating a buildup of CO_2 in the atmosphere. We figure out: • Photosynthesis is a way to get CO_2 out of the atmosphere, but the rate of photosynthesis is not enough to take up CO_2 from combustion of fossil fuels and cellular respiration combined. • Combustion of fossil fuels is creating a carbon imbalance in the atmosphere.	
⇓ **Navigation to Next Lesson:** We figured out that CO2 entering the atmosphere is not balanced by CO2 taken out of the atmosphere. We think we can explain what is causing the temperatures to rise.			
LESSON 12 2 days **How are changes to Earth's carbon system impacting Earth's water system?** Putting Pieces Together	Tweet Claims Chart Claims — Climate change is having effects all over the world. Climate change creates floods, typhoons, landslides, droughts, and wildfires. We need to protect our environment by planting more trees to prevent air pollution. We need to plant more trees to prevent flooding. Climate change is caused by air pollution. Claims that match our understanding — Climate change is having effects all over the world. Claims that are inaccurate or need clarification — Climate change creates floods, typhoons, landslides, droughts, and wildfires. We need to protect our environment by planting more trees to prevent air pollution. We need to plant more trees to prevent flooding. Climate change is caused by air pollution. Our clarification of the claims — Natural disasters occurred before we added extra carbon to our system. The extra carbon is keeping extra energy in our atmosphere, warming things up. The increased temperatures cause evaporation to occur faster. The water vapor moves from one place to another, and some places get wetter while others get drier. Pollution is caused by our use of fossil fuels putting extra carbon into the air. The extra carbon needs to be removed, but that would be a lot of trees. Carbon makes global warming happen, and global warming causes the climate to change. *Some social media posts need additional clarification to reflect accurate science ideas.*	We model the causal relationship between fossil fuel use and changing water resources. We review a tweet regarding climate change and its impacts, break the tweet down into claims, and clarify the information as a class. We take an assessment identifying claims made in another tweet and refute any inaccurate claims by providing an explanation of the causal relationships between human activities and climate change. We figure out: • Changes in the carbon system have an effect on Earth's water system. • We can use our scientific understanding to clarify claims about the connection between the carbon system and Earth's water system.	
⇓ **Navigation to Next Lesson:** While we now understand the connection between the changing carbon system and our changing water system, we still have questions about what we can do to help fix the problem of our changing climate.			

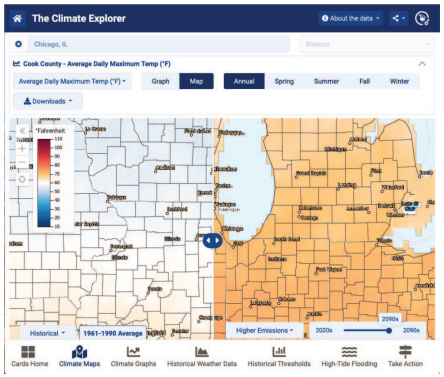
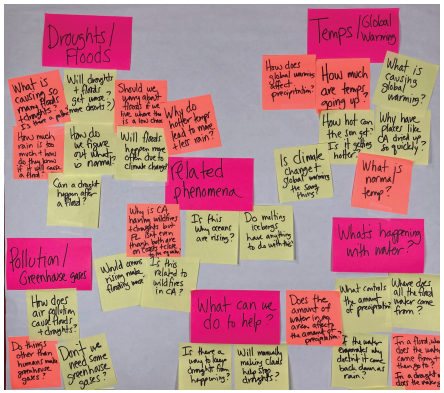
Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 13 1 day **Why is solving the climate change problem so challenging?** Problematizing	 *As CO2 emissions increase, so do global temperatures. To reach equilibrium, emissions need to be cut by 9 gigatons per year.*	We determine that the problem of increasing temperatures is due to the CO_2 imbalance in the atmosphere caused by human combustion. We use a simulation to determine what cuts are needed to emissions rates to reach equilibrium. We figure out: • Our carbon imbalance in our atmosphere is due to human combustion. • We release an estimated 10.5 gigatons of CO_2 from human combustion. • Simply cutting emissions in half will not halve temperature increases. • To reach CO_2 emissions equilibrium, emissions would need to be cut by 9 gigatons. • Any reduction in emissions helps to slow the global temperature increase.	
⇓ Navigation to Next Lesson: We think we've heard of things we can do to solve this, like turning off lights, changing out bulbs, driving less, eating less meat. But how much do our daily actions impact the CO2 levels in the atmosphere?			
LESSON 14 1 day **What things can people do to reduce carbon dioxide going into the atmosphere?** Investigation	 *Everyday actions and behaviors emit CO2, and changes to those behaviors can reduce emissions.*	We calculate our daily carbon footprint and create a class Carbon Scoreboard. We calculate the average carbon footprint for someone in our class and compare it to the average American's footprint. We revisit our footprint and choose carbon reduction activities and behaviors we are willing to make that would reduce our carbon emissions and would benefit our family in other ways. We compound the effects of these changes if everyone in our classroom, school, and community are willing to make changes. We figure out: • Changes to daily activities and behaviors can reduce atmospheric CO_2. • If more people do these things, we will have further reduction in CO_2. • Changes to behaviors are limited by other constraints, so each person may have different options available to them.	
⇓ Navigation to Next Lesson: We are wondering not only how to engage more people in these kinds of behaviors, but also what other solutions could we consider on a larger scale?			

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 15 3 days **How can large-scale solutions work to reduce carbon in the atmosphere?** Investigation	Evaluating the solution against our criteria and constraints: Solution / Criteria: Ability to reduce CO_2 in the atmosphere / Constraint 1 / Constraint 2 / Constraint 3 / Constraint 4 / Constraint 5 / Constraint 6 Plant Rich Diets ●●● Reducing Food Waste ● Wind Turbines ● LED Lighting ● Recycling ● Reducing Plastic ● Reforestation ●●● *Solutions have differing effects towards the reduction of atmospheric CO2. Implementing multiple solutions can compound the reduction in CO2 emissions.*	We use a Design Matrix to organize the different solutions for reducing CO_2 in the atmosphere that we evaluated last class. From our evaluations we determine our constraints for the solutions in trying to meet the criteria of reducing the imbalance of carbon in the air. We reevaluate each solution using our constraints and decide that multiple solutions would need to be implemented to meet our criteria. We figure out: • There are many different solutions that can be implemented to reduce the amount of CO_2 being emitted into the atmosphere. • There are some solutions that help take CO_2 out of the atmosphere, though there are very few of these. • Implementing only one solution will not lead to a decrease of CO_2 in the air. Multiple solutions need to be done together in order for any reduction to occur to help decrease the imbalance of CO_2 in the air.	
LESSON 16 1 day **How are these solutions working in our communities?** Investigation	 *Community plans include ways to mitigate carbon or adapt to changes.*	In this lesson, we obtain information from community plans to determine how the solutions are being used in the communities and how they rebalance carbon and/or help the community to become more resilient to changes already occurring in the community. We use these plans as examples to help motivate the need to evaluate and/or develop a plan for their own community. We figure out: • Communities develop plans to rebalance CO_2 levels in the atmosphere while also building a more resilient community adapting to changes already occurring within the community. • Plans include many solutions across different parts of the community and at different scales, from individual and family options to large-scale community solutions.	

⇓ **Navigation to Next Lesson:** We figure out some likely solutions that are accessible for many people. Now we want to know who is responsible for implementing the solutions and what people are already doing.

⇓ **Navigation to Next Lesson:** We are wondering if our community has a plan or if we should develop a plan for our community.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 17 4 days **What solutions work best for our school or community?** Investigation, Putting Pieces Together	 *Schools, communities, and businesses adopt new behaviors or technologies to contribute to rebalancing carbon and to build resilience to changes happening now.*	We create a checklist for what a resilience plan for our school and local community should include. We work in groups to design resilience plans that contribute to the long-term rebalancing of carbon and also prepare the community for change. We provide feedback to other groups and evaluate the plans by asking questions. We brainstorm how to communicate our plans to other audiences. We argue for the one best for our community. We figure out: • Communities can design plans to help rebalance carbon dioxide which will take awhile, but they can also do things to make the community resilient to changes happening now. • Communities design plans based on community member needs and characteristics of the community itself. • Some places and people may be more at risk for impacts in the community. • Solutions adopted at home and school can make the whole community more resilient.	*What an effective plan does* / *What we should include* *Tell people about the problem(s).* ☐ Our community will experience more drought or flood, or both. ☐ Some seasons might become drier or wetter than before. ☐ Some areas or some people in our community might be at more risk or more impacted. *Teach people about what's causing the problem.* ☐ CO_2 is building up in the atmosphere. ☐ CO_2 traps energy in the atmosphere that causes temperatures to rise. ☐ Warmer temperatures means more evaporation and water vapor in the atmosphere, but it doesn't fall evenly. ☐ Photosynthesis is one way to take CO_2 out of the atmosphere but there are also ways to reduce putting it in the atmosphere. Some combination is necessary to solve the problem. *Directs people to solutions.* ☐ Share solutions their community can take to: ○ Reduce CO_2 going into air ○ Pull CO_2 out of air ○ Be prepared for higher temperatures ○ Be prepared for more/less precipitation. ☐ Give people more than one way to help. ☐ Include different actions that different people can take in different situations.
⇓ **Navigation to Next Lesson:** We will celebrate learning by answering questions from the DQB.			
LESSON 18 1 day **What can we explain now, and what questions do we still have?** Putting Pieces Together	 *Asking questions about phenomena gives us a mission for our science learning.*	We identify the questions from our DQB that we can now answer. We celebrate all that we have learned in this unit and across the school year. We spend time identifying the questions that we did not answer and build a new DQB of these questions. We create a plan to answer some of them on our own and in school next year and beyond. We figure out: • Science learning is about asking questions and gathering evidence to answer those questions. • As some questions get answered, new questions come up.	
⇓ **Navigation to Next Lesson:** This is the last lesson in the unit.			

LESSONS 1-18
33 days total

TEACHER BACKGROUND KNOWLEDGE

Lab Safety Requirements for Science Investigations

It is important to adopt and follow appropriate safety practices within the context of hands-on investigations and demonstration, whether this is in a traditional science laboratory or in the field. In this way, teachers need to be aware of any school or district safety policies, legal safety standards, and better professional practices that are applicable to hands-on science activities being undertaken.

Science safety practices in laboratories or classrooms require engineering controls and personal protective equipment (e.g., wearing safety goggles, non-latex aprons and gloves, eyewash/shower station, fume hood, and fire extinguishers). Science investigations should always be directly supervised by qualified adults, and safety procedures should be reviewed annually prior to initiating any hands-on activities or demonstration. Prior to each investigation, students should also be reminded specifically of the safety procedures that need to be followed. Each of the lessons within the OpenSciEd units include teacher guidelines for applicable safety procedures for setting up and running an investigation, as well as taking down, disposing of, and storing materials.

Prior to the first science investigation of the year, a safety acknowledgement form for students and parents or guardians should be provided and signed. You can access a model safety acknowledgement form for middle-school activities at the following location: http://static.nsta.org/pdfs/SafetyAcknowledgmentForm-MiddleSchool.pdf.

Disclaimer: The safety precautions of each activity are based in part on use of the specifically recommended materials and instructions, legal safety standards, and better professional safety practices. Be aware that the selection of alternative materials or procedures for these activities may jeopardize the level of safety and, therefore, is at the user's own risk.

Please follow these lab safety recommendations for any lesson with an investigation:

1. Wear safety goggles (specifically, indirectly vented chemical splash goggles), a non-latex apron, and non-latex gloves during the set up, hands-on investigation, and take down segments of the activity.
2. Immediately wipe up any spilled water and/or granules on the floor, as this is a slip-and-fall hazard.
3. Follow your teacher guide for instructions on disposing of waste materials and/or storage of materials.
4. Secure loose clothing, remove loose jewelry, wear closed-toe shoes, and tie back long hair.
5. Wash your hands with soap and water immediately after completing this activity.
6. Never eat any food items used in a lab activity.
7. Never taste any substance or chemical in the lab.

Specific safety precautions are called out within the lesson using this icon and a callout box.

TEACHER BACKGROUND KNOWLEDGE

What is the anchoring phenomenon and why was it chosen?

This unit begins by introducing students to two phenomena from different parts of the country: a drought event in California and a flood event in Mississippi. The anchor lesson then broadens beyond those two events to reveal a pattern of unusual drought and flood events in recent years from communities across the nation. The move to broaden to related events is important. It helps students see that, while each single event may initially appear to be "random," they are part of a pattern of unusually high and low precipitation happening in many communities, all of which seem to be linked to rising temperatures.

Each OpenScied unit's anchoring phenomenon is chosen from a group of possible phenomena after analyzing student interest survey results and consulting with several external advisory panels. We selected this anchor for the following reasons:

1. It is relevant to communities across the country and allows for you to localize parts of the unit using events and data from your community. Other climate-related phenomena considered seemed distant to some communities or only applicable (directly) to few communities (e.g., arctic ice melt, sea level rise, coral reef loss). When narrowing down to different possible phenomena, it was important that the unit help students explain current climate-related impacts in their own communities. Changes in water and water resources is one of those impacts. The unit includes support for you to integrate drought or flood events from your community in the anchor lesson and to use local precipitation and temperature data for your community in Lesson 2. There is an option to explain changes to precipitation in your community in the first Putting the Pieces Together lesson (Lesson 5). The public release version of the unit includes additional support for local solutions to changing water resources due to precipitation change (and per-capita consumption in some communities). In Lesson Set 3, students consider both carbon and water solutions that are relevant to their families and communities and presents an opportunity to create a community plan.
2. The anchoring phenomenon requires DCIs taught in OpenSciEd units that come earlier in the Scope and Sequence in order to explain it. In particular, *OpenSciEd Unit 6.3: Why does a lot of hail, rain, or snow fall at some times and not others? (Storms Unit)* and *OpenSciEd Unit 6.5: Where do natural hazards happen and how do we prepare for them? (Tsunami Unit)* and *OpenSciEd Unit 7.5: How does changing an ecosystem affect what lives there? (Palm Oil Unit)* all provide important ideas that are used again in this unit, and to explain this particular phenomenon.
3. The anchoring phenomenon can be explained using grade-level appropriate science ideas.
4. Anchoring the unit in changing precipitation patterns that cause droughts and floods helps students to develop science ideas that they can use to explain other climate-related phenomena that are impacting communities, such as wildfires.
5. Other anchoring phenomena, such as sea level rise and coral reef loss, scored high for student interest, but further investigation of these options indicated that the phenomenon would be hard to connect back to many communities, may require additional high school science ideas to explain, and may feel distant for a notable number of students.

What are the NGSS Dimensions developed in this context?

As students investigate the drought and flood events from the anchor lesson, they will figure out that each community has a unique water story. The communities depend on different water resources and those resources are mostly changing due to a precipitation and temperature change. For some communities, there is also a problem with consuming more water than can be replenished by precipitation. One thing that links all of these events together is the rise in temperature. Explaining these phenomena requires students to understand how greenhouse gases regulate atmospheric temperature and how atmospheric temperature affects water cycling. Essentially, students work to build an understanding that changes in Earth's carbon system affect atmospheric temperatures, which, in turn, impact Earth's water system.

This unit builds toward these performance expectations:
MS-ESS3-1. Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes. **MS-ESS3-3.*** Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment. **MS-ESS3-4.** Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems. **MS-ESS3-5.** Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century. **MS-ETS1-2.*** Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

*Performance Expectations marked with an asterisk are partially developed in this unit and shared with other units. Review the *Where does this unit fall within the OpenSciEd Scope and Sequence?* for more information.

Focal Disciplinary Core Ideas**	Focal Science and Engineering Practices	Focal Crosscutting Concepts
ESS3.A. Humans depend on Earth's land, ~~ocean,~~ atmosphere, and ~~biosphere~~ for many different resources. Minerals, fresh water, and ~~biosphere resources~~ are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geologic processes. The anchor phenomenon launches students into a series of investigations in Lesson Set 1 about how fresh water resources are changing in communities. Some places have too much and some too little. Across Lesson Set 1, students are given opportunities to examine how freshwater is unevenly distributed across places, and processes that allow for water to move and/or be stored. Extension learning activities can engage students in how groundwater and glacier resources are replenished in comparison to how they are used by human communities. In Lesson Set 2, students examine the role of fossil fuel use for energy, and in Lesson 10, there is an extension opportunity to explore the formation and uneven distribution of fossil fuels based on past geologic processes, that is then broadened to other Earth resources. Through discussions and readings, students learn about how these mineral resources are not replaceable over human lifetimes. **ESS3.C. Human activities have significantly altered the biosphere, ~~sometimes damaging or destroying natural habitats and causing the extinction of other species~~. But changes to Earth's environments can have different impacts (negative ~~and positive~~) for different living things.** Students fully developed this DCI in the *Palm Oil Unit*, but will apply parts of this idea again in this unit as they make connections across human activity and global change. In the previous unit, students designed land use systems to minimize impact on natural habitats and the biosphere. In this unit, students investigate how changes in Earth's environments include negative consequences of changing the normal precipitation patterns in those places. They figure out that consumption of natural resources, like fossil fuels, is impacting Earth's systems and humans.	**Asking Questions and Defining Problems.** This unit **intentionally develops** this practice. Students engage in this practice in substantial ways by asking questions and defining problems related to a complex socio-scientific issue. While students have had substantial experience with aspects of this practice in previous OpenSciEd units, this unit engages students in (1) asking questions that require sufficient and empirical evidence to answer, and (2)for the first time in middle school, asking questions to challenge the premise of an argument. **Using Mathematics and Computational Thinking.** This unit **intentionally develops** this practice. Students continue to develop and use mathematical concepts of rate and ratio reasoning to make sense of phenomena. This is similar to the work they did in the previous unit, the *Palm Oil Unit*. However, they add to this practice by using math to make sense of percent change in GHGs over time, proportional relationships between GHGs and temperature, rates of carbon fluxes that lead to imbalance, and rates of carbon offset that can solve the carbon imbalance. They also engage in using digital tools to create and/or analyze graphs of data to determine trends and patterns over time. Finally, they use mathematical concepts to support their decisions about whether carbon solutions meet the class agreed-upon criteria and constraints to reduce the carbon imbalance. **Constructing Explanations and Designing Solutions.** This practice is **key to the sensemaking** in this unit. Throughout the unit, students are gathering evidence and using reasoning to develop explanations for how precipitation is changing in communities and the mechanisms behind those changes. In Lesson 5, for example, students write an explanation to explain how rising temperatures change water stories in a community of their choice. Later in the unit, students apply science ideas to evaluate various design solutions for minimizing human impacts, both in terms of rebalancing carbon and adapting to changes in water in their communities.	**Stability and Change**. This crosscutting concept is **intentionally developed** in this unit. From the first lesson in the unit, students use the lens of stability and change. In their initial models, students explain how a small change in temperature could lead to large changes, like floods and droughts. They work toward a scientific explanation for why different communities' water resources are changing from a small rise in temperature (in Lessons 5 and 6). Stability and Change stays in the foreground throughout Lesson Set 2 as students make sense of the current level of greenhouse gas concentrations in comparison to short-term and long-term data. In the final lesson set, students ask questions about different CO_2 reducing solutions and how gradual changes over time might lead to a reduction in atmospheric carbon dioxide and global temperatures. One aspect of the final project is to communicate a message about how small changes in behavior or the use of technology, when done across a larger group of people over a sustained time, can have a greater impact on atmospheric CO_2. **Cause and Effect.** This crosscutting concept is **key to the sensemaking** in this unit. In Lesson Set 1, students begin developing a cause-and-effect diagram that explains changing precipitation patterns in communities. They continue this work in Lesson Set 2 as they question whether rising concentrations of gases in the atmosphere are correlationally or causally related to temperature change (Lesson 7). From this point forward, they use the lens of cause-and-effect as they make sense of the mechanisms that regulate temperatures in the atmosphere. Students gather evidence to support the causal relationships (by Lesson 10). Their final consensus carbon system model (Lesson 11) and cause-and-effect diagram for the unit (Lesson 12), combines all evidence to establish a causal relationship between fossil fuel use and changing water resources and the floods and droughts observed in the anchor lesson.

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ESS3.C. Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth, unless the activities and technologies involved are engineered otherwise. In Lesson Set 2, students gather evidence to show an initial correlation between human activity (specifically combustion of fossil fuels) and increased atmospheric CO_2, which is causing elevated air temperatures and changing precipitation patterns. Lesson Set 3 provides students opportunities to better understand the ways in which activities and technologies are engineered to correct the carbon imbalance and help communities adapt to changes they are already experiencing. **ESS3.D. Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding human behavior and applying that knowledge wisely in decisions and activities.** Throughout this unit, but particularly Lesson Sets 2 and 3, students gather evidence and build a case that the composition of greenhouse gases in Earth's atmosphere are changing due to the combustion of fossil fuels. This change in composition is the result of increased emissions of CO_2 into the atmosphere from human activity. Students spend Lesson Set 3 learning about different scales of solutions that are aimed at either reducing CO_2 emissions, capturing atmospheric CO_2, or helping vulnerable communities adapt to changes they are experiencing now. **ETS1.B. There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.** Students work through a diverse set of solutions throughout Lesson Set 3 with a focus on reducing CO_2 emissions. They define the problem and criteria for solutions to reduce atmospheric CO_2 levels, they consider tradeoffs in the solutions and the scales at which the solution has to effectively occur, and then they develop a suite of solutions they feel are viable for their community or school.	**Obtaining, Evaluating, and Communicating Information.** This practice is **key to the sensemaking** in this unit. Throughout the unit, students obtain information from informational texts, videos, tweets, graphs, maps, simulations, and data visualization tools. The integration of information across multiple forms of media is substantial. In Lesson 4, for example, they obtain additional information about components of the water system and are cued to evaluate the claims made by scientists and other reliable, valid sources and the data they use to support their claims. Students also engage significantly with this practice in Lesson 17 as they evaluate and communicate carbon solutions to their chosen stakeholder audience. The following practices are also **key to the sensemaking** in the unit: • Developing and Using Models • Analyzing and Interpreting Data • Engaging in Argument from Evidence	**Scale, Proportion, and Quantity.** This crosscutting concept is **key to the sensemaking** in this unit. Students use scale, proportion, and quantity to make sense of the magnitude of change in greenhouse gases and the proportional relationship they have with temperature. In Lesson 7 they examine the concentration of gases in the atmosphere and calculate the percent change over a 100-year time frame. Students see that some gases make up a small proportion of the atmosphere, but those same gases are changing by a notable amount. In Lesson 8, students develop a model idea that the concentration of GHGs in the atmosphere are proportionally related to temperatures. They use this relationship in Lesson 13 to problematize the magnitude of reduction in carbon dioxide emissions that must happen to see a temperature decline. In Lesson 14, students calculate a carbon savings rate per person. They scale this number to larger populations. Throughout this process, students work with different quantities to understand the magnitude of reduction in carbon dioxide emissions that is possible with different degrees of participation in changed behaviors. The following crosscutting concepts are also **key to the sensemaking** in the unit: • Patterns • Systems and System Models • Energy and Matter

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A special note about ESS2.C and ESS2.D

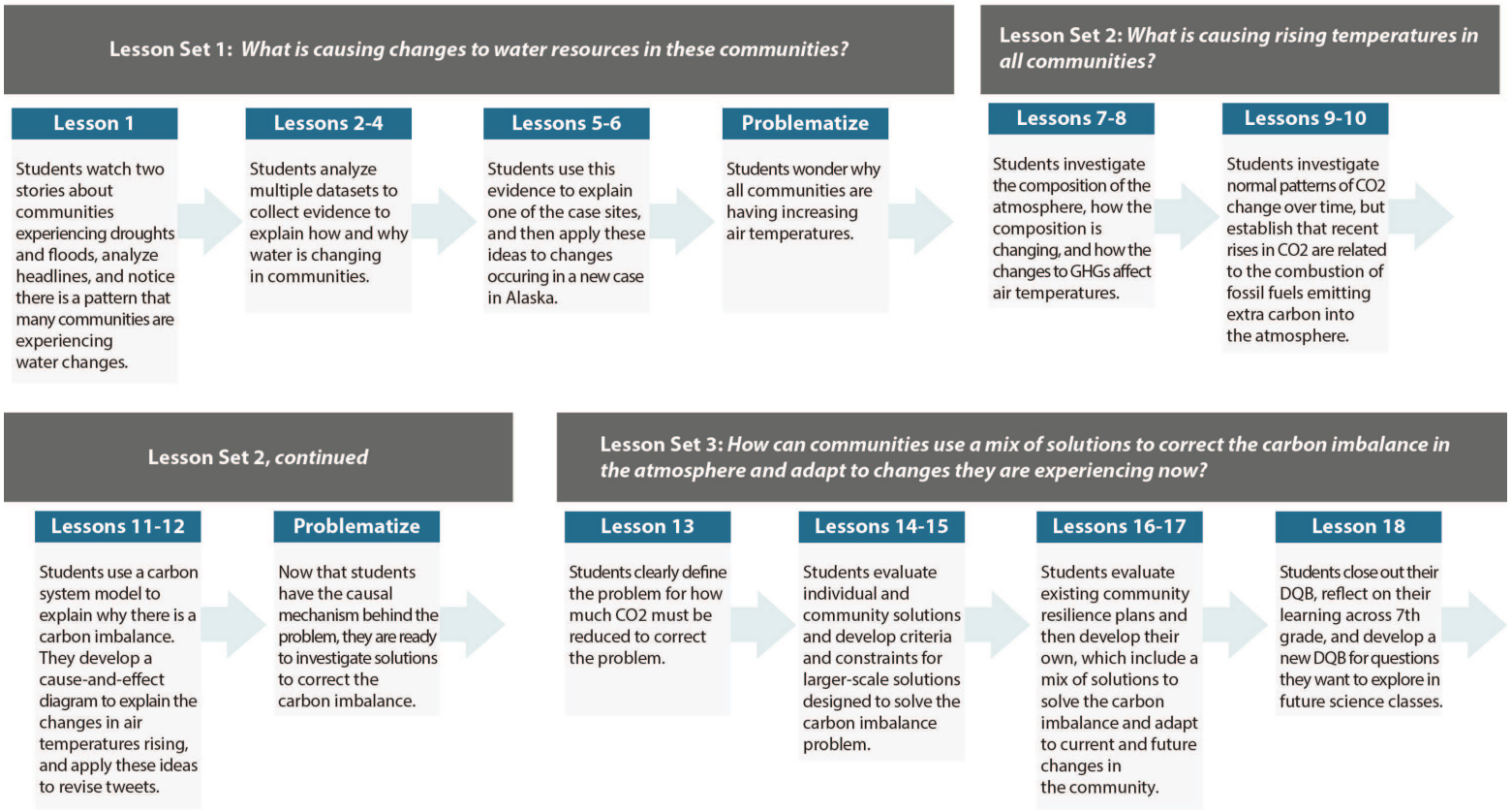
Given the context of the anchoring phenomena for this unit, students will activate their prior knowledge of ESS2.C The Roles of Water in Earth's Surface Processes and ESS2.D Weather and Climate in a substantial way. Students are not developing new ideas from these DCIs; these were previously fully developed in *OpenSciEd Unit 6.3: Why does a lot of hail, rain, or snow fall at some times and not others? (Storms Unit)*. However, they will use this prior knowledge in an extensive way throughout the unit, but especially in Lesson Set 1. Given that students will first investigate droughts and floods at the start of the unit, a heavy focus on this prior knowledge occurs. This prior knowledge is also important for students' initial explanations of phenomena. For this reason, you will notice that these DCIs play a central role in student assessment early in the unit before students transition to the focal DCIs they will develop throughout the remainder of the unit (i.e., the DCIs listed in the table above).

Connections to the Nature of Science (NOS)	
Which elements of NOS are developed in the unit?	How are they developed?
• Science investigations use a variety of methods and tools to make measurements and observations. (NOS-SEP) • Science depends on evaluating proposed explanations.(NOS-SEP) • Theories are explanations for observable phenomena & Science theories are based on a body of evidence developed over time. (NOS-SEP) • Science is a way of knowing used by many people, not just scientists. (NOS-CCC) • Scientists and engineers are guided by habits of mind such as intellectual honesty, tolerance of ambiguity, skepticism, and openness to new ideas. (NOS-CCC) • Advances in technology influence the progress of science and science has influenced advances in technology. (NOS-CCC) • Scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes. (NOS-CCC)	• Throughout the unit, students examine and collect data from a variety of sources (including measurement tools and observations). For example, students also learn methods in which science can investigate data from past millenia using air bubbles trapped in ancient ice cores. • Students investigate common ideas for why Earth's atmosphere is a higher temperature than in the past, with resources to explore alternative explanations (e.g., ozone hole, getting closer to the sun). Students also evaluate proposed design solutions in how well they will address the carbon imbalance problem. • In Lesson 12, there is an opportunity to introduce students to the term, theory, as a powerful scientific explanation that explains many phenomena and is supported by a body of evidence. There is opportunity for a rich discussion on what 'theory' means in science as compared to outside of science. • The first portion of the unit draws upon accounts and knowledge from community individuals who are experiencing shifting changes in temperature and precipitation in their community. This includes accounts from residents, farmers, and members of the Navajo Nation. The accounts draw upon local, long-term knowledge of water resources and precipitation and temperature patterns within communities. Additionally, during the transfer task, traditional knowledge of the rural, Indigenous communities of Alaska is valued and used to make claims about changes occuring in the arctic, including changes to the sea ice and local ecosystems that are anomalous to traditional seasonal patterns. • Students explore different ideas to explain why air temperatures are rising around Earth. They do this to ensure that they have explored multiple possible explanations for why something might be happening before they pursue investigating the changes to atmosphere composition further. • Students investigate trends in CO_2 data over millennia and also the last few hundreds years. As part of this work, students learn about scientific and technological advancements that changed the energy sources used by people, which then requires science to study those energy sources and what impact they may have. Students also encounter technological solutions to minimize carbon sources and/or increase carbon sinks, though these technologies are not yet widely available. • Students develop a causal model for why climates are changing, but as they investigate possible solutions, students realize that making decisions to solve societal problems can be more complex and they must consider community problems and needs and solutions available in those contexts.
Connections to Engineering, Technology and Applications of Science (ETS)	
Which elements of ETS are developed in the unit?	How are they developed?
• All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. • The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. • Technology use varies over time and from region to region.	• Students investigate the energy resources that humans depend upon to power our world, including the positive aspects of developing new energy sources (e.g., ability to power cars) as well as the negative aspects (e.g., producing extra CO_2 into the atmosphere). • Students evaluate possible solutions and learn that some technologies are more feasible, usable, or meet other criteria and constraints in some communities versus others. Communities have needs and limitations that must be accounted for as they implement new technologies. • Students learn about existing and new, innovative technologies designed to address carbon in the atmosphere or help communities adapt to changes. They investigate how the use of technology varies across communities and is adopted at different rates.

How is the unit structured?

The unit is broken into three lesson sets. Lesson Set 1 investigates how rising temperature could be related to changes in precipitation and other water resources for communities. In this first lesson set,students establish that the long-term trends in two climate variables (i.e., temperature and precipitation) are changing over time for many communities. Students use their understanding from ESS2.C and ESS2.D to make sense of changing precipitation patterns, and they also start to see how human communities rely on freshwater resources (ESS3.A, freshwater resources). Students develop an understanding of "climate change" as a measure of a change in long-term temperature and precipitation for a place. In the second lesson set students investigate the cause of rising temperature. Students gather evidence about changing greenhouse gas concentration and the link between GHGs and burning fossil fuels. Students must use ideas from ESS3.A (mineral resources), ESS3.C (per-capita consumption), and ESS3.D (greenhouse gases, fossil fuels) to make sense of rising temperatures. They situate what they learn about the combustion of fossil fuels in the context of a simplified terrestrial-based carbon system. Students bring additional ideas from the physical sciences (PS1.B, PS3.A) and life sciences (PS2.B) to develop and use the carbon system model to explain how temperature change has resulted from a carbon imbalance. Students evaluate solutions (ETS1.B) in the final lesson set. The beginning of this lesson set problematizes the solutions so that students begin their evaluation process recognizing the complex nature of carbon solutions, which need to consider more than science to solve. Students explore different technologies and changes to human behavior (ESS3.D) that must occur to solve the carbon imbalance problem, while also meeting societal constraints and the needs of stakeholders.

Driving question: How do changes in Earth's system impact our communities and what can we do about it?

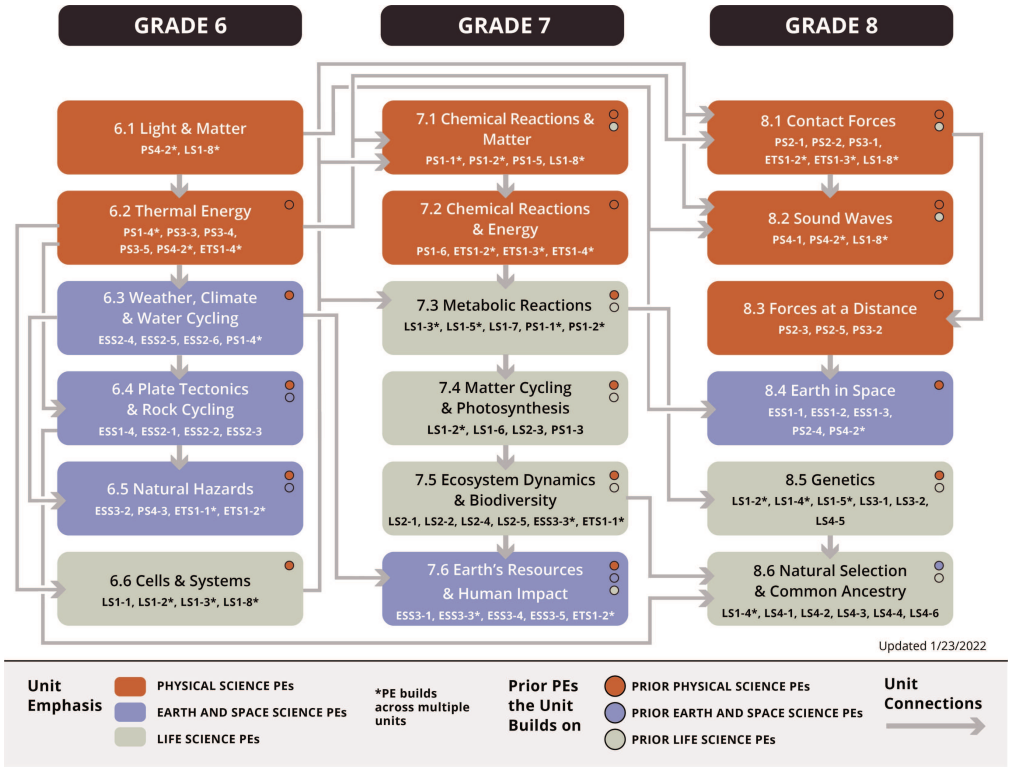


Where does this unit fall within the OpenSciEd Scope and Sequence?

This unit is designed to be the last unit of 7th grade in the OpenSciEd Scope and Sequence. It comes after critical units that build some needed foundational ideas, such as the *Storms Unit*, the *Bath Bombs Unit*, the *Maple Syrup Unit*, and the *Palm Oil Unit*. It is important to note the following about specific additional DCI connections for the unit:

- DCIs that are fully developed in this unit include: **ESS3.D:** This DCI is fully developed in this unit. This DCI is not developed further in other OpenSciEd units until high school.
- DCIs that are partially developed in this unit, but also developed in other units: **ESS3.C.** Aspects of these DCIs are developed initially in the *Palm Oil Unit* and then used again in a new context in this unit with some new development of ideas.
- DCIs that are fully developed if all in class discussions, home learning, and extension activities are used: **ESS3.A.** While this unit does support students in building towards an understanding of the uneven distribution of resources (with a focus on freshwater resources), the home learning and extension activities would need to be completed to develop ideas around mineral resources and past geologic processes.
- DCIs that are considered prior knowledge that students will bring from previous middle school units:
    - **ETS1.B**: Developed in the *Tsunami Unit*, the *Homemade Heater Unit*, and the *Palm Oil Unit*.
    - **ESS2.C & ESS2.D:** Developed in *Storms Unit* and parts of these are used again in this unit and are integral to explaining the anchoring phenomena.
    - **PS1.B:** Developed in the *Bath Bombs Unit*.
    - **PS3.D:** Developed in the *Inside Our Bodies Unit* and the *Maple Syrup Unit*.
    - **LS1.C**: Developed in the *Maple Syrup Unit*.

Also, as a result of this placement in the Scope and Sequence, almost all elements of the SEPs and CCCs have been introduced to the students in the prior 11 units. At this point in the program, we expect students to be able to engage with many of these practices and crosscutting concepts independently. We provide some scaffolds for students who may still struggle with some aspects of the SEPs and CCCs.



What additional ideas will my students have or know from earlier grades or OpenSciEd units?

This unit is designed to leverage science ideas from previous units and grades, including ideas about:

- temperature, precipitation, and water cycling developed in *Storms Unit* and in 5th grade. In particular, students will use what they have learned about the normal cycling of water to help identify and explain why precipitation patterns are changing in communities as air temperatures rise.
- chemical reactions and conservation of matter developed in *Bath Bombs Unit* and *Homemade Heater Unit*. In particular, in Lesson 10, students trace carbon dioxide as a product of a combustion reaction between fossil fuels and oxygen.
- matter (carbon) cycling developed in *Maple Syrup Unit*. Across Lesson Set 2, students identify the matter in the system (i.e., Earth's atmosphere), how the composition of the matter in the system is changing, and the causes for the change in the system from adding a carbon source to the atmosphere from burning fossil fuels.
- human impact on ecosystems and designing solutions to reduce these impacts developed in *Palm Oil Unit*. Students build on their previous knowledge to add additional ideas for how human energy use is changing the atmosphere, which then has numerous climate and ecosystem impacts on communities. Students then focus on investigating and evaluating design solutions to reduce the impact from human activities.
- defining problems, defining criteria and constraints, and evaluating solutions using systematic processes, previously developed in the *Cup Design Unit*, the *Tsunami Unit*, and the *Homemade Heater Unit*. Students apply systematic processes, including identifying criteria and constraints, and identifying stakeholders and their needs, in order to better understand which solutions might work and why for some communities versus other communities.

What are some common ideas students might have?

In addition to the science ideas that students have developed above, some common ideas students may still have are:

- **Climate versus Weather:** Students may confuse climate as simply long-term weather and, therefore, unpredictable. In reality there are important differences in the ways scientists study and measure both weather and climate. While weather is measured by examining atmospheric conditions at a given time and place, climate is the statistical average of those conditions over long periods of time (30 years +). Students may use weather anomalies, such as a very hot summer or an unusually strong snowstorm, as evidence for or against climate change. Looking at trends in extreme weather events over a long period of time can be an indication of change for a place, but any single event is not an indicator of climate change.
- **Temperature and Water Cycling:** Students may view the water cycle as a reliable and predictable cycle. In truth, as climate changes, our understanding of the water cycle, atmospheric circulation, and long-term trends in precipitation and water resource availability is less certain and predictable.
- **Causes of Global Warming and Climate Change:** Students may identify global warming as a result from the ozone hole because the hole lets in more radiation. They may also think the sun is getting warmer and/or closer to Earth. It is becoming more common for students to identify carbon dioxide or greenhouse gases as the cause of climate change, and not to conflate global warming with ozone depletion. However, an extension opportunity is shared in Lesson 7 should your students have these conceptions.
- **Pollution versus Greenhouse Gases:** Students may equate pollution with greenhouse gases, or they may believe that greenhouse gases are "bad" gases. In Lessons 7 and 8, pay attention to how students talk about components of the atmosphere, the different gases, and what is "good" or "bad." If students identify pollution as the cause of temperature rising, help them articulate what they mean by pollution (e.g., What makes up the pollution? Is it the gas molecules themselves that are bad, something mixed in with the gas molecules, or has something bad happened to the gases?). Press students to articulate their ideas about pollution so that you can adapt your instruction to respond to their ideas and questions. With respect to the "good" versus "bad" distinction, pay attention to which gases students characterize in this way. Oxygen, for example, is often seen as a "good" gas because our bodies need it; on the other hand, carbon dioxide is seen as good for plants, but not for people. Help students move away from the "good" versus "bad" labels for individual gases. Instead, focus on the role of each gas to support life on Earth, that our systems depend on the gases in certain amounts, and when those amounts shift (i.e., changing a variable), other changes in the system are inevitable.

How will I need to modify the unit if taught out of sequence?

This is the final unit in 7th grade in the OpenSciEd Scope and Sequence. Given this placement, several modifications would need to be made if teaching this unit earlier or later in the middle-school curriculum. These include:

- If taught before the *Bath Bombs Unit* or at the start of the school year, supplemental teaching of classroom norms, setting up the Driving Question Board, and asking open-ended and testable questions would need to be added. (These supports are built into Unit 7.1.)
- Given the anchoring phenomenon, this unit relies a great deal on students understanding water cycling concepts from 5th grade and the *Storms Unit* (ESS2.C The Role of Water in Earth's Surface Processes). In 5th grade, students figure out major freshwater reservoirs (components of the water system), which includes groundwater and glaciers. In the *Storms Unit*, students add to their understanding of the processes that move water through this system (e.g., evaporation, precipitation, etc.). These concepts are important for building students' initial Earth's Water System Model at the start of Lesson 2. If students do not know about freshwater reservoirs from 5th grade or water cycling processes from 6th grade, consider starting with an initial Earth's Water System Model that is not fully developed. Add new components and interactions (and the vocabulary that goes along with them) as students figure out which ones matter in the context of the phenomena. For example, add new components, like groundwater and snow/ice, after students explore the StoryMap and learn that some communities get their water from these sources. Add precipitation as students explore the precipitation data in Lesson 2. Add evaporation to the model after Lesson 3. Essentially you will need to build the model across Lessons 2-4, rather than all at once at the start of Lesson 2.
- While this unit is about climate and climate change, it was intentionally sequenced at the end of 7th grade, as opposed to following 6th grade, because students' understanding of Earth's carbon system is heavily dependent upon students learning of conservation of matter through reactions (the *Bath Bombs Unit*), cellular respiration in living organisms (the *Inside Our Bodies Unit*), and photosynthesis and matter cycling in ecosystems (the *Maple Syrup Unit*). In each of these units, students figure out chemical processes that transform carbon. This is essential for students to understand prior to Lesson 10 when students will make sense of combustion of fossil fuels and Lesson 11 where they make sense of how combustion results in a carbon imbalance in the whole system. If teaching this unit out of order, Lesson 10 and 11 may need to be modified to better support students in articulating what is happening to carbon during the different carbon transforming processes. For example, students may need more support tracing atoms and conserving the atoms through reactions. .
- This unit is highly dependent on 6th-grade math concepts, such as rate, percent, and proportion. If this unit is taught in 6th grade, it is suggested to work very closely with a 6th-grade math teacher to understand when students will learn the mathematical concepts and process (listed below) so that this unit can reinforce those concepts in a real-world problem context but not come before students have developed these ideas in their math classes (or working in conjunction with math and science simultaneously).

How do I shorten or condense the unit if needed? How can I extend the unit if needed?

This is a substantial unit requiring 6-7 weeks of instructional time with 45 minute class periods. The length of the unit can be modified in the following ways.

To shorten or condense parts of the unit without eliminating important sensemaking for students:

- Lesson 3: If students have had the *Storms Unit*, they do not need to repeat the temperature and humidity lab, though the setup here is slightly modified compared to the previous unit. You can leverage their prior experience of the lab, then provide data for analysis.
- Lessons 5 or 6: Choose only one assessment (either the assessment from Lesson 5 or from Lesson 6) to use at the end of Lesson Set 1.
- Lesson 9: Eliminate the lab experience, and have students explore the long-term (800,000 years) CO_2 data analyzing the given graphs in the StoryMap.
- Lesson 10: Have students explore the more recent CO_2 data using graphs provided in the student edition (instead of using Tuva).
- Lesson 11: Choose a more scaffolded version of the carbon system model to reduce time needed to fully develop the model. There are three options offered in *Guidance on Carbon System Model Templates*.
- Lesson 15: Reduce the total number of solutions to even fewer than 12 and reduce the number of solutions to be read by individual students.
- Lesson 16: Review and analyze two community plans as a class instead of analyzing in groups.

To extend or enhance the unit, consider the following:

- Lesson 7: Have students read about common ideas related to the warming atmosphere using *Exploring Possible Causes of Warming*.
- Lesson 8: Use the full PhET simulation for students to more fully explore ideas; however, please note that this simulation uses high school level ideas and should only be offered to students who have fully mastered the middle school ideas.
- Lesson 9: Have students explore the long-term (800,000 years) CO_2 data using the Tuva platform.
- Lesson 10: Have students explore the more recent CO_2 data using the Tuva platform.
- Lesson 10: Include the uneven distribution of fossil fuel extension in *Extension Opportunity: Uneven Distribution of Fossil Fuel Resources*, *Fossil Fuel Formation Illustrations*, and *Fossil Fuels Long Ago and Today*.
- Lesson 15: Create and include any locally utilized or considered carbon solutions to the *Solutions Cards*. These can sometimes be found in local community plans.
- Lesson 17: Create and include any locally utilized or considered local water or heat solutions to the *Water Adaptation Solutions*.
- Lesson 17: This project can be extended as time is available for students to fully develop and communicate their plan to community members.

What mathematics is required to fully access the unit's learning experiences?

Throughout the unit, students will engage in mathematical thinking, rate and ratio reasoning, and encounter many histograms, line graphs, and/or scatterplots that they will need to interpret. In particular, Lessons 7, 8, 9, 10, 13, and 14 utilize a number of math concepts in the context of explaining phenomena and solving problems.

- Prerequisite math concepts that are helpful include:
    - CCSS.Math.Content.6.RP.A.1 Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities.
    - CCSS.Math.Content.6.RP.A.2 Understand the concept of a unit rate a/b associated with a ratio a:b with b ≠ 0, and use rate language in the context of a ratio relationship.
    - CCSS.Math.Content.6.RP.A.3 Use ratio and rate reasoning to solve real-world and mathematical problems.
    - CCSS.Math.Content.6.NS.B.3 Fluently add, subtract, multiply, and divide multi-digit decimals using the standard algorithm for each operation.
    - CCSS.Math.Content.6.SP.B.5.c Giving quantitative measures of center (median and/or mean) and variability (interquartile range and/or mean absolute deviation), as well as describing any overall pattern and any striking deviations from the overall pattern, with reference to the context in which the data were gathered.
- In Lessons 8, 13, and 14, students start to develop an understanding of the proportional relationship between greenhouse gas concentrations and air temperature. Proportional relationships are a focus of math learning in 7th grade (CCSS.Math.Content.7.RP.A.2 Recognize and represent proportional relationships between quantities). Because this unit falls at the end of the 7th-grade school year, it is likely that your students have learned about proportional relationships. However, talk with your math colleagues to confirm so that you can better anticipate what students will understand or not understand as they work to establish this relationship.
- In Lessons 9 and 10 students encounter graphs that show exponential growth. Focus on the overall trends upward and avoid discussing the shape of the curve and the exponential function, which is a high school math concept.

What additional strategies are available to support equitable science learning in this unit?

OpenSciEd units are designed to promote equitable access to high-quality science learning experiences for all students. Each unit includes strategies which are integrated throughout the OpenSciEd routines and are intended to increase relevance and provide access to science learning for all students. OpenSciEd units support these equity goals through several specific strategies such as: 1) integrating Universal Design for Learning (UDL) Principles during the unit design process to reduce potential barriers and provide more accessible ways in which students can engage in learning experiences; 2) developing and supporting classroom norms that provide a safe learning culture, 3) supporting classroom discourse to promote students in developing, sharing, and revising their ideas, and 4) specific strategies to supporting emerging multilingual students in science classrooms.

Many of these strategies are discussed in the teacher guides in sidebar callout boxes titled "Attending to Equity" and subheadings such as "Supporting Emerging Multilingual Learners" or "Supporting Universal Design for Learning." Other callout boxes with strategies are found as "Additional Guidance", "Alternate Activity," and "Key Ideas" and various discussion callouts. Finally, each unit includes the development of a Word Wall as part of students' routines to "earning" or "encountering" scientific language.

For more information about each of these different strategies with example artifacts, please see the OpenSciEd Teacher Handbook.

Supporting hazard-related trauma

This unit launches with anchoring phenomena around the weather-related hazards of droughts and floods. Throughout the unit, students learn about how communities are being impacted by these two hazards as well as other community impacts. It is likely that students may have experience these types of hazards and will have stories about themselves or people they care about being impacted. When stories about extreme weather and hazardous events come up, teachers can respond in a way that continues to encourage students to connect the lesson to their own lives and discuss that with their class, support the student in the event they may share a distressing event or thought, and still stay within the structure and routine of the lesson to accomplish instructional goals.

The three steps of **Be Curious, Validate,** and **Thank the Student** provide a repeatable "recipe" that teachers can use in a variety of group discussions to accomplish these goals.

1. Be curious. Students are amazingly resilient. **What defines an event as traumatic is the student's response to and experience of the event, not the event itself.** Helping students accurately label and express feelings is a key skill for social-emotional learning. When a student is sharing an experience, being curious about how they felt about it and providing support to help them accurately label those feelings is important.

Instead of...	**Try...**
That must have been really scary for you.	What was that like for you?
I would have felt really worried if that happened.	Can you use our class feelings wheel to share how you felt?
You must have been so scared!	I can imagine having a lot of feelings about that.

2. Validate. Validation begins with listening to what the student shares and then reflecting back a quick summary and closing with a statement that you understand why the student may have experienced it that way. Here are a few examples:

	You might say...	
If the student says...	**Summary**	**Statement of Understanding**
I felt really scared during the tornado warning yesterday.	It sounds like you and a few other students were really scared when they heard the warning.	It makes a lot of sense why that would be scary - I know some other people who felt scared too.
My grandma and grandpa were in Florida for the hurricane.	So your grandparents experienced that weather.	I can see why you thought of that during our discussion today.
I run out of the room when scary weather comes on the news at night.	So if you see extreme weather on the news you get right out of there.	Sometimes I see things on the news and want to turn it right off too.

3. Thank the student. Thanking the student for sharing their thoughts and experiences conveys the message that connecting their life experience and voice to the lesson is valued and appreciated. These are key messages for a trauma-informed classroom experience. You might say:

- "Thank you for sharing that with us."
- "I can see you are really thinking about our discussion today. Thanks for sharing your idea."

In some situations, a teacher may also choose to **follow up** with a student after a large group discussion to see if additional support is needed. Connecting students to caring adults is a key way to address or mitigate the impact of trauma, so follow-up may consist of a quick check-in or ensuring the student can identify a caring adult they can talk to, such as a parent/guardian, another family member, or a neighbor or member of their faith community.

If you have students who have traumatic experiences from natural hazards, a recommended source to read is: https://www.cdc.gov/childrenindisasters/schools.html

What are recommended adult-level learning resources for the science concepts in this unit?

The OpenSciEd instructional model focuses on the teacher being a member of the classroom community, supporting students to figure out scientific ideas motivated by their questions about phenomena. Students iteratively build their understanding of phenomena as the unit unfolds. To match the incremental build of a full scientific explanation across the unit, the science content background necessary for you to teach individual lessons incrementally builds too. Throughout the unit, we provide just-in-time science content background for you that is specific to the Disciplinary Core Ideas (DCIs) that will be figured out in a lesson. Places to look for this guidance include the "Where we are going" and "Where we are not going" sections for each lesson. Additionally, the expected student responses, keys, and rubrics have illustrated important science ideas that should be developed in each lesson. In addition to this information, the K-12 Science Framework is a great resource to learn more about the DCIs in this unit (ESS3.A; ESS3.C; ESS3.D; ETS1.B), including what students have learned previously and where they are headed in high school. In addition to the science content background information embedded in the lesson resources, below we provide recommended resources that can help build your understanding of phenomena and Performance Expectations bundle for this unit:

To learn more about extreme weather events (e.g., floods, droughts, etc.) and/or climate change:

- EPA's Climate Indicators: https://www.epa.gov/climate-indicators/weather-climate
- National Climate Assessment: https://nca2018.globalchange.gov/
- NOAA's Climate Literacy: https://www.climate.gov/teaching/climate
- Paul Anderson's Bozeman Science video on ESS3D: http://www.bozemanscience.com/ngs-ess3d-global-climate-change

To learn more about solutions and local case studies:

- NOAA's Climate Resilience Toolkit: https://toolkit.climate.gov/
- Project Drawdown: https://drawdown.org/solutions

GUIDANCE FOR DEVELOPING YOUR WORD WALL

This unit refers to two categories of academic language (i.e., vocabulary). Most often in this unit, students will have experiences with and discussions about science ideas before they know the specific vocabulary word that names that idea. After students have developed a deep understanding of a science idea through these experiences, and sometimes because they are looking for a more efficient way to express that idea, they have "earned" that word and can add the specific term to the class Word Wall. These "words we earn" should be recorded on the Word Wall using the students' own definition whenever possible. On the other hand, "words we encounter" are "given" to students in the course of a reading, video, or other activity, often with a definition clearly stated in the text. Sometimes, words we encounter are helpful only in that particular lesson and need not be recorded on the Word Wall. However, if a word we encounter will be frequently referred to throughout the unit, it should be added to the Word Wall. As such, the Word Wall becomes an ongoing collection of words we will continue to use, including all the words we earn in the unit and possibly a few key words we encounter.

It is best for students if you wait and create cards for the Word Wall in the moment, using definitions and pictorial representations that the class develops together as they discuss their experiences in the lesson. When they co-create the posted meaning of the word, students "own" the word—it honors their use of language and connects their specific experiences to the vocabulary of science beyond their classroom. It is especially important for emergent multilingual students to have a reference for this important vocabulary, which includes an accessible definition and visual support.

Sometimes creating Word Wall cards in the moment is a challenge. The teacher guide provides a suggested definition for each term to support you in helping your class develop a student-friendly definition that is also scientifically accurate. If you keep one Word Wall in your classroom for several sections of students, you might choose to record each class's definition separately and then propose at the next class meeting to post an "official" definition that captures the collected meaning. The words we earn and words we encounter in this unit are listed in this document and in each lesson to help prepare and also to avoid introducing a word before students have earned it. They are not intended as a vocabulary list for students to study before a lesson, as that would undermine the authentic and lasting connection students can make with these words when they are allowed to experience them first as ideas that they're trying to figure out.

Lesson	Words we earn	Words we encounter	Words we reinforce or apply from previous units
L1		drought, flood	precipitation, evaporation, condensation
L2	drought, flood, vary, short-term variability, long-term trend	groundwater, aquifer, average annual temperature, Palmer Drought Severity Index (PDSI), snowpack, snow water equivalent, storm events, flash floods, sea level, tides	weather, climate, total annual precipitation
L3			evaporation, humidity
L4		streamflow	
L5			
L6	climate change	sea ice	
L7		parts per million (could be a "word we earn")	
L8	greenhouse gases	greenhouse effect	molecule
L9		ice core	
L10	per-capita consumption, combustion	fossil fuel	chemical reaction, reactants, products
L11			
L12			
L13		carbon footprint	
L14			
L15		a variety of words related to carbon solutions	criteria, constraint
L16	resilience	community resilience, a variety of words from community plans	
L17		a variety of words related to water adaptation solutions	stakeholder

L18			

HOME COMMUNICATION

Dear Guardian,

Your child's 7th grade science class is starting a unit called, *How do changes in the Earth's system impact our communities and what can we do about it?* as part of the OpenSciEd middle school science curriculum. This unit builds science ideas around Earth's resources and human impact, specifically, related to why our communities are experiencing more droughts and floods.

Howard Greenblatt/FEMA

While reading news stories and headlines, students are introduced to what's starting to become a disturbing new normal: droughts and floods across the US. As different as they are, students recognize that rising temperatures are connected somehow. As the unit progresses, students examine how small changes could lead to large disruptions to community water resources. Meanwhile, students define, investigate, and explain what could be the cause of all these temperature changes and flood and drought events.

Students work with data to examine how present-day human activities are changing the Earth, creating an imbalance in carbon between the Earth and its atmosphere. By defining the problem, students work to brainstorm and evaluate different kinds of solutions for particular communities, including their own.

Helping your child make sense of their learning:

- Encourage your child to talk more about what they are learning in class and give examples.
- Ask your child to reflect on how their individual actions might impact broader populations.
- Ask your child to share what they have learned about droughts, floods, and warming temperatures, and discuss with them how your own community might be experiencing changes.
- Encourage your child to start constructing their own local water story. For example, how has the amount of water changed in your local community? Who and what might be connected to the changing amounts of water?
- Rephrase or paraphrase what your child says as a way to clarify their ideas. Hearing their idea from someone else is a powerful reflective tool for a child.

Having conversations about science:

- Provide your child space and time to think aloud with a drawing, objects, or their voice about different (maybe conflicting) ideas for processing. Sometimes processing ideas won't lead to a clear "answer" or solution yet.
- Ask your child how what they are learning now is connected to other units they have done in school.

Estimado guardián,

La clase de ciencias de 7° grado de su hijo está iniciando una unidad llamada, *¿Cómo impactan los cambios en el sistema de la Tierra a nuestras comunidades y qué podemos hacer al respecto?* como parte del plan de estudios de ciencias de la escuela intermedia de OpenSciEd. Esta unidad construye ideas científicas sobre los recursos de la Tierra y el impacto humano, específicamente, relacionadas con por qué nuestras comunidades están experimentando más sequías e inundaciones.

Howard Greenblatt/FEMA

Mientras leen noticias y titulares, a los estudiantes se les presenta lo que está comenzando a convertirse en una nueva normalidad inquietante: sequías e inundaciones en los EE. UU. Tan diferentes como son, los estudiantes reconocen que el aumento de las temperaturas está conectado de alguna manera. A medida que avanza la unidad, los estudiantes examinan cómo los pequeños cambios pueden provocar grandes interrupciones en los recursos hídricos de la comunidad. Mientras tanto, los estudiantes definen, investigan y explican cuál podría ser la causa de todos estos cambios de temperatura y eventos de inundaciones y sequías.

Los estudiantes trabajan con datos para examinar cómo las actividades humanas actuales están cambiando la Tierra, creando un desequilibrio en el carbono entre la Tierra y su atmósfera. Al definir el problema, los estudiantes trabajan para generar ideas y evaluar diferentes tipos de soluciones para comunidades particulares, incluida la propia.

Ayudar a su hijo a dar sentido a su aprendizaje:

- Anime a su hijo a hablar más sobre lo que está aprendiendo en clase y dar ejemplos.
- Pídale a su hijo que reflexione sobre cómo sus acciones individuales podrían afectar a poblaciones más amplias.
- Pídale a su hijo que comparta lo que ha aprendido sobre las sequías, las inundaciones y el aumento de las temperaturas, y discuta con ellos cómo su propia comunidad podría estar experimentando cambios.
- Anime a su hijo a comenzar a construir su propia historia local sobre el agua. Por ejemplo, ¿cómo ha cambiado la cantidad de agua en su comunidad local? ¿Quién y qué podría estar conectado a las cantidades cambiantes de agua?
- Reformule o parafrasee lo que dice su hijo como una forma de aclarar sus ideas. Escuchar su idea de otra persona es una poderosa herramienta de reflexión para un niño.

Tener conversaciones sobre ciencia:

- Proporcione a su hijo espacio y tiempo para pensar en voz alta con un dibujo, objetos o su voz sobre ideas diferentes (quizás contradictorias) para procesar. A veces, el procesamiento de ideas aún no conduce a una "respuesta" o solución clara.
- Pregúntele a su hijo cómo lo que está aprendiendo ahora se conecta con otras unidades que ha hecho en la escuela.

LESSON 1: Why are floods and droughts happening more often?

PREVIOUS LESSON *There is no previous lesson.*

THIS LESSON

ANCHORING PHENOMENON

3 days

In this lesson, we observe two news clips that tell the story of extreme flood and drought events in two different communities and share our own stories of when water in our communities has changed. We examine headlines that show a "new normal" of increased floods and droughts across the United States and notice that, in both situations, there is a pattern of record heat and rising temperatures. We develop an initial model explaining what could be causing those warmer temperatures and how those warmer temperatures could lead to both droughts and floods. We develop questions for our Driving Question Board (DQB) and brainstorm investigations we could do and sources of data that could help us figure out answers to our questions.

NEXT LESSON *We will develop a systems model to describe where Earth's freshwater is stored above, at, and below the surface. We will analyze and interpret temperature, precipitation, and drought or flood data in our local community and six other places in the United States to figure out whether water or temperatures in these communities is changing over time.*

BUILDING TOWARD NGSS

MS-ESS3-1, MS-ESS3-3, MS-ESS3-4, MS-ESS3-5, MS-ETS1-2

WHAT STUDENTS WILL DO

1.A Develop a model to explain how a small change in temperature can cause large scale changes in precipitation leading to floods and droughts.

1.B Develop a model to explain what could cause an increase in temperatures that are linked to an increase in floods and droughts.

1.C Ask questions that arise from initial observations of stories and headlines about rising temperatures, floods, and droughts to clarify whether increasing temperatures are related to or causing both floods and droughts.

WHAT STUDENTS WILL FIGURE OUT

- Droughts and floods are happening more often, and both cases seem to be linked to warmer temperatures.
- Changes in evaporation may be related to why, where, and when droughts and floods occur.
- We have some ideas and many questions about what might be causing the warmer temperatures.

Lesson 1 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	25 min		**INTRODUCE TWO STORIES ABOUT FLOODS AND DROUGHTS** Record and share noticings and wonderings from two news clips—a drought in Porterville, CA, and flooding in Vicksburg, MS. Discuss what it might be like to live in one of those communities.	A-H	The Town Without Water video, Floods Hit US. Small Towns along Mighty Mississippi video, chart paper, markers
2	15 min		**IDENTIFY PATTERNS IN HEADLINES ABOUT FLOODS AND DROUGHTS IN SMALL GROUPS** Examine and organize headlines from US communities related to floods and droughts.	I-K	*Drought and Flood Headlines*, sticky notes
3	5 min		**ASSIGN HOME LEARNING** Assign students to talk to members of their families or communities to gather water stories.	L	
					End of day 1
4	7 min		**SHARE OUR WATER STORIES** Add our water stories to the stories explored on day 1.	M	large sticky notes
5	8 min		**DISCUSS PATTERNS IN HEADLINES ABOUT FLOODS AND DROUGHTS AS A CLASS** Identify similarities and differences between the drought- and flood-related headlines.	N	T-chart of drought/flood headline patterns
6	5 min		**IDENTIFY WHAT WE NEED TO INCLUDE IN OUR MODELS** Identify what we need to include in our models to explain how increasing temperatures could lead to increased floods and droughts and what is causing the temperatures to rise.	O-R	
7	15 min		**DEVELOP AN INITIAL MODEL AND COMPARE WITH A PARTNER** Develop an initial model to answer the questions, "How can increased temperatures lead to both droughts AND floods?" and "What is causing the temperatures to increase?"	S-T	
8	10 min		**BEGIN TO DEVELOP AN INITIAL CONSENSUS MODEL** Gather in a Scientists Circle and facilitate a Consensus Discussion among students to develop the initial class consensus model.	U-V	chart paper, markers
					End of day 2
9	10 min		**CONTINUE TO DEVELOP AN INITIAL CONSENSUS MODEL** Continue the Consensus Discussion with a focus on what is causing temperatures to rise.	V	
10	5 min		**INDIVIDUALLY GENERATE QUESTIONS** Students generate questions about the phenomenon in preparation for building the DQB.	W	2 sticky notes, marker
11	20 min		**BUILD THE DRIVING QUESTION BOARD** Develop a Driving Question Board to create a shared space for student questions.	X	
12	10 min		**BRAINSTORM IDEAS FOR DATA AND INFORMATION WE NEED** Have students identify the data and information that would help them answer questions.	Y	Driving Question Board, chart paper
					End of day 3

Lesson 1 • Materials List

	per student	per group	per class
Lesson materials	• science notebook • 2 sticky notes • marker	• *Drought and Flood Headlines* • sticky notes	• The Town Without Water video • Floods Hit US. Small Towns along Mighty Mississippi video • chart paper • markers • large sticky notes • T-chart of drought/flood headline patterns • Driving Question Board

Materials preparation (20 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Test video clips:
- *The Town Without Water* at https://youtu.be/cjGLcgy0qVs
- *Floods Hit Towns in US* at https://youtu.be/X-iBXOHCEL0

Use *Drought and Flood Headlines* to prepare cards for the headline sorting activity.

Prepare all posters (e.g., Notice and Wonder charts, Ideas for Data and Information We Need) ahead of time.

Determine where to set up the Driving Question Board (DQB) and posters so that students can gather around them.

Make and post a discussion norms poster near your DQB space if you haven't already.

Review *Natural Resources Guidance and Extension Opportunities*. This document provides an overview of how to integrate ESS3.A more fully throughout the first lesson set with respect to fresh water resources and during lesson set 2 for mineral resources.

Lesson 1 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students are introduced to the anchoring phenomena—two news clips that tell the story of extreme flood and drought events in two different communities, their own stories of changes in water in their communities, and headlines that show a "new normal" of increased floods and droughts across communities in the United States. This lesson elicits students' initial ideas about what could be causing warmer temperatures and how those warmer temperatures could lead to an increase in both droughts and floods.

Students will come to this unit with prior knowledge and experiences that can be leveraged. Students might use terms like global warming, greenhouse gases, and climate change. However, this unit pushes students to understand the mechanisms behind increasing global temperatures.

It is preferred that students come to this unit with prior knowledge from *OpenSciEd Unit 6.3: Why does a lot of hail, rain, or snow fall at some times and not others? (Storms Unit)* unit related to these three NGSS performance expectations:

- MS-ESS2-4: Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.
- MS-ESS2-5: Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.
- MS-ESS2-6: Develop and use a model to describe how unequal heating and rotation of Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.

Relevant ideas from this previous work include:

- Air particles near the ground get warmed up by the sun, and this energy is transferred from the particles in the ground to the air through conduction.
- The temperature of water or soil increases as energy is added to them/the substance.
- As more energy is added, some water molecules turn into a gas and become water vapor (evaporation).
- As water vapor rises in the atmosphere, it cools and will turn back into liquid. It condenses on dust particles or other things in the air and begins to form clouds and eventually falls as precipitation.
- The role of wind in moving parcels of air around.
- Weather is the minute-by-minute or day-by-day variation in the condition of the atmosphere, while climate is longer term (years to centuries).

When students set up their initial models, push students to bring this prior knowledge to their modeling work and to push their models to think about how temperature could affect what they already know about the system.

Where We Are NOT Going

The terms "climate change" and "global warming" will likely be used throughout this lesson. At this point in the unit, it is not important for students to have a complete understanding of these words, and most likely, many students will use them without a full understanding. This is OK for this lesson as students will develop a fuller understanding of both terms across the unit.

In addition, it is not important for students to have a complete understanding of the different components and interactions in the system as students will most fully build a water system model in Lesson Set 1 and a carbon system model in Lesson Set 2.

LEARNING PLAN for LESSON 1

1 · INTRODUCE TWO STORIES ABOUT FLOODS AND DROUGHTS

25 min

MATERIALS: science notebook, The Town Without Water video, Floods Hit US. Small Towns along Mighty Mississippi video, chart paper, markers

Set the stage by making a connection to a local water story.✱ Tell students about a local situation related to a change in the amount of precipitation in your area. Here are some possible connections:

- Share a picture of a local body of water that is or was unusually low. Say something like, *I remember that this reservoir was really high in March, and now it is super low. I was thinking maybe we are getting less rain than usual or we are in a drought or something. It got me thinking about what else is out there, so I found some videos of other locations experiencing something like this, too.*
- If you are in an area that has put in measures to address water shortages (e.g., no watering of lawns, etc.), say something like, *We have been doing things to address the recent water shortages. It got me thinking about what it's like in other places and what they are doing about things like water shortages. It also made me wonder about places where the opposite is happening.*
- If you are in a place that has experienced floods or the bodies of water are unusually high, say something like, *Who can remember the recent flood we had? It got me thinking—are we the only place experiencing this, and what are other people doing about floods? It also made me wonder about places where the opposite is happening.*
- If you are in a place where neither droughts nor floods seem to be happening with enough frequency or seemingly little direct impact on the people living there, you could connect to other issues related to too much or too little water, such as earlier snowmelt or dry conditions that lead to wildfires.

Set up for Notice and Wonder charts. Display **slide A**. Tell students that you have found 2 news stories that may relate to their own experiences with places that are getting too much or too little water. After preparing space in their notebook for this new unit, have students make a two-column chart on the next available page to record their noticings and wonderings from the videos. If students need support in recording noticings and wonderings from a video, you can show optional **slide B** and **slide C**, which offer suggestions for ideas they could include.

SCIENCE NOTEBOOK

This is the first use of the science notebook for this new unit. You may need time to organize a new section in the notebook. It is recommended to have students do the following:

- Reserve a blank page at the start of the unit, to be titled on day 3 of this lesson when students are ready for the unit question.
- After the title page, reserve 2 pages (4 pages front-to-back) for the table of contents (unless all tables of contents are at the front of the notebook).
- Reserve 8 pages (16 pages front-to-back) for the Progress Tracker.
- Number the pages so that everyone begins the first investigation on the same page number (e.g., page 1 for the first page of the table of contents, page 5 for the first page of the Progress Tracker, and page 21 for the first Notice and Wonder chart they are making).

Remind students that the notebook is their tool for recording their observations, evidence, and ideas to share with the classroom community. They should see it as a space to brainstorm and record their thinking, as well as a place to show how their thinking changes as they learn more.

ALTERNATE ACTIVITY

You may wish to change the order of the stories that you show to connect to the situation that is more closely connected to what your community has experienced. For example, if your community has experienced flooding, you may want to start with the Vicksburg, MS, story and then show the drought story. If the story order is changed, you will also need to change the Notice and Wonder titles on **slides A**, **B**, **C**, **D**, and **F**.

✱ ATTENDING TO EQUITY

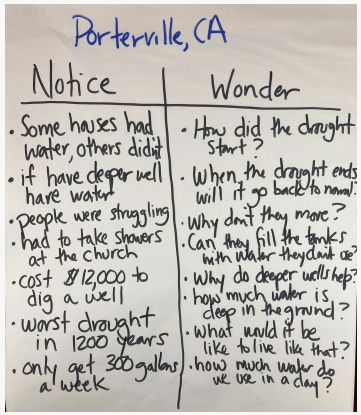
Students will find the anchoring phenomenon more compelling if it is presented in a meaningful context. Additionally, throughout Lessons 2-5, there are opportunities to weave your community's story into the overall storyline. Therefore, adding a local story or local connection now will serve to increase relevance and interest for your students and will engage them in a deeper study of their community across the first lesson set.

✱ ATTENDING TO EQUITY

Supporting empathy and emotions: A unit on floods and droughts is likely to elicit emotional stress from some students, either in terms of the empathy they feel for those affected, or from experiencing the natural hazard directly or through the experiences of family and friends.

Emotional stress from these events can often be great in students who feel they do not understand the situation or that they have no control over the situation. While droughts and floods often bring impacts that students cannot control, the aim of this unit is to help students understand what is happening to cause these events and to feel as though they can understand them, and use their knowledge to understand a community's response to them (e.g., water restrictions, flood warnings). If you have students who have traumatic experiences from a drought or flood event, a recommended source to read is located at the CDC Children in Disasters: Teachers and Childcare website at https://archive.cdc.gov/#/details?q=children%20in%20disasters%20school&start=0&rows=10&url=https://www.cdc.gov/childrenindisasters/schools.html.

Show the first clip. Play *The Town Without Water* video clip from https://youtu.be/cjGLcgy0qVs, which is also linked on **slide D**. This clip takes place in Porterville, CA. Have students record noticings and wonderings as the clip plays. Once the clip is over, give students an additional minute to record their noticings and wonderings on their charts.

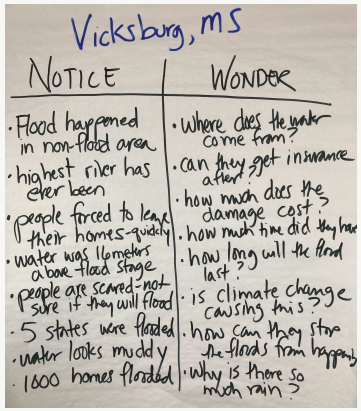


Share noticings and wonderings from the first clip. Show **slide E**. Take 3-4 minutes to have students share a few of the things they noticed and wondered about from the clip. There are two additional prompts on the slide to help guide students as they share noticings and wonderings. Start a public record of what they share, using chart paper, whiteboard, or digital document.

Show the second clip. Say, *I found another case that is having the opposite problem—too much water.* Ask students to add a heading for Vicksburg, Mississippi, on the opposite page, and draw a second Notice and Wonder chart. Then play the *Floods Hit US Small Towns along Mighty Mississippi* video clip from https://youtu.be/X-iBXOHCELO, which is linked on **slide F.** As the clip plays, have students record noticings and wonderings. When the clip concludes, give students an additional minute to record their ideas.

Share noticings and wonderings from the second clip. Show **slide G**. Take 3-4 minutes to have students share their noticings and wonderings with the class. There are two additional prompts on the slide to help guide students as they share noticings and wonderings. Start a public record of what they share, using chart paper, whiteboard, or digital document.

Reflect on how it might feel to live in one of these communities. Show **slide H**. Ask students to turn and talk about the questions on the slide: ✱



- How might you feel if your town ran out of water? How would it change your daily life?
- How might you feel if your town flooded and you had to leave your home?

Briefly hear a few ideas (e.g., ask someone to share an idea their partner said). Some sample student ideas are listed below:

- *If my town was flooded, I would feel scared because I could lose everything, and my house that I paid a lot of money for did not have flood insurance.*
- *I would feel nervous and scared because if my house flooded, I don't know where I would go and if I could still even live in it.*
- *I would feel sad and frustrated if my town had flooded and I had to leave, since I would lose a lot of things.*
- *If my town ran out of water, I would feel scared and would have to collect water for my family.*
- *I would feel upset because I literally depend on water. I only take hot showers, I drink only water, and I wash my hands all the time. It would be a very difficult thing to not have water.*
- *It would be more difficult without having water for a while. Everything requires some form of water to operate, so without water nothing will work.*
- *I would feel stressed or overwhelmed because then I would constantly be counting the gallons of water I used.*

2 · IDENTIFY PATTERNS IN HEADLINES ABOUT FLOODS AND DROUGHTS IN SMALL GROUPS

15 min

MATERIALS: *Drought and Flood Headlines*, sticky notes

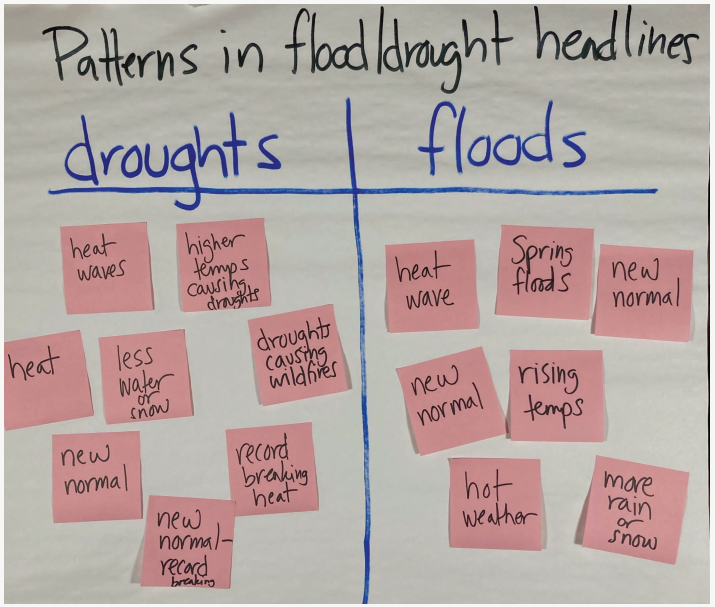
Introduce the headlines. Show **slide I**. Say, *These stories made me wonder what is happening with floods and droughts in other parts of the country, and I found some other locations that seem to be having problems with too little and too much water as well. I gathered some headlines from those locations that might help us learn more about what is happening elsewhere.*

Explain that the map shows locations that have had droughts and floods in just the past few years. Brown markers represent a location that experienced a drought, while green marks a location of a flood.

Say, *Let's look at headlines from these locations to see if we can find any patterns to help us explain what's going on.*
Arrange students in pairs or small groups to examine headlines✱. Project **slide J**. Pass out the headline cards or provide a link to the headlines on an electronic whiteboard. Assign half of the pairs to the drought headlines and half to the flood headlines. Give students about 8-10 minutes to read and organize the headlines in order to identify patterns.

Ask groups to post their patterns to a shared document. Display **slide K**. Create a T-chart on chart paper, whiteboard, or digital document with the headings shown on **slide K**: patterns you noticed across drought-related headlines/patterns you noticed across flood-related headlines.

Ask groups to post their sticky notes for the patterns they recorded on the class T-chart. The sticky notes will need to be grouped and arranged together before the next class period. During the next class period, the class will use these groupings and headlines to discuss the patterns they noticed and what is similar or different between the droughts and floods.



✱ ATTENDING TO EQUITY

Universal Design for Learning: To promote student *engagement* you may choose to differentiate the degree of difficulty or complexity of the task by giving some groups both sets of headlines. Learners vary not only in their skills and abilities, but also in the kinds of challenges that motivate them to do their best work.

3 · ASSIGN HOME LEARNING

5 min

MATERIALS: None

Explain the home learning✱. Say, *Next class period we are going to share some of what we noticed about these headlines and floods and droughts in other communities. However, in the meantime, you and your families may have experienced or heard about situations that are similar to those we have heard about today.* Display **slide L**. Explain that students should talk to members of their families or communities and bring back any stories to share on day 2. Use the following prompts on the slide:

- Has our community experienced anything like this?
- Have you or your family lived in or traveled to a community that experienced anything like this?
- Has a member of your family or community experienced anything like this?

✱ ATTENDING TO EQUITY

Universal Design for Learning: This home learning is used to broaden students' thinking to related phenomena and leverage these everyday science experiences they have outside of school to augment the learning that happens in the classroom. Locating the anchoring phenomena in the context of their community helps the phenomenon become more personally meaningful to each student and supports student *engagement*. It also provides students an opportunity to talk about the phenomena with family members and other community members.

End of day 1

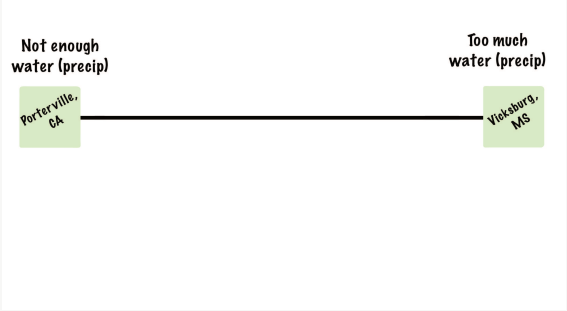
4 · SHARE OUR WATER STORIES

7 min

MATERIALS: large sticky notes

Navigate back to the stories from day 1. Say, *Yesterday we started with 2 communities that were facing challenges related to water. Let's look back at our Notice and Wonder charts. What was the problem in each of those communities?* Listen for the idea that Portersville was running out of water because of a drought, and Vicksburg was flooding worse than ever before.

Set up a visual continuum to record our water stories. Write "Vicksburg, MS" and "Porterville, CA" on 2 big sticky notes (or on chart paper or a virtual whiteboard) and place at either ends of a continuum drawn between the two places. Say, *So, in one case, the community had too much water and, at the other end, not enough.* Add those labels to the continuum.



Ask students to share their water stories and add them to the continuum. Say, *In addition to Porterville and Vicksburg, we analyzed headlines for other places experiencing similar things. Our own community may be experiencing problems, too. Let's come up with some example headlines from our own stories and think about where they fit in relation to the other stories we've already seen.* Show **slide M**. Ask a few students to share any stories they gathered about similar situations they or their families might have experienced. As students share, write a headline for what happened onto a sticky note and add it to the continuum (e.g., Hurricane Irene causes record flooding; Basements overflow as rivers rise; Families in Vietnam experience floods and droughts).

5 · DISCUSS PATTERNS IN HEADLINES ABOUT FLOODS AND DROUGHTS AS A CLASS

8 min

MATERIALS: T-chart of drought/flood headline patterns

Return to the headlines to identify similarities and differences. Show **slide N**. Say, *Let's see if the headlines we analyzed yesterday have a similar story to what we/our community/our families have experienced. Let's return to our observations to see if we can find any patterns to help us explain what's going on.*

Return to the class T-chart and the sticky notes that students added. Discuss differences and similarities. Connect back to the stories the class added by posing the question, "Do any of these headlines have a similar story to what we/our community/our families have experienced?"

Patterns in drought-related headlines	Patterns in flood-related headlines
• **Less precipitation: e.g.** less rain/snow/dry; less winter snow; droughts, dry • **New normal:** e.g. normal changing; weird weather is new normal; record-breaking • **Record-breaking heat: e.g.** during drought; hot and dry; heat wave; hot • **Dry and fires**	• **More precipitation: e.g.** historic flooding; major flooding; worsening floods; more rain, floods, snow; wettest on record • **"new normal"**: e.g. more often; happening more • **Rising temps** • **More in spring**
Similarities: • "New normal"; historic, record-breaking • Heat, heat wave, rising temperatures	

Say, *It's really curious to me how these two very different kinds of problems share some things in common. Let's see if we can explain what is causing this "new normal" of increased floods and droughts and increased temperatures.*

6 · IDENTIFY WHAT WE NEED TO INCLUDE IN OUR MODELS

5 min

MATERIALS: None

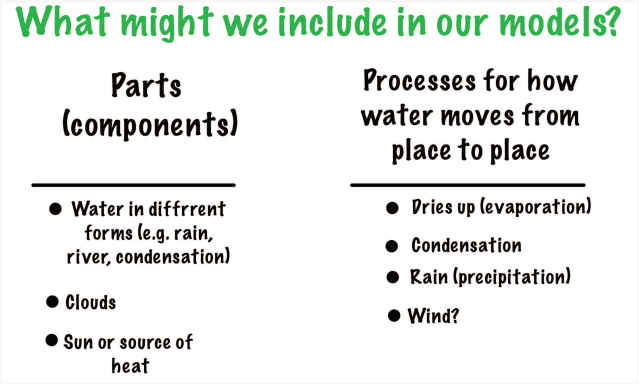
Set the purpose of the model. Display **slide O**. Say, *So, it seems like we have 2 puzzling questions—what is causing those warmer temperatures and how could those warmer temperatures lead to both droughts and floods? We're going to try to explain as much as we know about this, but first, let's decide what to include in our models.*

Identify possible parts or components to include in our models. Display **slide P**. Say, *If we want to figure out how droughts and floods happen, what are some parts or components we might want to include? What things are involved in causing a drought to happen? A flood?* Ask students to turn and talk about this question. After a minute ask students to share ideas with the whole class and record for the class to use as they are developing their individual models. Listen for ideas such as:

- *Some source of heat (sun)*
- *Water in different forms (e.g. rain, puddles, rivers)*
- *Clouds*
- *Wind (this may not come up until later)*

Discuss ideas for how water can move from place to place. Display **slide Q.** Say, *OK, so we all said we need water in different forms, but how did that water in the puddle get there? Or how did the water in the air get there? Let's think about what we know about how water moves from place to place that we might want to include in our models.* Ask students to turn and talk about the prompt on the slide: How can water move from place to place? What are some processes we might want to include in our models? After a minute, ask students to share ideas and add them to the public record. Listen for ideas such as:

- *dries up or evaporation*
- *condensation*
- *rain or precipitation*
- *wind*



Discuss the second question our model is trying to address. Display **slide R**. Remind students that we also want to explain what might be causing the warmer temperatures in the first place. Remind students to explain **why** this is happening, not just **what** is happening.

ADDITIONAL GUIDANCE

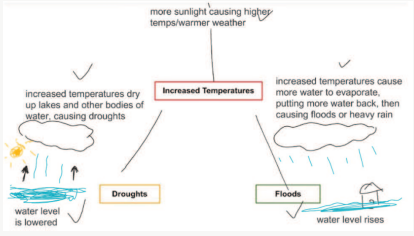
This lesson (and this unit) builds on ideas that students figured out in *OpenSciEd Unit 6.3: Why does a lot of hail, rain, or snow fall at some times and not others? (Storms Unit)* about how water cycles through the atmosphere. In that unit, students figured out that air particles near the ground get warmed up by the sun and that this energy is transferred from the particles in the ground to the air through conduction. The temperature of water or soil increases as energy is added to them/the substance. As more energy is added, some water molecules turn into a gas and become water vapor (evaporation). As water vapor rises in the atmosphere, it cools and will turn back into liquid. It condenses on dust particles or other things in the air and begins to form clouds and eventually falls as precipitation. Students may also recall the role of wind in moving parcels of air around. If your students have not experienced the *Storms Unit*, you may need to spend additional time developing these ideas with your students.

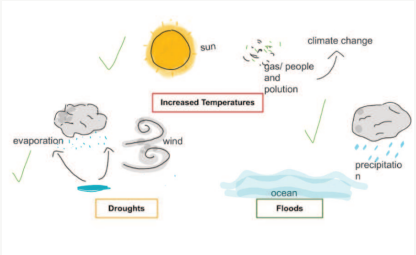
7 · DEVELOP AN INITIAL MODEL AND COMPARE WITH A PARTNER

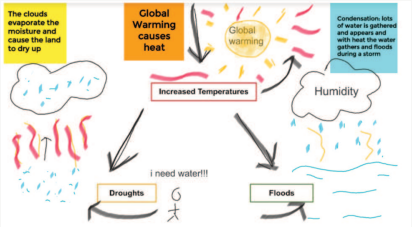
15 min

MATERIALS: science notebook

Individually develop an initial model. Project **slide S**. Give students about 8 minutes to develop an initial model to answer the questions, "How can increased temperatures lead to both droughts AND floods?" and "What is causing the temperatures to increase?" Keep the slide with the questions and image for the model visible, as well as the list of things to include in their models.







✱ SUPPORTING STUDENTS IN THREE-DIMENSIONAL LEARNING

While students work on their models to connect temperature changes to droughts and floods, use prompts such as the following to help students think about both cause and effect and stability and change:

- How did your partner explain how a small change in temperature leads to large changes in other parts of the system?
- What cause did your partner identify that led to an effect of temperature going up?

ASSESSMENT OPPORTUNITY

Building towards:
1.A Develop a model to explain how a small change in temperature can cause large scale changes in precipitation leading to floods and droughts.

1.B Develop a model to explain what could cause increased temperatures that are linked to increased floods and droughts.

What to look for:
1.A Look for students to use:

- Water cycling processes, such as evaporation and precipitation, in their initial causal accounts of floods and droughts. See if students are connecting temperature change to a change in these processes.
- Look at how students' individual models accounted for these changes in temperature and water cycling processes compared to the model co-constructed by the class. This will give you insight as to where each individual student is in their initial understanding of the phenomenon and their modeling practice to explain it.
- Look at students' causal accounts to see if they use single words, like evaporation, as a "sufficient" causal explanation, or if they elaborate on a mechanism for how temperature change could affect a water cycle process.

1.B Look for students to explain what is causing temperatures to rise using language or images that link the causes (e.g., greenhouse gases) to the effect (rising temperatures).

What to do: Ask students to leave their notebooks in the classroom for you to assess their work.

- 1.A If your students struggle with identifying important parts (components) and processes for the cycling of water, you may need to spend additional time reviewing those key processes before they develop their individual models. If students don't explain how the change in temperature is causing the changes to the processes and components that the class identified, use prompts to solicit those connections (e.g., I see you are showing that evaporation is changing, can you add some words to explain how that is connected to the increased temperatures?).
- 1.B If students use language they have heard connected to increased temperatures (e.g., climate change, greenhouse effect, pollution, global warming) but don't explain *how* this could cause increased temperatures, prompt them to use words or images to explain what the words they use mean to them, how those processes, such as climate change, work, and how they lead to increased temperatures.

Compare models and explanations in pairs. Display **slide T**. Explain that, as you were circulating the room, it seemed like we had ideas that were both similar and different across our models. Tell students that we should spend some time comparing our models and explanations to see what we can agree upon and where we aren't as sure about what is occuring. To help students begin this process, share examples and non-examples of productive comparisons (e.g., a non-productive example would be focusing on the artistry of the drawing or diagram; a productive example would be noting how other students talked about why a change could lead to increased temperatures or floods and droughts).

Arrange students in partner pairs to share their models. Ask students to focus on identifying similarities and differences in what they think is happening to cause increased floods and droughts and increased temperatures.

As partner pairs note similarities between the diagrams, explain that students can make a small check mark on their diagram noting that it is similar to a diagram by their partner. If students have a different idea, or they are confused about part of the system, they can mark those parts of the model with a question mark.

- Did they explain how or why that caused an increase in temperature?

8 · BEGIN TO DEVELOP AN INITIAL CONSENSUS MODEL

10 min

MATERIALS: science notebook, chart paper, markers

Gather students in a Scientists Circle to develop an initial consensus model. Have students bring their science notebooks with them to the circle. Take this opportunity to remind the class how we listen to one another, press upon one another's ideas, and ask questions of one another; and it's OK to disagree with ideas, but it's important to be respectful. Remind students of the agreed-upon classroom norms.

SCIENTISTS CIRCLE

Your students may be familiar with the Scientists Circle from a previous unit. Remind students of the norms for participation and the logistics for forming and breaking down that space. A Scientists Circle includes these important features:

- Students sitting so that they face one another to build a sense of shared mission and a community of learners working together.
- Celebrating progress toward answering students' questions and developing more complete explanations of phenomena.
- Focusing on where students need to go next and how they might go about the next steps in their work.

As a class, work together to build a consensus model.✱ Project **slide U** to remind your students of the purpose of this initial consensus model discussion. Remind students that the model is a chance to decide what the class agrees upon with the explanation for the phenomenon/problem and where the class is less certain and has questions. Before starting the discussion, project **slide V** to remind students of the 2 questions our model is trying to explain.

KEY IDEAS

Purpose of this discussion: Develop an initial class consensus model to capture the ideas we agree and disagree on or are more uncertain about to explain how increasing temperatures could be causing an increase in floods and droughts and what could be causing the increasing temperatures. Help students realize that, while we have agreement upon some common ideas, we still have many questions.

Listen for these ideas:
Possible areas of agreement:

- Precipitation is changing—more in the areas where there are floods and less in places where there are droughts.
- Increased temperatures mean changes in evaporation.
- Something has occurred to cause an increase in temperature, but we cannot agree on the exact cause of that temperature change.

Possible areas of disagreement or controversy:

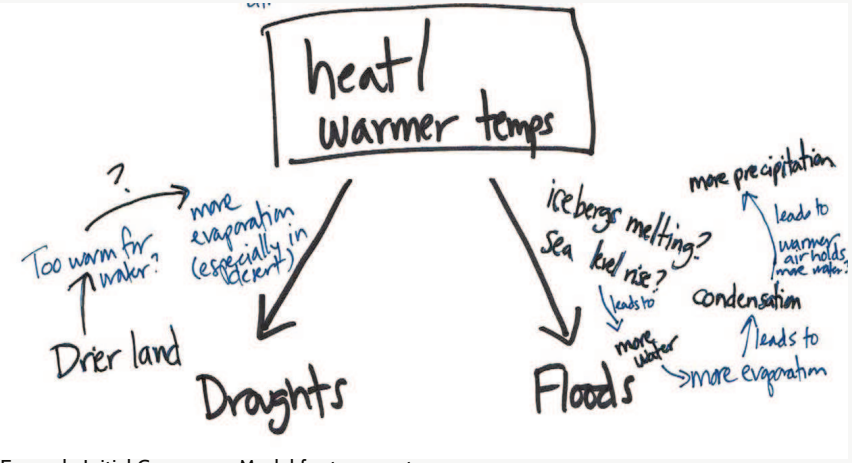
- **How is evaporation changing in each situation?** Is it too dry in places where there are droughts for evaporation to happen or does it evaporate and then it is so hot it dries up and can't condense?
- **What else might contribute to increased water in the atmosphere?** Is this related to other things we have heard of like ice caps melting? What about sea levels rising?
- **What is actually causing temperatures to rise?** We've heard of global warming but what causes it? How do greenhouse gases cause temperatures to rise? How is carbon dioxide related to this problem? What is climate change? Does it have something to do with pollution?

Lead a discussion about how an increase in temperatures causes an increase in both floods and droughts. As students share their ideas, listen to what they believe is important to represent on the consensus model. During this modeling moment, it is important to honor students' ideas and create a model that reflects their thinking versus making an exact copy of the model shown here. An example of this first

✱ ATTENDING TO EQUITY

Universal Design for Learning: You may use color coding to foreground parts of the model. Although color coding is a useful way to quickly reference the parts of the model, letter or number coding helps ensure accessibility for any student who may be color-blind. Create a key to track what colors, symbols, numbers, or letters represent different parts of the system. Keep this in mind as students begin to develop their Earth's Water System Model in L2 and later when students develop their Carbon System Model in lesson set 2.

part of the initial consensus model can be found below. This is just one example of the model, and it could potentially have different areas of agreement and disagreement. It's important to follow your students' ideas during this discussion and not feel strongly tied to replicating this exact model.



Example Initial Consensus Model for temperature

Suggested prompts	Sample student responses	Follow-up questions
What are some ideas you and your partner agreed on for how increased temperatures might be leading to more droughts?	We both said there isn't a lot of water because the ground is dry.	*Is this something others showed?* *What might be causing this? Are there other sources of water besides the ground?*
What other ideas did you have for increased droughts?	I said there was more evaporation because it's super hot. We said that, since it is so hot and it is dry, there is less evaporation to then turn into clouds.	*So, are you saying that the increased temperatures mean more evaporation? Can you say more about that?* *Can anyone put in their own words the different ideas that X and Y just shared?* *If more water is evaporating and it's not coming back down where there is a drought, where is it going?*
What about floods—what were some ideas you and your partner had about that?	We both showed a lot of precipitation and clouds. I also labeled water sources, like a river and melted snow.	*Did anyone else show that?* *How does that relate to increased temperatures?*

Suggested prompts	Sample student responses	Follow-up questions
What other ideas did you have for increased floods?	I said that there is more evaporation when it is warmer, so then there is more water in the air that turns into clouds. If there is more water around, then there is more to condense and cause more rain. I added that there is more water because of the ice melting.	*So, more heat means more evaporation? Can you say more about that?* *How is that different from what we showed for droughts?* *How might that relate to where we are seeing the floods?* *Which of these ideas are we sure about? Which of these ideas would we need more evidence for?*

Say, *It sounds as though we have some ideas about how increased temperatures might lead to changes in evaporation and precipitation but are still not sure about how both of these things could be happening at the same time when temperatures increase. Tomorrow we will continue with our model and compare our ideas for what is causing this increase in temperatures.*

End of day 2

9 · CONTINUE TO DEVELOP AN INITIAL CONSENSUS MODEL

10 min

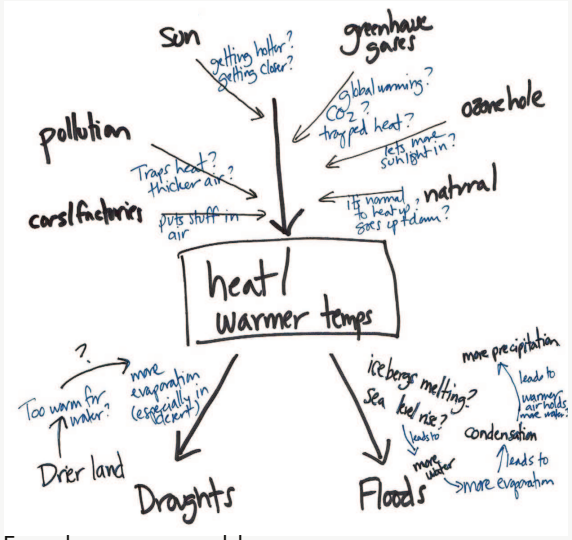
MATERIALS: None

Gather in a Scientists Circle to continue the initial consensus model. As students enter the classroom, have them bring their notebooks to the Scientists Circle. Display **slide V** and the first part of the model that the class worked on during the previous class period. Ask a student to remind the class of the questions we are trying to answer with our model.

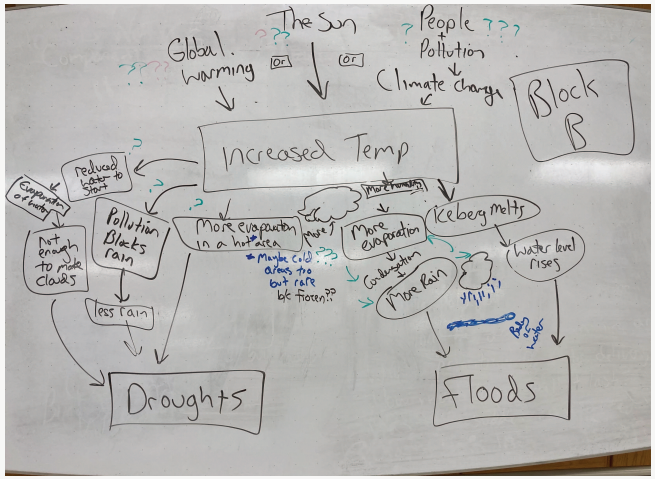
Turn and talk about temperature changes. Give students 2 minutes to turn and talk with a partner about the ideas that they generated to answer the question: What is causing the temperatures to increase? If students are having trouble explaining what is causing the temperatures to increase, direct them to look back at their individual models and consider what their partners had shared with them while looking for similarities and differences.

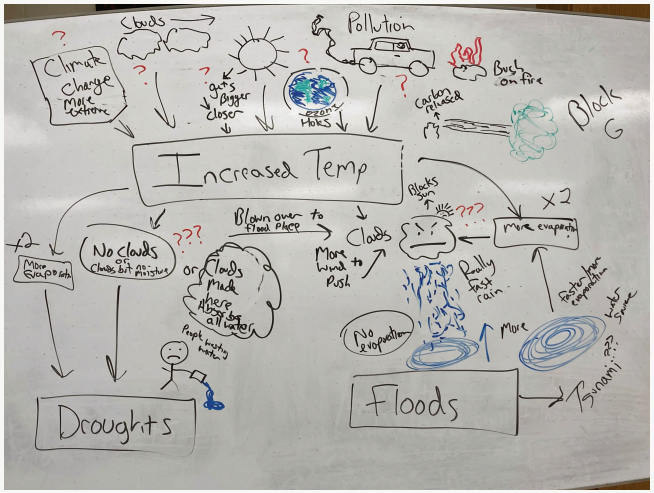
Discuss similarities and differences in ideas. After students have had a chance to share their ideas with a partner, lead a discussion regarding the mechanism that might be causing an increase in temperatures. Capture ideas on the initial class consensus model as they are shared by the class, paying special attention to areas of agreement and disagreement.

Additional examples of an initial consensus model can be found below. These are only examples of the model, and it's important to follow your students' ideas during this discussion and not feel strongly tied to replicating this exact model.



Example consensus model





If students mention a widely used word, such as global warming, probe students to explain what the word means and how or why global warming could cause a temperature increase. Example prompts and responses are below.

Suggested prompts	Sample student responses	Follow-up questions
What are some ideas you and your partner agreed on for what might be causing increased temperatures?	We both said global warming.	*Can you say more about what you mean when you say global warming?* *Did others include this? How did you describe what global warming is and how it explains increased temperatures?*
What other ideas did you have for what might cause an increase in temperatures?	I said pollution, and my partner said greenhouse gases.	*So, are you saying that pollution and greenhouse gases are the same thing?* *Did anyone else talk about this in their model?* *How could pollution or greenhouse gases be causing an increase in temperatures?*

Suggested prompts	Sample student responses	Follow-up questions
For those who included greenhouse gases or the greenhouse effect, can you tell us more about how that might cause temperatures to rise?	I said they trap heat. I don't really know how, but it's like a greenhouse—the air gets trapped and warmed up. I just put it down, but I'm not really sure how; I know they say it is connected to climate change. I know carbon dioxide is a greenhouse gas—are there other ones?	*Hmm...that's interesting—how could gases trap heat?* *So, I'm hearing that greenhouse gases might trap heat somehow, but we're not sure how or exactly what they are. How could we represent that?*
What other ideas did you have for what might cause an increase in temperatures?	I said the sun is getting hotter, or we are getting warmer from the sun. I heard someone say that Earth is tilted differently than it used to be, so it's just getting hotter in some places.	*Can you say more about that? Does this connect to any other ideas that people had?*
What other words have you heard or read about that come up when people are discussing that Earth is getting warmer?	I heard about a hole in the ozone layer. I heard that methane is bad.	*Can you say more about those?*

Say, *It seems as though we have a lot of ideas about what might be causing temperatures to increase, but we have a lot of gaps in our ability to explain how they work. We don't really know exactly how these things we have heard of could be causing the temperatures to rise. Perhaps we need to find some more information or data or do more investigations to figure this out!*

10 · INDIVIDUALLY GENERATE QUESTIONS

5 min

MATERIALS: 2 sticky notes, marker, science notebook

Prepare for the Driving Question Board. Display **slide W**. Remind students that we are going to try to capture all of our questions about what could be causing an increase in floods and droughts and an increase in temperatures. Explain to students that we can use our questions to guide our investigation into what is going on. To do this, we are going to build a Driving Question Board (DQB).✱

Prompt students to take out and review the following resources (in their science notebooks):

- noticings and wonderings from stories and headlines
- your initial model
- the initial class model

Discuss types of questions that can help us get to an explanation for our phenomena. Say, *We are really curious about what is causing temperature changes, how temperature changes cause floods and droughts, and how even air temperature could be related to water cycling processes. Let's think about how we can ask our questions to help us get to these explanations. What kinds of questions could help us get at the causes of all this stuff? What kinds of questions could help us answer how all of the things—even things that don't seem related—could be connected?*

✱ ATTENDING TO EQUITY

A DQB provides a public representation of the class's joint mission. Students can share their questions and wonderings with one another, and the visual representation offers another modality for students to access science in the classroom. The DQB should be centrally located in the classroom so that it can be referenced and added to throughout the unit.

Post question stems like the ones below to support students in asking causal questions or systems-related questions.

- How does ___ cause __ to happen?
- If we do ___, will ___ happen?
- How is this ___ in the system related to ___?
- What is happening with _____ to cause ____?

Using their resources, ask students to generate a list of questions that they have about what could cause increased temperatures and their link to droughts, floods, and other related phenomena.✱ Students should record their questions on sticky notes—one question per sticky note. They should write their questions so that they are big and bold and so that everyone can see the questions clearly.

ADDITIONAL GUIDANCE

It may be helpful to ask students to generate questions in rounds. For example, they could first generate a question about the floods and droughts and then generate questions about changing temperatures. This will encourage a range of questions across the model ideas.

ASSESSMENT OPPORTUNITY

Building towards: 1.C Ask questions that arise from initial observations of stories and headlines about rising temperatures, floods, and droughts to clarify whether increasing temperatures are related to or causing both floods and droughts.

What to look for: Look for questions that are open (how/why) versus closed (yes/no), and also testable questions in the classroom. Also listen for questions that address both parts of our model.

What to do: Since students will put their initials on the backs of these sticky notes, you will have a few opportunities to take stock of the kinds of questions students ask in this initial lesson after they are posted on the DQB, as well as when they are writing them. When students share these questions for the DQB, they will likely only have time to share one. Collect the remaining questions that don't get posted after the development of the DQB is complete. If your students are asking mostly closed questions, you can provide a copy of a photo of the questions on the Driving Question Board, and ask them to work on refining three or more of these questions so that they become "how" and "why" questions that can help answer the original question posted, as well the original yes/no question. This could be an in-class or home-learning assignment.

✱ ATTENDING TO EQUITY

Supporting Emergent Multilingual Students: Asking questions in everyday language allows students to share their thinking or experiences, even if they do not have the appropriate scientific vocabulary yet. This is helpful for emergent multilingual students because by not requiring scientific words at the onset, you do not limit their participation in classroom discourse.

11 · BUILD THE DRIVING QUESTION BOARD

20 min

MATERIALS: None

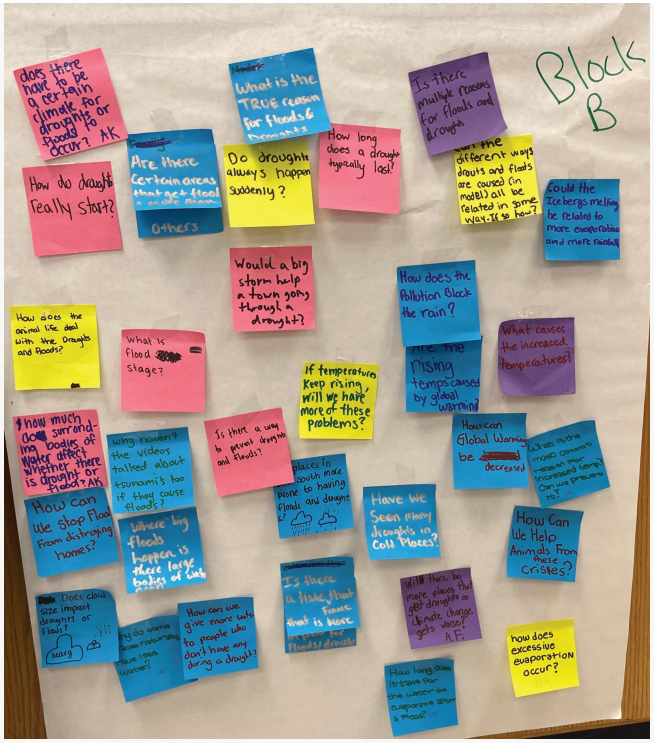
Instruct students to share their questions, one by one, with the whole group.✱ Display **slide X.** Explain to students how you will create the DQB:

- The first student reads his or her question aloud to the class, then posts it on the DQB.
- Students who are listening should raise their hands if they have a question that relates to the question that was just read aloud.
- The first student selects the next student whose hand is raised.
- The second student reads his or her question, says why or how it relates, and posts it near the question it most relates to on the DQB.
- The student selects the next student.
- Continue until everyone has at least one question on the DQB.

If the question is a new question and doesn't fit with any questions that are already on the board, students should create a new cluster.

✱ ATTENDING TO EQUITY

First and foremost during the formation of the DQB is reinforcing a classroom community wherein all ideas are valued and everyone has a question up on the board. Use your judgement on how to press students to form "how" and "why" questions. If a student struggles with sharing, encourage them to go public with questions rather than focusing specifically on forming a "how" or "why" question.



Cluster the questions. After all students have shared their questions, you will end up with a DQB that has several different clusters of questions. As a class, decide on "umbrella" questions or topics for the clusters of questions.

After creating the DQB, discuss an overarching driving question. Say, *It seems like we have questions about how changes in things like temperature and the amount of precipitation impact us and what we can do about it*. Suggest that we add a broader question that our model and DQB are seeking to answer: How do changes in Earth's system impact our communities and what can we do about it?

12 · BRAINSTORM IDEAS FOR DATA AND INFORMATION WE NEED

10 min

MATERIALS: science notebook, Driving Question Board, chart paper

Brainstorm ideas for data and information we need. Project **slide Y**. Now that the class has created a DQB, tell students that it is time to really dig into the hard work of figuring out what is going on! Ask students, *What kinds of information or data do we need to figure out the answers to our questions?*

Prompt students to use the categories of questions from the DQB to identify the data and information that would help them answer the category of question. Refer to the initial classroom consensus model. Encourage students to also look at the areas where we have questions noted by question marks and think about what we could do to help us better understand these parts of our consensus model.

Have students turn and talk about their ideas before sharing out with the whole group. Assign each small group a category of questions to focus on. Have small groups share out their ideas with the whole group. Make sure that all groups get to share at least a few ideas. Make a class record of the ideas for future investigations and data we need. You may want to prompt students to keep a record of our proposed investigations in their science notebooks. Some examples are provided below:

Category of questions	Data and information that we need
What do pollution/greenhouse gases have to do with this?	Trap air in bottles/jars to see what changes it with certain gases? Make little greenhouses using plastic bags? Use a simulation.
What's happening with floods and droughts?	Look at other locations besides 2 videos—data and other videos?
What is happening with temperatures/global warming?	Look at temperature data over a really long period of time.

Say, *It seems like we have identified areas that we think are changing. But what is changing? What is normal? How could we figure out what is normal for Porterville and Vicksburg, and whether it is just in these places, or happening elsewhere?* Tell students we'll pick up from there in the next class.

Additional Lesson 1 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA

CCSS.ELA-LITERACY.RST.6-8.1: Cite specific textual evidence to support analysis of science and technical texts.
On days 1 and 2, students analyze text in the form of headlines to find patterns in what is happening with floods and droughts in different locations and what might be causing them.

CCSS.ELA-Literacy.SL.6.1.c: Pose and respond to specific questions with elaboration and detail by making comments that contribute to the topic, text, or issue under discussion.
When the class is building the Driving Question Board, if a student forgets to explain why or how their question is linked to someone else's question, press that student to try to talk through their own thinking. This is a key way to emphasize the importance of listening to and building off of one another's ideas and to help scaffold student thinking. If students can't figure out which question to connect their question to, encourage them to ask the class for help. After an idea is shared, ask the original presenter if there is agreement and why, and then post the question.

LESSON 2: What would we normally expect for these places and how do we know it's really changing?

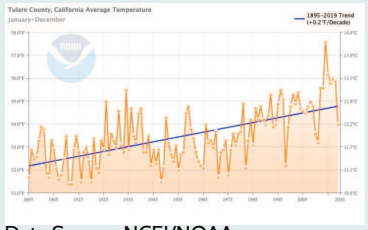
PREVIOUS LESSON

We observed two news clips of extreme flood and drought events and shared our own water stories. We examined headlines that showed a "new normal" of increased floods and droughts and noticed a pattern of rising temperatures. We developed an initial model explaining what could be causing warmer temperatures and how warmer temperatures could lead to both droughts and floods. We developed a Driving Question Board (DQB) and brainstormed investigations and sources of data that could help us figure out answers to our questions.

THIS LESSON

INVESTIGATION

3 days



Data Source: NCEI/NOAA

In this lesson, we first develop a systems model to describe where Earth's freshwater is stored above, at, and below the surface. We then analyze patterns in data to determine what is normal and not normal about temperature and precipitation as it relates to floods and droughts. We first investigate data from our local community to become familiar with how to analyze and interpret data. This helps us better understand ideas around weather and climate, as well as short-term variability in the data versus long-term trends. We then split into groups and analyze case sites around the US to better understand what is happening in other places. We figure out that the amount of water above the surface (rainfall or snowfall), at the surface (in rivers, lakes, oceans, soil, or snowpack), or below the surface (groundwater) in these communities is changing. We also figure out that all of our case sites show rising temperatures over the last 125 years.

NEXT LESSON

We will create closed bottle setups to test the relationship between temperature and evaporation. We will conclude that increased temperatures cause an increase in evaporation. We will wonder how the water vapor behaves in a large, open system. We will observe NASA water vapor and temperature visualizations and determine that warmer temperatures at the surface increase evaporation, but the water vapor that enters the atmosphere does not move around evenly. We will wonder what other changes to Earth's water system are occurring due to rising temperatures.

BUILDING TOWARD NGSS

MS-ESS3-1, MS-ESS3-3, MS-ESS3-4, MS-ESS3-5, MS-ETS1-2

WHAT STUDENTS WILL DO

2.A Develop and use a model to describe the components, interactions, and processes of water distribution and movement on Earth.

2.B Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal patterns in temperature, total precipitation, and seasonal precipitation in the local community and at case sites.

2.C Analyze and interpret data about patterns in rates of change and numerical relationships to determine similarities and differences between drought and flood sites.

WHAT STUDENTS WILL FIGURE OUT

- Earth's freshwater is distributed in the air, at the ground, and below the ground and moves in between these spaces.
- Year-to-year variability in precipitation and temperature is a normal pattern.
- Data averaged over long periods of time can give us the trends for an area.
- Precipitation or heavy storm events show increasing trends in the areas where there are more floods.
- Precipitation, groundwater, and snowpack show decreasing trends in areas where there are more droughts.
- Temperatures are increasing for all of the places we investigated.

Lesson 2 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	5 min		**NAVIGATION** Brainstorm where freshwater is on Earth.	A-B	Driving Question Board, classroom consensus model
2	10 min		**DEVELOP AN EARTH'S WATER SYSTEM MODEL** Develop a system model to help figure out what could be changing to cause droughts and floods.	C	chart paper, three colored markers
3	10 min		**OUR COMMUNITY** Determine data that helps us figure out what is normal or not normal in these places.	D-F	Earth's Water System Model, Ideas for Investigations and Data chart, chart paper, markers
4	18 min		**EXAMINE LONG-TERM LOCAL DATA** Analyze and interpret local, long-term temperature and precipitation data.	G-I	*Analyzing Our Local Data*, *About the Data*, computer and projector, NOAA Climate at a Glance website
5	2 min		**NAVIGATION** Motivate the need to look closer at the data.	J	
					End of day 1
6	3 min		**NAVIGATION** Students link to previous day's work and consider where they will go next.	K	
7	10 min		**TAKE A CLOSER LOOK AT THE DATA--SHORT-TERM DATA** Students analyze and interpret short-term data as a class.	L-N	computer and projector
8	20 min		**MAKE SENSE OF LOCAL DATA COMBINED** Convene a Building Understandings Discussion to develop ideas about long-term data trends across the data sets.	O	large sticky notes for Word Wall, markers, Communicating in Scientific Ways poster
9	12 min		**EXPAND TO NEW CASE SITES** Provide an overview of the six case sites in the StoryMap and references.	P-Q	StoryMap of Case Sites, *Data for Porterville, California*, *Data for Vicksburg, Mississippi*, *Data for the Navajo Nation*, *Data for Boston, Massachusetts*, *Data for Yakima, Washington*, *Data for Windom, Minnesota*, *About the Data*, computer and projector, Earth's Water System Model
					End of day 2

Part	Duration		Summary	Slide	Materials
10	22 min		**ANALYZE AND INTERPRET CASE SITE DATA** Work in teams to make observations and interpretations of assigned case sites.	R-S	StoryMap of Case Sites, *Data for Porterville, California*, *Data for Vicksburg, Mississippi*, *Data for the Navajo Nation*, *Data for Boston, Massachusetts*, *Data for Yakima, Washington*, *Data for Windom, Minnesota*, *About the Data*
11	18 min		**CONSENSUS ACROSS CASE SITES AND PROGRESS TRACKER UPDATE** Build consensus around the similarities and differences across the case sites and update progress trackers.	T	StoryMap of Case Sites, Case Site data sheets, *About the Data*, computer and projector, Earth's Water System Model, prepared sticky notes with arrows, prepared sticky notes with case site location.
12	5 min		**NEXT STEPS** Motivate the need to figure out how increasing temperature is affecting precipitation patterns.	U	Earth's Water System Model

End of day 3

Lesson 2 • Materials List

	per student	per group	per class
Lesson materials	• science notebook • *Analyzing Our Local Data* • *About the Data*	• StoryMap of Case Sites • *Data for Porterville, California* • *Data for Vicksburg, Mississippi* • *Data for the Navajo Nation* • *Data for Boston, Massachusetts* • *Data for Yakima, Washington* • *Data for Windom, Minnesota* • *About the Data* • Case Site data sheets	• Driving Question Board • classroom consensus model • chart paper • three colored markers • Earth's Water System Model • Ideas for Investigations and Data chart • markers • computer and projector • NOAA Climate at a Glance website • large sticky notes for Word Wall • Communicating in Scientific Ways poster • StoryMap of Case Sites • prepared sticky notes with arrows • prepared sticky notes with case site location.

Materials preparation (30 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Ensure a copy of *Communicating in Scientific Ways* is visible for students as a poster or handout in their science notebook.

Prior to the beginning of this lesson, prepare a poster with the title "Earth's Water System Model." This will be developed together during the beginning of this lesson and will be revised over the course of this lesson and the next few lessons. It might also be helpful to quickly research where your community gets their water from (e.g., Is it mostly surface water sources and precipitation, or does the community pump water from any groundwater sources, too?).

You will need to access, gather, and prepare data for your local community prior to day 1. Watch the screencast video on how to access local data at https://youtu.be/V0ytqQu07KI or read the instructions on the teacher reference, *Instructions for Accessing Local Data*. Save the images for your local data. Place the long-term graphs into **slide H** for day 1. Also, insert them into the template provided in the lesson reference materials, *Analyzing Our Local Data*. Make 1 copy per student. Place the short-term graphs for your community on the appropriate slides for day 2 (**slides L-N**).

To save time on day 1, create a T-chart on chart paper that says "Data we need and why." On the left side, the column should be titled "Data" and the right-side column should be titled "Why." Importantly, save room for a third column, "Predictions," to add to the chart.

When working on case sites, ensure that each group has access to at least 1 computer. There are six groups or case sites in this lesson. Test the link to *StoryMap of Case Sites* at https://arcg.is/1SKjOG0. The data for each case site is also provided in student reference *Data for All Case Sites*. Also, read *Rationale for Case Sites*, which explains the rationale for the selection of case sites.

On day 3, students will be in groups of 4 and each student in the group will need a handout for their assigned case site:

- *Data for Porterville, California*,
- *Data for Vicksburg, Mississippi*,
- *Data for the Navajo Nation*,
- *Data for Boston, Massachusetts*,
- *Data for Yakima, Washington*, and
- *Data for Windom, Minnesota*).

If not using the StoryMap, videos for each case site can also be viewed by students with the OpenSciEd YouTube channel.

To save time on day 3, also prepare 10-12 sticky notes with a bold arrow pointing up and 10-12 sticky notes with a bold arrow pointing down. Also record the name of each location in the StoryMap on a separate sticky note. Additionally, prepare 2-3 sticky notes with an equal sign and 2-3 sticky notes with question marks. You will add these sticky notes to the classroom consensus model during the Consensus Discussion at the end of day 3.

Consider assigning *Changes to Groundwater* for home learning after day 3 of this lesson. This reading provides background information about groundwater resources. The reading can be used to deepen students' understanding of how the stability of groundwater resources are determined by a balance of use by people and refilling from natural processes (ESS3.A).

Lesson 2 • Where We Are Going and NOT Going

Where We Are Going

Students will bring background knowledge from earlier grades about where Earth's freshwater and saltwater are located and come from. Prior to this unit, students should have figured out that water is found in oceans, rivers, lakes, and ponds. Water exists as solid ice and in liquid form (2-ESS2-3), and nearly all of Earth's available water is in the oceans. Most freshwater is in glaciers or underground; only a tiny fraction is in streams, lakes, wetlands, and the atmosphere (5-ESS2-2). It is expected that students will bring many of these ideas to the start of this lesson, so one purpose is to draw out their prior understanding. However, this lesson adds a new idea about how water is distributed unevenly in the air, at the surface, and underground and that communities rely on certain places where water is located and processes that move water for their water source. Because water is distributed unevenly and in different ways, one community might rely on one place in the system (e.g., groundwater), but another community will rely on another (e.g., snowpack).

Students will use this systems model to frame a few additional case sites in the United States that are experiencing floods and droughts. Students will be given data and information on each site to understand which component of the water system the community relies on. Students will explore and begin to make sense of what is happening with precipitation and temperature patterns at the case site and how changes to these two factors influence the system.

In all case sites, students will notice that average temperatures are rising. This is true for almost all locations in the United States, and it is a clear pattern for students to discern. Students will revisit this pattern in Lesson 5 and will build a causal mechanism for rising temperatures in Lesson Set 2.

Precipitation data is a bit more complex when discerning patterns in all locations. Total annual precipitation alone is not the only data that represents whether a place is in a flood or a drought. Often, places might experience one or two heavy precipitation events but then might experience prolonged periods without any rainfall at all. *The total annual precipitation may not show the true water stress a place is experiencing.* The lesson includes other data indicators as well, including snowpack (for places that rely on snow melting in the spring), groundwater (for places that rely on groundwater to offset low precipitation), and the Palmer Drought Severity Index (PDSI), which is a combination measurement of temperature, precipitation, and soil moisture. Similarly, the lesson provides additional data about the frequency of heavy precipitation or flood events using the National Oceanic and Atmospheric Administration's (NOAA) Storm Database (1996 to current day). Students can use this data to develop a more nuanced understanding that precipitation changes may be more than the result of overall change in amount and could be a change in timing, frequency, intensity, and type of precipitation.

Where We Are NOT Going

For the Earth's Water System Model, we are not including most human-engineered water system components (e.g., water towers, water tanks, wells, pipes, aqueducts). We *are* including reservoirs, since, in many communities, reservoirs are synonymous with lakes.

This lesson includes challenging data analysis focused on understanding concepts around short-term variability and long-term trends in data. For the purpose of this lesson, variability is change or variation in data from year to year, while a trend is the increase or decrease in the average data over time. Students can build on their understanding of annual variation and overall trend from their reasoning about populations in the *Palm Oil Unit*. However, students will *not* explore any statistical concepts around variability and trends in this lesson.

We've provided students with only a select amount of data with which to understand these concepts and begin to explain the floods and droughts they've observed; however, even though the data does not completely represent the complexity of each case site, it will bring to light important overall patterns that need explanation.

LEARNING PLAN for LESSON 2

1 · NAVIGATION

5 min

MATERIALS: science notebook, Driving Question Board, classroom consensus model

Connect to questions and ideas from the previous class. Have **slide A** displayed as students enter the classroom and ask them to stop by the Driving Question Board and consensus model that are posted in a central place in the room. Students should look at the groups of questions, as well as the ideas we've had about data and information that we need to help answer some of these questions.

As class begins, say, *So far we've noticed that temperature and precipitation are changing in different places in the US. But, we have a lot of questions about how and why temperatures are increasing and how this might be related to why some areas are getting more or less precipitation.*

Have students record any new ideas they have into their notebook. These can also be added to the class charts as well.

Say, *We had some questions about where all of the water is coming from or going to, and we wanted to look at more places than just the two places in the videos. Before we look at more data, let's first track what we already know about where water is normally located and how it moves between places.*

Brainstorm and record what we know about where freshwater is on Earth. Display **slide B**. Have students open to the next blank page in their science notebook and title the page, "Where water is found on Earth." Say, *Now take a few minutes to record all of the places you know water is naturally located on Earth. If we were to go out and try to find water, where would we look in the natural environment?*

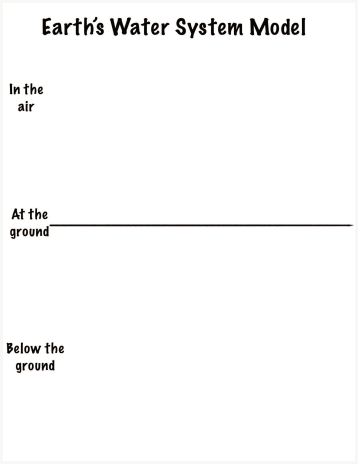
Give students a few minutes to record their ideas.

2 · DEVELOP AN EARTH'S WATER SYSTEM MODEL

10 min

MATERIALS: science notebook, chart paper, three colored markers

Convene an Initial Ideas Discussion. Display **slide C**. As a class, develop an initial diagram to represent where water is distributed on Earth. This diagram will become a systems model that will track what is happening to water in the system. Students can already identify some of the places in the system where water is located. Data about the places and processes will be added to in subsequent lessons, so develop it on chart paper and keep it in the public space through Lesson 6. The diagram should include a space for listing locations in the air, at the ground, and underground. Title this chart "Earth's Water System Model."



An example is included to the right but adjust the layout however it makes best sense for your class.

Say, *We think that something about where water is located and how it moves around is changing. And we think this might be causing droughts and floods. Let's draw out a diagram to identify the places where water is normally located and then see if we can use it to identify what is changing to cause droughts and floods.*

As students share, add the locations to the diagram. Some examples of what students might share are included below:

At the ground:

- Ponds
- Lakes/Reservoirs
- Oceans
- Ground/Grass/Soil
- Puddles
- Rivers
- Snow/ice or glaciers

Underground:

- Aquifers or groundwater

In the air:

- Clouds
- Water vapor from evaporated water

ADDITIONAL GUIDANCE

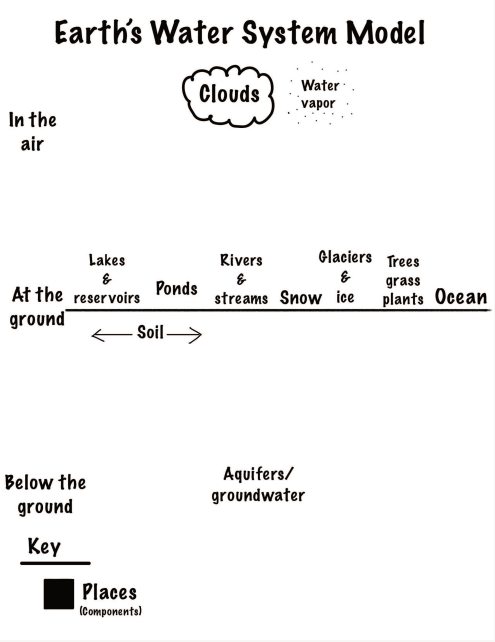
Students should have some background knowledge from earlier grades about where our water comes from on Earth.

- Water is found in oceans, rivers, lakes, and ponds. Water exists as solid ice and in liquid form. (2-ESS2-3)
- Nearly all of Earth's available water is in the oceans. Most freshwater is in glaciers or underground; only a tiny fraction is in streams, lakes, wetlands, and the atmosphere. (5-ESS2-2)

This new model will eventually support these new ideas: (1) identifying that water is unevenly distributed for communities, (2) reminding them of the normal interactions between these sources of water (i.e., water cycling), and (3) providing them a way to track what is changing in the system to cause floods or droughts.

When students have tracked all of the places onto the model, be sure to remind them that the model we are creating is to support us in figuring out what might be changing in this system. An example of the Earth's Water System Model with the key places is shown to the right.

Introduce the idea of distribution of water for communities. Get students' initial ideas for how communities are connected to this Earth's Water System Model, starting with Porterville and Vicksburg and broadening from there to think about other communities, including your own.



Suggested prompts	Sample student responses	Follow-up questions
Using our model, what is changing about water in Porterville? In Vicksburg?	In Porterville, the wells were dry, so there was no water under the ground. In Vicksburg the river was flooding, so there was a lot more water in the river.	*Why do we think the water below the ground was drying up?* *Where do we think all of the water in the river came from? Where did the water go after it went through the town of Vicksburg?*
Do all communities get their water from all of the same places we included on our model?	No! We don't have glaciers or snow where we live. A lot of places get their water from rivers or lakes, though. I get my water from the city! I just turn on the tap.	*Well, where do you think the city got the water in the first place?*
Using our model, does anyone know where our community gets water?	Our water comes from _____reservoir. We get our water at home from a well.	*So what component of the system is that?*

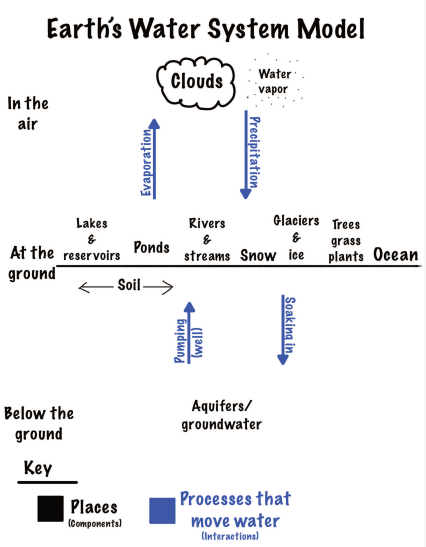
ADDITIONAL GUIDANCE

It's OK if students do not know any or all of the sources of their community's water. This move is mainly to help students get a better understanding of their own community's water resources, in anticipation of brainstorming the data we need to support what is changing in the model. If students do not know, tell students something like, *Well, I had to look up where our community gets water because mostly I just turn on the tap, so I didn't really know. We get our water from _____ and _____. So, what part of the system is that?*

Say, *So, our model shows that water is found in these places on Earth; but they are located, or distributed, differently around Earth, so communities don't always get their water from the same places in the system. Let's see if we can show the processes that move water between these places.* Accept all student ideas. If students still disagree on some ideas, that is OK at this point.

Transition to adding processes that move water in Earth's Water System Model. Ask students to brainstorm with partners how water moves (i.e., the processes) between the surface and the atmosphere and between the surface and below ground. After 1 minute, bring students back together and add these processes to the model using a different colored marker. Students should mention the following:

- Evaporation gets water from the surface into the air.
- Precipitation gets water from the atmosphere back to the ground.
- Water seeping or soaking into the ground is how water gets into aquifers (students likely won't say infiltration, which is OK).
- Pumping water, drilling water, etc., is how we get water from underground back up to the surface.
- Melting, runoff, and freezing are processes students may mention that move water between surface sources (optional to record).



ASSESSMENT OPPORTUNITY

Building towards: 2.A Develop and use a model to describe the components, interactions, and processes of water distribution and movement on Earth.

Look for/listen for: This is an early formative assessment moment to figure out how much students are bringing from earlier grades and OpenSciEd units. Students should have ideas about the following:

- Places, such as water's location in oceans, lakes, rivers, ponds, and in groundwater sources, such as aquifers.
- Students might develop new ideas about:
    - Water being distributed in the air, at the surface, and underground.
    - Maybe: Communities having access to different places where water is located; some communities have access to precipitation and surface water; and other communities rely on groundwater for their water source.
    - Maybe: Water being unevenly distributed on Earth. Not all places have access to all of these sources of water.

What to do: Labeling the places where water is located in the system is something students have likely done before in earlier grades. However, they likely have not categorized them into "In the Air," "At the Ground" and "Underground," so this might be a new way of thinking about the water system on Earth and representing the traditional "water cycle." Students might struggle to identify sources in the air or underground. If students have done the *Storms Unit*, remind them that they were working with water at and above the ground in that unit.

Students may need some support in thinking about water underground, such as aquifers. This should be something they figured out in earlier grades (5th grade), but if they only mention water that is at or just below the surface, like soil moisture or water in the grass, then remind them of the case from the previous lesson in Porterville. Ask them questions, such as, "How were people in Porterville getting water?" Students should mention that they saw some people were using large tanks in their front yards because their wells had dried up, and there are other other people who still have wells. Use this to talk about where the water for wells comes from. Encourage students to look back at their noticings about Porterville for anything they noted about the wells. They should remember that, in the news clip, many people talked about digging deeper wells. Connect that this water, which is stored far below the surface in aquifers, is a source of "groundwater." If these are new words for students, you may wish to add them to the Word Wall at this time.

If students don't quite understand the idea that communities get water from different places in the system, they will revisit this idea using the StoryMap on day 2. This StoryMap will introduce students to additional ideas about where these communities get their water. They will circle back to this idea again in Lesson 4.

Transition to using the system model. Say, *Now that we have recorded all of the places on Earth that water is located and we've recorded how it moves between these places, let's think about which processes in the system might affect droughts and floods if a part of the system changed. Is there a part of this system that, if it changed, might cause droughts and floods?*

Allow several students to offer ideas. One idea that should surface is if there is more evaporation there would be drought and if there was more precipitation, there would be more floods. Follow with a dialogue similar to the one shown below.

Suggested prompts	Sample student responses	Follow-up questions
You mentioned more evaporation and more precipitation. What is the connection between evaporation and precipitation?	Evaporation puts water into the air and precipitation takes it out!	*Can you say more about how this happens?*
	It's the water cycle!	*What causes these processes to happen?*
	The Sun! When it heats things up, more evaporation occurs.	*What "things" are heating up?*
What do you think would happen if our atmosphere gets warmer? How do you think that would affect the evaporation and precipitation?	I think we would have more evaporation.	*Why do you think there would be more evaporation?*
	We learned in the Storms Unit unit that there was more evaporation over warmer ocean waters. And I know puddles of water dry up faster when it is hot outside!	*So you have some evidence for your ideas. But we may want to check this out by doing an investigation to get more evidence. (If this idea is not on the Ideas for Investigations poster, add it now.)*
	But that would mean there would be more precipitation too because of the water cycle. But the precipitation is happening in a different place than the evaporation.	*It seems we still have questions about that.*

ADDITIONAL GUIDANCE

Evaporation is a process that should be on your initial classroom consensus model. During this activity, students will analyze data about many of these processes but not the process of evaporation. They may think that higher temperatures cause more evaporation. They will not get data to support this claim in this lesson--they will investigate the link between evaporation and temperature in the next lesson. However, if it does, press students for the need for data to support their claims. This will set them up well for the investigations in Lesson 3.

Say, *We read that the temperatures are rising, which seems to be related to more extreme precipitation that causes floods or lack of precipitation that causes droughts. Do you think these events could be happening here in our area?* Allow a few to respond. Remind students of their water stories from the previous lesson. Ask them to draw from those stories that relate to what is going on in their area.

Continue by saying, *Using what we have represented in our model, let's begin by figuring out what could be going on by looking more closely at where water is located in our community and how it is moving.*

3 · OUR COMMUNITY

10 min

MATERIALS: science notebook, Earth's Water System Model, Ideas for Investigations and Data chart, chart paper, markers

Determine what is normal for the local community. Ask students if they see any similarities between their Lesson 1 water stories and the stories of Portersville and Vicksburg. As they share, ask if they think that their water stories are unusual for this area. The goal is to have students ask the question, "Is this normal for our area?" or start to wonder if the events in their stories are normal or not. Once the idea of normal has come up, have a discussion similar to the following example using conditions from your community and the water stories students told in the previous lesson.

Display **slide D**.

Suggested prompts	Sample student responses	Follow-up questions
How would we know if these sources of water and how much we are getting is normal or not normal for us? *(if students suggest it is normal)*	Well, sometimes we get really bad storms here, and it floods. It seems pretty normal, since it happens every year. It's been dry here most years. We kind of live in a desert, so I would think it is normal to not get much rain.	*So how do we measure or determine how bad a storm is to know if it is one of our normal yearly storms or something different?* *So how much rainfall would we normally expect to have in our community that is in a desert-like environment?*
How would we know this is normal or not normal for us? *(if students suggest it is not normal)*	It is flooding more and more here, and it hasn't been like that in the past. Lakes are drying up, and we get a lot more wildfires here; so it is really different than it used to be.	*So how could we compare what it is like now to what it was like in the past? What could we look at?* *What kind of information would we need to see if it is different now?* *Where might we find that information?*
If we want to figure out if the temperature is rising where we live, what should we do?	We need to look at temperature data. No, we need temperature data from now and what it was like in the past--a long time ago.	*Just temperature data for today—like how hot or cold it is outside right now?*

Determine what data would be helpful and why. Say, *So, we need to gather some information and data about what is normal precipitation and temperature in our community. And several of us mentioned what it is like today and what it was like in the past, so information from past years would be helpful for us to compare to what it is like today. How might looking at today's data compared to long ago help us determine whether what we are experiencing is normal or not?*

Display **slide E**. Start a three-column chart on chart paper that is titled: "Data we need and why" (see example). On the left side, the column should be titled "Data," and the middle column should be titled "Why." Importantly, save room for a third column. Have students do the same in their science notebook.

Data We Need and Why		
Data	Why	

ALTERNATE ACTIVITY

Pre-thinking what data is needed and what we might see in data (predictions) is an important aspect of analyzing and interpreting data and prepares students to work with the data set. If time is short, this section could be done as a discussion rather than charting ideas in science notebooks.

Give students a couple of minutes to consider these questions:

- If we wanted to find evidence for deciding if what we are experiencing is normal or not, what kind of data would we want to look at and why?
- What information would the data provide us?

ADDITIONAL GUIDANCE

It might also be helpful to refer back to their Ideas for Investigation chart from Lesson 1. If they listed data on this chart, they can add it to their notebooks here and explain why it would be helpful.

Share ideas as a class. When ready, have students share their ideas for data and their reasoning for why it would be helpful. Track their ideas onto the chart paper. Likely ideas will include the following:

- How much rain or snow we get/How much rain we got in the past.
- How often we get bad storms (or floods, or droughts) now and in the past.
- How much rain falls in a bad storm/How much rain it takes to flood a place.
- What normal temperatures are like in our community now and in the past.
- What the cut-off point is to determine whether it is a drought (or flood) or not.
- Students might also include data on related events, such as how many wildfires happen in a place.

Accept all ideas at this point, but press students to include a reason for why the data will help the class determine if these events are normal or not normal for the community. Also challenge students to think about how many years of data they would need. They do not need to suggest a specific number of years but more importantly consider if just a few years of data would be enough or if they want many years of data.

Make predictions about what we would see in the data. Display **slide F** and add "Predictions" to the third column of the chart. As a whole class, ask students to add their ideas about what we expect to see in the data if these events are normal or not normal for us.

Data We Need and Why		
Data	Why	Predictions
Rainfall data Snowfall data	To see if we are getting more rain or snow.	If we are having more floods, then we are probably getting more rain or storms.
The number of floods (or how long droughts last)	To see if we are getting more floods (or droughts).	If we are having more droughts, then we are probably getting less rain.
Temperature data over time	To see if temperatures are rising like the other places.	If it is getting warmer, then our temperatures would be going up over time.

Transition to looking at data by saying, *Let's look at some of this data for our community and see what we can figure out.*

4 · EXAMINE LONG-TERM LOCAL DATA

18 min

MATERIALS: *Analyzing Our Local Data*, *About the Data*, computer and projector, NOAA Climate at a Glance website

Introduce the data and the data source. Tell students that the National Oceanic and Atmospheric Administration (NOAA) and its partners (such as the National Weather Service) have weather monitoring stations all over the country. The stations collect data, up to every 15 minutes, and when combined over days and years, we have a historical data set that gives us a view of precipitation and temperature in any place in the US. We can choose how long we want our data to span.

Say, *You said earlier that you wanted to look at data as far back as we can to see if what we are experiencing is normal or not. We can look back many years and get a long-term view of our data.*

Hand out a customized version of *Analyzing Our Local Data* to each student. This is the version of the handout that has graphs of local data for precipitation, temperature, and the Palmer Drought Severity Index (PDSI) for the last 125 years.

Determine the context and purpose of the data part 1). Display **slide G**. Provide students with *About the Data*, which explains some of the data. This reference will be used now and again on day 2.

For part 1, students should read about the first three data sources: Total Precipitation, Average Annual Temperature, and the Palmer Drought Severity Index. Have students put a check mark beside these three data sources to indicate which ones to read. On part 1 of *Analyzing Our Local Data*, have students jot down notes about the data sources and why they think they could be helpful for figuring out if conditions are normal or not.

ADDITIONAL GUIDANCE

The Palmer Drought Severity Index (PDSI) is a new data source for students to use. It is a combination of measurements across precipitation, temperature, and soil moisture, among other things, to provide a score of wetness (+) and dryness (-) for place. Scores closer to + or - 4 indicate much more severe conditions for a place. This data provides a more complete view of total water available in a place, so it can enhance students' interpretations by moving beyond precipitation alone.

Discuss the Palmer Drought Severity Index (PDSI). This graph can be challenging for students because it is a graph of the index. Take time to answer questions students may have about this data set. It will be helpful to students for them to draw a line across the graph at +4 and another at -4. Then tell students that data closer to or over these values indicate much more severe conditions for a location.

Orient students to the long-term graphs. Display **slide H**. Say, *These graphs provide us data for our local area for several years. Look closely at the graphs—how many years are we looking at? What else do you notice?* ✱

- It shows about 125 years.
- There are a lot of bars and points.
- Time is on the *x*-axis.
- Temperature (or precipitation) is on the *y*-axis.
- Lines go above and below zero for this graph (PDSI graph).
- There is a line through all the data.

Ask students, *What do you think that line through the data represents? Didn't we work with something similar in the last unit--Palm Oil Unit?* Students should recall that this line is a trend line and it is an average plotted over a long time. Emphasize to students that the website has powerful digital tools to help analyze data sets. One of these tools is adding a trend line.

✱ SUPPORTING STUDENTS IN ENGAGING IN ANALYZING AND INTERPRETING DATA

Although students are not using digital tools directly to analyze trends in these complex data sets, emphasize that you used these tools to make this graph. You should emphasize that digital tools are available on this website and on most digital graphing programs for them to use as they analyze data in the future. Remind students that the trend line on these long-term graphs is generated by averaging data over each decade, plotting those points, and then drawing a line that best fits those data points.

✱ SUPPORTING STUDENTS IN ENGAGING IN ANALYZING AND INTERPRETING DATA

Students will use the Identify and Interpret (I^2) sensemaking strategy to analyze the data table. This strategy helps students break down an information-rich data set into smaller pieces to interpret, which will allow them to use the data to provide evidence for a phenomenon. For example, one WIS statement might be that the line on the graph goes up. The WIM statement paired with it would be that it means that temperature is increasing. Use the format of first identifying what you see and then moving to what it means for key features of a data set, even in class discussions. Doing so will build a habit of mind for students as they begin to analyze and interpret various data sets.

ADDITIONAL GUIDANCE

Students have seen or used trend lines in past OpenSciEd units, such as the previous *Palm Oil Unit*. If your students have not experienced these units and trend lines, take a few moments to explain what they mean and what we can learn from them. The trend lines on graphs are created by average data across each decade in the set and then plotting a smooth line to represent the trend from one decade to the next.

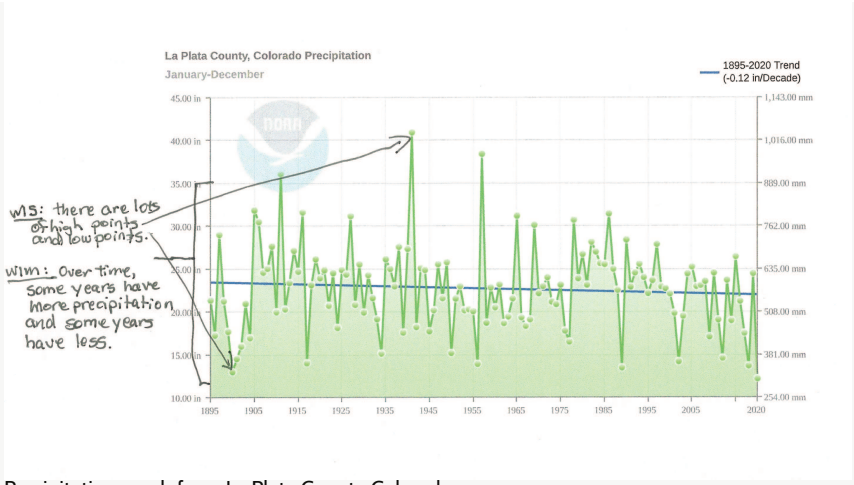
Prepare for the I^2 sensemaking strategy (part 2 of handout). ✱Project **slide I** to students and remind them how to use the I^2 strategy to analyze and interpret data. Arrange students in groups of three.

Use I^2 as a class to complete an example of using the strategy to analyze graphs. It may have been some time since students have used I^2 or this may be their first time. It will be helpful to work through an example of a pair of WIS and WIM statements so students understand how to use the I^2 strategy. Navigate to the *NOAA Climate at a Glance* time series data website at https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/county/time-series and display the local data following the instructions you used from *Instructions for Accessing Local Data* to prepare the graphs. Project the precipitation graph and work through an example of a pair of WIS and WIM statements with your class. Ask students to copy the example onto their graphs so they have a guide for completing the analysis. Use the following dialogue as a guide but use your student responses to write the WIS and WIM statements.

Suggested prompts	Sample student responses	Follow-up questions
Let's start with the precipitation graph. What is one thing you notice or you see when you look at this graph?	I see that there are lots of peaks and valleys--the graph goes up and down a lot. (Make the observation into a WIS statement and write it directly on the graph. Draw an arrow to show what you are describing.)	*Does the rest of the class see what _____ sees on his/her graph?*
Talk to your partner about what you think the many peaks and valleys on the graph mean. *Can someone share what they think it means?*	I think it means that over the years, some years there is more precipitation and some years there is less precipitation.	*How does that data match with your water stories?*
	The precipitation varies from year to year. No two years in a row are exactly the same.	*You said more and less. More than what? And less than what?*
	(Write their interpretation as a WIM statement near their WIS statement. See the example shown below.)	*What does it mean when you say the "precipitation varies?"*

✱ SUPPORTING STUDENTS IN ENGAGING IN ANALYZING AND INTERPRETING DATA

Students often do not include enough details when recording data and observations. You can encourage them to do so by asking questions that include: *I noticed you say it is "changing a lot"? Can you add details about what is changing and by how much?* Or you can say, *How would you describe the way the data looks from year to year? What about the overall direction the data is going over time? Be sure to add details to your notes so that other people can understand what you observed in the data.* By doing this, you will help all students understand how being specific in descriptions and observations will make it easier when they analyze and interpret the data to find similarities and differences, which will result in the collected data serving as stronger evidence.



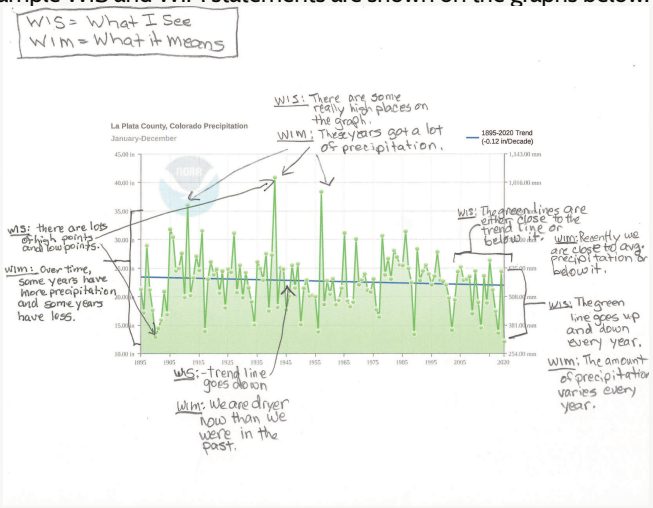
Precipitation graph from La Plata County Colorado

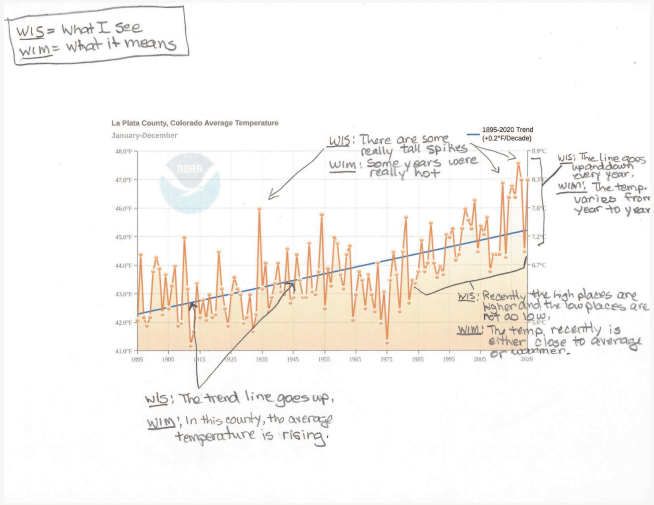
Add "vary" to the Word Wall. If the word, vary, is new to your students, take time now to add it to the Word Wall. Have students help to construct a definition for vary that is similar to "to change or to be different."

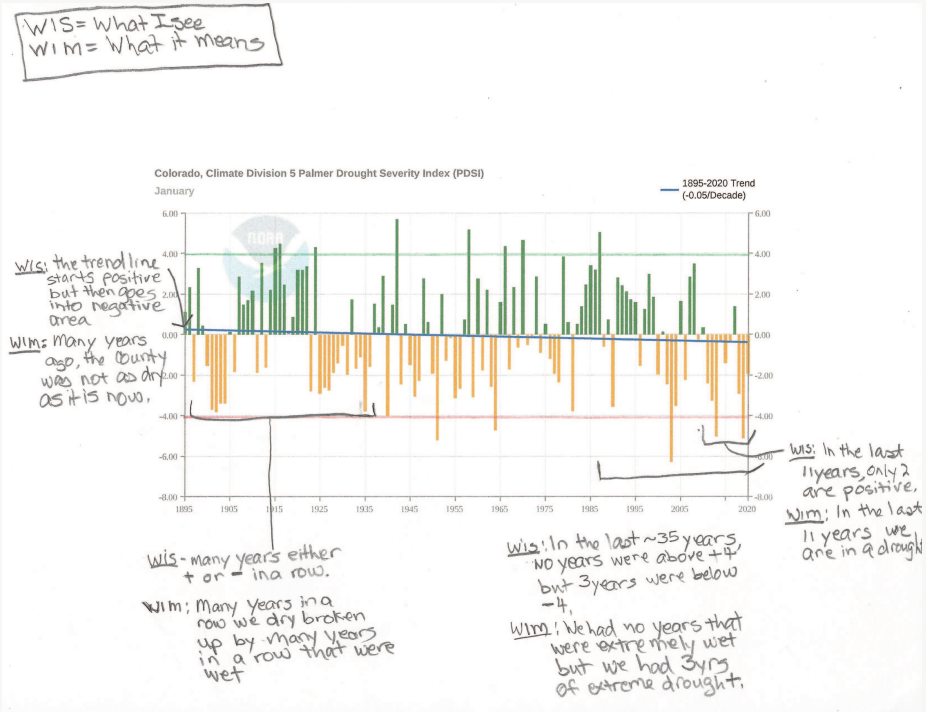
Small groups use I^2 to analyze the long-term graphs.✱ In small groups, give students time to work on their WIS and WIM statements for the three graphs. Leave **slide I** up to guide their work. Sample discussion prompts are included below to guide students' work as you visit small groups.

Suggested prompts	Sample student responses	Follow-up questions
What are you noticing on the precipitation graph? What do you see?	Well, the lines on the graph go up and down a lot. Some years it is wetter and some years it is drier.	*So what do you think that means?*
What about temperatures?	It is kind of the same, since it goes up and down from year to year; but overall the trend line is going up. Even though we have colder years and warmer years, when we average all the years together, we are having more warmer years. It could mean that the colder years are not as cold.	*So what does that mean?* *So what does that mean for our community?*

Example WIS and WIM statements are shown on the graphs below.







ADDITIONAL GUIDANCE	Students who are proficient at analyzing data may find it awkward to start with WIS statements--they will go directly to WIM statements when using the I^2 strategy as they have internalized the WIS step. The purpose of the strategy is to give struggling students a scaffold, not to get in the way of more proficient students. The purpose is not to correctly identify and distinguish WIS statements from WIM statements but for students to be successful in analyzing and interpreting the data. An important feature of this strategy is for students to write these statements directly on the graph, indicating what they are describing with arrows or brackets. Pairing each WIS statement with a WIM statement is also a key feature that will help students sort out the most important aspects of the data that will help them move forward or answer their questions. A student who records a WIS statement such as, *I see a lot of green on the graph*, will find it difficult to pair a WIM statement if the color on the graph is not important. However, green could be used as a color coding for an important feature of the data and therefore would be a helpful feature to identify and interpret.

5 · NAVIGATION

2 min

MATERIALS: None

Set up students for the next class. Display **slide J.** Suggest that students complete or review their WIS and WIM statements for the three graphs for home learning.

Ask, *What have we done today that will help us figure out if what we are experiencing is normal or not?* Allow several to respond. Possible responses might include:

- We have looked at long-term data to see what the conditions usually are.
- We are noticing some changes that are happening recently that seem to be different than it was in the past.

Continue by asking, *Is there any data from today that you want to take a closer look at? If so, what is it?* Likely responses will include ideas along the lines of looking closer at more recent data to get more evidence for current conditions.

End of day 1

6 · NAVIGATION

3 min

MATERIALS: None

Link to previous day's work. Display **slide K.** Begin the class by recapping what we accomplished in the last class or allow students to recap for the class. Allow each group to share one pair of WIS and WIM statements to highlight what they are figuring out from the data. The class will have an opportunity to share all their ideas more in depth later in the lesson.

Consider looking closer at more recent data. Continue by saying, *We ended the class before by wanting to look closer at the data. We can look closer by zooming in on the most recent years--say, the last 10 years. Can someone remind the class why looking at this short-term data is important?* Accept several responses but having a comparison to the long-term data and getting more evidence for the current conditions should be ideas that surface.

7 · TAKE A CLOSER LOOK AT THE DATA--SHORT-TERM DATA

10 min

MATERIALS: computer and projector

Analyze and interpret data from the last 10 years. Use **slides L-N** where you have copied the short term data for your community onto the slides.

You will display each slide and have the class engage in a verbal I^2 strategy with the class. Follow these steps as you take the class through the strategy.

- Display the first slide and ask students to take a minute to look at the graph and share with a partner what they see or notice about the graph and what the observation means.
- Ask pairs of students to share their WIS and WIM ideas with the class.
- As they share, record the statements on the projected graphs.

Consider how the data helps answer our question. Ask, *How do these ideas compare to the water stories you told in the last lesson?* Allow several students to share their comparisons.

Continue by asking, *How does looking at the short-term data help us figure out if what is happening is normal or not?* Allow students to share their ideas, but some ideas that may surface are that it gives evidence to support some of their water stories. They can use these stories and the evidence to compare to the long-term data.

8 · MAKE SENSE OF LOCAL DATA COMBINED

20 min

MATERIALS: large sticky notes for Word Wall, markers, Communicating in Scientific Ways poster

Turn and talk about interpretations of patterns in the data.✱ Project **slide O**. Facilitate a Building Understandings Discussion during which students share their interpretations of the long-term precipitation, temperature, and drought data for their local community. Ask each group to try to make connections between their WIS and WIM statements across the data sets. Give students about **2 min** to talk to a partner about patterns or trends they see between and across the three data sets. Encourage students to go beyond sharing their initial WIS and WIM statements by using their statements across the three graphs to identify and explain patterns or trends. Examples may include that the temperature seems to be going up and the precipitation is going down. That pattern makes sense because the PDSI is also getting higher. This shows that the student is making sense of all three datasets as they give evidence for the climate in the community and how it is or is not changing.

Reference the Communicating in Scientific Ways chart. Call students' attention to the Communicating in Scientific Ways poster and encourage students to use the sentence starters to help them communicate their ideas during the discussion.

ADDITIONAL GUIDANCE

This discussion provides a valuable opportunity to help students communicate in scientific ways with each other as they share their ideas with the class. Students do not have this skill naturally and must be taught using tools or modeling this kind of communication. Use the OpenSciEd Communicating in Scientific Ways poster to help them during the discussion. Offering students appropriate sentence starters can help struggling students begin the discussion by sharing their ideas, observations, questions, or analysis of data. You can suggest appropriate rows of the handout that will help students depending on the type of discussion in which the class is engaged. For this Building Understandings Discussion, several rows from the poster are appropriate.

✱ SUPPORTING STUDENTS IN THREE-DIMENSIONAL LEARNING

This is a three-dimensional moment in the lesson as students are bringing together their ability to analyze and interpret data to discover important temporal patterns in how Earth's systems (e.g., temperature, precipitation, and drought data) are changing (or not) over time.

✱ ATTENDING TO EQUITY

Supporting emerging multilingual students: When developing new vocabulary, strategies that may benefit emergent multilingual learners are to use student-friendly definitions, make connections to cognate words when possible, and include a visual representation of the word. Variability is variabilidad and trend is la tendencia in Spanish. Using cognate stems like "vary" or words like "trends show where the data 'tends' to head..." might be able to help

Students share interpretations of patterns in the data. As students share, encourage students to piggyback off of one another by saying things like:

- Our group saw that, too, and we also want to add...
- We saw that pattern, but we have a different interpretation...
- We are still confused about _____. Did anyone else have a question about what that means?

ASSESSMENT OPPORTUNITY

Building towards: 2.B Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal patterns in temperature, total precipitation, and seasonal precipitation in the local community and at case sites.

Look for/listen for:

- General ideas about the trend in temperature and precipitation for your community (this will vary depending on your location).
- Ideas about the data serving as evidence that it is getting wetter, drier, warmer, or cooler in the community. Or maybe, overall, it is about the same over time with just a tiny change.
- Questions about how much of a "change in the data" matters.
- Some confusion or questions about the "ups and downs" year to year versus the straight trend line.

What to do: This is the first time students have worked with this data set, so it is OK to have some new ideas here but also some lingering questions about the data. This is a formative assessment to better understand what patterns are apparent to students in the data, but what they are also struggling to understand. If students are struggling with the graphs, try the following sensemaking with data strategies:

- Ask students to re-orient to a graph by saying: What is this graph showing us again? What is on the *x*-axis? The *y*-axis? So, the dots for each year are showing what?
- Let's just look at year ____. What is the data for that year? Is it similar or different to data for the next 5 years? Or the previous 5 years?
- Overall, our precipitation falls within ____ and ____ inches of rain each year, but there are a few years where it is above or below those points. So, in general, we can say _____ about our precipitation.
- Students might still have some questions about the data and how it varies year to year. The next conversation will focus on what that variability means versus long-term trends in data.

ADDITIONAL GUIDANCE

Almost all locations across the world see temperatures increasing. However, there is a slight chance that your local community may be seeing a slight decrease in temperatures. This trend could be because of increased rainfall or cloud cover in your area. If your community is one of these places, suggest students consider if the decrease in temperature is common across the country or an exception to the trend. This would be a good opportunity to discuss how it is important to consider all the evidence. As you make decisions, evidence from a few cases of decreasing temperatures across the country does not carry equal weight as the preponderance of evidence from the multitude of cases across the country that have increasing temperatures.

Discuss long-term trends and short term variability. Say, *OK, it looks like, over a long period of time, we see that the temperature has been _____, and the precipitation has _____ for our community. How did looking at this data help us figure this out?*

Say, *So, we noticed that the data bounced around a bit year to year. Well, scientists have a word they call the change that can happen year to year—it is called "variability." Remember the word "vary" that we added to our Word Wall? The word, variability, comes from that word. Average annual temperature and total precipitation can change, or vary, from year to year. Some years can be colder or hotter, wetter or drier--these represent short-term changes. No place on Earth has the exact same temperature or amount of precipitation every year. Sometimes it changes a little or sometimes it changes a lot from one year to the next. It varies, but it also generally stays in a range of high and lows.*

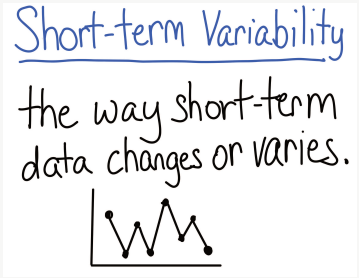
emergent multilingual students. Include a drawing as well for a visual clue to distinguish the two words. Use these strategies throughout the unit for both "words we earn" and "words we encounter."

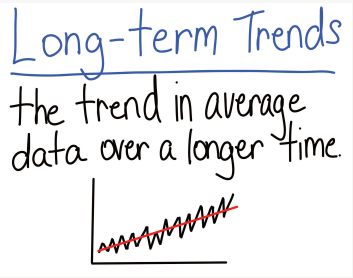
Now ask, *What did the trend line represent on the graphs with more data?*

- It showed how the average amount changed over time.

Say, *So, when we average data and look at averages over longer periods of time, we could plot which direction the average is headed—whether it is increasing or decreasing over time. This is really important to study changes in a place to distinguish from the year-to-year changes or if it is a pattern of change over time. This is called a long-term trend. Can we come up with a way to define each of these phrases (short-term variability and long-term trends) for our Word Wall?*

Work with the class to co-construct definitions. Then add "short-term variability" and "long-term trends" to the Word Wall.✱ Consider using different colors for these two words. You will use these colors again next as you make connections to weather and climate. These are important ideas for students to understand as they move forward and examine data in future lessons.





KEY IDEAS

Purpose of the discussion: to help students recognize that short-term variation in data is a normal pattern to notice, but examining long-term trends helps to see whether there are changes in the system over longer periods of time.

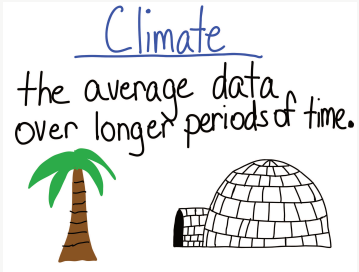
Listen for:

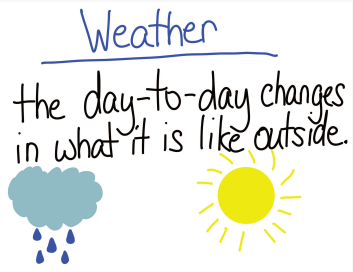
- Short-term variability is how much data can change or vary year to year.
- Long-term trends show the tendency in where the data is heading over time.

Establish the difference between "weather" and "climate." Many students might be intermixing words like "weather" and "climate," and now is a good opportunity to clarify these terms by using some of the data set to help explain them. As you are highlighting key ideas for students, consider using the same color for the word weather that you used to record the phrase short-term variability on the Word Wall. Similarly, use the same color for the word climate that you used to record the phrase long-term trends.

Say something like, *We just looked at some data over a short period of time and over a longer period of time and talked about what is normal for our community in terms of temperature and precipitation. We've been looking at total annual precipitation and average annual temperature. We learned that this is the total amount we get all year and the average of all the temperatures all year. But that is not what it is like day to day in our place. If we are talking about "weather," what kind of data might we be looking at?* Sample student responses might include:

- The temperature outside right now.
- Whether it is sunny or cloudy outside right now.
- What the forecast might be for the week.
- It is even shorter term than the 10 years we looked at--it is more like a day or a few days.





Continue by saying, *OK, so the day-to-day changes in what it is like outside is called "**weather**." But the data we have been looking at is very different. It shows what the average temperature and precipitation are over many years. That is called **climate**. It is the average data over longer periods of time.* Add "weather" and "climate" to the Word Wall.

ADDITIONAL GUIDANCE

Often it is helpful to use concrete examples for students to understand weather and climate. You might use your local climate and compare it to another place. For example, if you live in the Southwestern US, you might describe your climate as hot summers, mild winter temperatures, mostly sunny for the majority of the days of the year, and not that much expected rainfall. It consistently stays like that from year to year, and the ecosystems of the Southwest have adapted to warmer temperatures and less rainfall.

Conversely, a location in New England might describe their climate as milder summers, cold winters, a lot of snow, plenty of rainfall each year, and higher levels of humidity throughout the year. That climate is very different, and the ecosystems in that place are adapted to cooler annual temperatures and more rainfall.

Weather refers to the short-term conditions that we experience, so it can be much more variable day to day. The accumulation of those conditions over many years is what we call climate. A good analogy of this for kids is: Weather determines what clothes you wear to school each day. Climate determines what is in your closet. Students in the southern US probably have a lot of shorts and tank tops, while students in the northern US have more pants and sweaters overall.

9 · EXPAND TO NEW CASE SITES

12 min

MATERIALS: StoryMap of Case Sites, *Data for Porterville, California*, *Data for Vicksburg, Mississippi*, *Data for the Navajo Nation*, *Data for Boston, Massachusetts*, *Data for Yakima, Washington*, *Data for Windom, Minnesota*, *About the Data*, computer and projector, Earth's Water System Model

Link to new case sites. Say, *We have figured out some data from our community, but it doesn't necessarily explain Porterville, Vicksburg, and other places?*

Continue by asking, *What do we need to help us use what we figured out about our community to explain what is going on in these other places?* Students should suggest that they need similar data for these other places. Accept all student ideas. Many might want to look at additional data such as how bad storms can get or other weather-related data (Vicksburg). Students might also want to look at how deep wells have to be (Porterville).

Prepare for investigating new case sites. Display **slide P**. Divide the class into groups of 4 and assign each group one of the case sites shown on **slide P**. Tell students they will investigate one of the case sites in depth using the skills they developed analyzing data for their community. Distribute the appropriate handouts to each student. They will complete # 1-2 of part 1 of the handout for their case site. Groups should assign data sets for their case site to each group member. They will not begin their individual work yet but they will be set up for the next class.

Sneak peek into new case sites. Give students access to the StoryMap: Lesson 2: Investigating Cases in the US at https://arcg.is/1SKjOG0. Display **slide P** with the homepage for the site or project the site. Show students where they should go to watch a video of their assigned site. The videos for each case range in length from 2 minutes to less than 5 minutes. Ask students to watch the video of their assigned case site and read about their case site at the top of the handout or in the StoryMap.

Display **slide Q** and make sure that students have the handout, *About the Data*. Call attention to the Home Learning assigned. Before students leave class, have one person from each case site give the class a sentence or two about what is going on at their site as a sneak peek into the next thing they will work on.

End of day 2

10 · ANALYZE AND INTERPRET CASE SITE DATA

22 min

MATERIALS: StoryMap of Case Sites, *Data for Porterville, California*, *Data for Vicksburg, Mississippi*, *Data for the Navajo Nation*, *Data for Boston, Massachusetts*, *Data for Yakima, Washington*, *Data for Windom, Minnesota*, *About the Data*

Prepare to explore the *StoryMap of Case Sites* further. Say, *You explored part of the StoryMap at the end of the last class. Let's take a look at other features within the StoryMap.* Take a moment to orient students to the additional features of the StoryMap. Project **slide R** and open the *StoryMap of Case Sites* from https://arcg.is/1SKjOG0. Show students the following:

- Show the tabs at the top.
- Show students the different case sites and resources for each:
  - A map
  - A video about the place
  - A short paragraph about the place--all of these they have experienced.
  - Additional information in the StoryMap includes 4-5 data sets with precipitation, temperature, PDSI, and 1-2 additional graphs.✱

ADDITIONAL GUIDANCE

A StoryMap is an interactive, web-based text that helps students explore a specific geographic story. This StoryMap is a new kind of informational text for students that integrates text, maps, images, and graphs to help students interpret key science ideas.

Each group has a different location to investigate. Within each group, they have divided up the data set for analysis. Each teammate will analyze only one of the graphs or maps. Groups will summarize all the data from their site and then all groups will share a summary of their findings as a class. Review this process with the class for exploring the StoryMap.

Work in small groups to analyze and interpret case site data. Display **slide S.** Students will use the handout to guide their WIS and WIM statements. Encourage students to focus their observations on the short-term variability and long term trends in the data. Students should have no more than two WIS/WIM pairs of statements.✱

Use the following timing suggestions as a guide. Adjust as necessary for your class times.
Timing for this work includes:

- 10 minutes:
  - Individually, analyze your data by writing WIS and WIM comments about the overall "story" of the data (part 2 on the handout).
  - Individually, summarize short-term variability and long-term trends (part 3 of the handout) by writing a caption for your data.
- 10 minutes: Each group member shares the caption for their graph and the rest of the team jots down notes in part 3 of the handout. As a team, decide what and how you will share about your site with the class (part 4 of the handout). If you have more than one group per site, combine groups for this part.

As students work in their group, circulate among the groups and ask questions such as the following:

Suggested prompts	Sample student responses	Follow-up questions
How does your data show short-term variability?	The lines on the graph go up and down every year. Sometimes it goes up more than others and some years are down more than others.	*Does it seem like the normal variability we were talking about or something unusually high or low?*

✱ ATTENDING TO EQUITY

Supporting Universal Design for Learning: The StoryMaps and student handouts illustrate each case site with multiple forms of media, including video, audio, pictures, maps, line graphs, histograms, and text. The information in the text is also written explicitly to help students make links across these multiple forms of media.

Suggested prompts	Sample student responses	Follow-up questions
What is the range of temperatures you are generally seeing?	It is typically falling between __ and __ inches except in these years.	*OK, so the general range is __ and __, so we would expect normal temperatures to be in that range?*
What is the overall trend showing?	The temperature trend is showing that the average temperature is going up over time.	*How is this different from short-term variability you described earlier?*

ALTERNATE ACTIVITY

If you do not have enough computers for students to work in groups of 4, there are three alternative ways to facilitate this activity: (1) project the StoryMap for the whole class to look at together, (2) have students use personal phones or tablets to view the StoryMap, or (3) use paper versions of the materials. See the preparation section of this lesson for more information.

ADDITIONAL GUIDANCE

Natural Resources guidance and extension opportunity:
In class learning: Porterville, California is a location highly dependent on groundwater for it's community water. Students observed this in lesson 1 when they learned that the wells were going dry. As students explore the "Groundwater Reserves" graph for Porterville, there is an opportunity to delve deeper into issues around how people use groundwater even when those resources are not being replenished at the same rate of use.

Probe students' sensemaking of the groundwater data with the following questions:

- How do you think the wells in Porterville continue to get water?
- What kinds of activities in the city and area pump water from these wells?
- How does the amount of precipitation in the area affect the water people can get from wells?

Home Learning or Extension opportunity: Lesson 2 includes an additional reading, *Changes to Groundwater*. The reading provides background information about groundwater. This reading can be used to deepen students' understanding of how the stability of groundwater resources are determined by a balance of use by people and refilling from natural processes.

11 · CONSENSUS ACROSS CASE SITES AND PROGRESS TRACKER UPDATE

18 min

MATERIALS: science notebook, StoryMap of Case Sites, Case Site data sheets, *About the Data*, computer and projector, Earth's Water System Model, prepared sticky notes with arrows, prepared sticky notes with case site location.

Gather in a Scientists Circle for a Consensus Discussion. Display **slide T.** Have students bring their handouts and reference materials and gather in a Scientists Circle. Have each group briefly share information about their case site and their claims based on the data (1-2 minutes each). Students should connect their data analysis with what is going on at their case site and share that with the class. Encourage others to listen closely and use their science notebook to track similarities and differences between their assigned site and the other sites that are being discussed.

ADDITIONAL GUIDANCE

Consider projecting the StoryMap throughout the discussion as a way of looking at the locations as students share their thinking. Optional **slide O** is available to support discussion if you choose not to project the StoryMap during the discussion.

Add Model Ideas to a poster. As students share and discuss their ideas, create a new chart titled "Model Ideas" and list the important science ideas from this lesson. An example of new ideas are shown here, but students may want to add additional ideas as well.

Model Ideas List

- Year-to-year variability in precipitation & temperature is a normal pattern.
- Data averaged over long periods of time show trends.
- Precipitation or heavy storm events are ↑ where there are floods.
- Precipitation, groundwater, and snowpack are ↓ where there are droughts.
- Temperatures are ↑ for all cases.

Set up the Progress Tracker for an individual reflection. Explain to students that we want to capture what we have figured out from our examination of data from each of the case sites. Have students turn to the Progress Tracker section in their notebooks. Use **slide T** to guide students in drawing a T-chart on the first page of this section and to complete the 2 columns, filling in the lesson question: "What would we normally expect for these places and how do we know it's really changing?" This should be followed by their responses in the second column.✱

Say, *Update your Progress Trackers as we are sharing our analyses of the case sites.* Encourage students to use words and drawings to show what they have figured out about the case sites. Ask students to draw a line underneath their responses when they are done. Prompt students to identify and interpret patterns from the case site data.

Identify sites and use sticky notes with arrows on the Earth's Water System Model. As students share, stand at the Earth's Water System Model with sticky notes. Write the name of the case site at the bottom of a sticky note. Add arrows to each sticky note to indicate the trend in water resources as either going up, going down, or staying about the same (↑ , ↓ , or =). For example, the group investigating the Navajo Nation would share that precipitation is decreasing. On the class model, place Navajo Nation and next to the section of the model for precipitation. Add a down arrow to this sticky note to show that the precipitation is decreasing.

As the first group shares about temperature, offer to add "temperature" to the model if it is not already there, so we can keep track of that data. Write the word "temperature" off to the side of the class model and add arrows each time a group says something about temperature. Each group will have temperature data and the trend for all sites will show that the temperature is rising. Consider using half sticky notes for this use on the model due to space constraints.

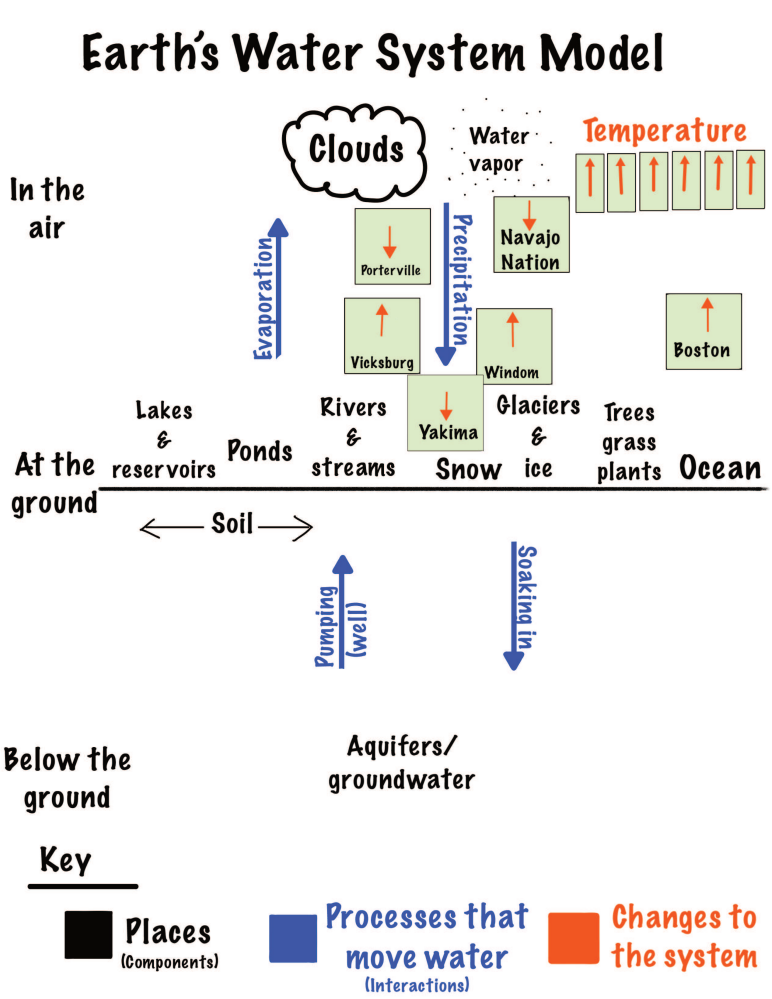
✱ ATTENDING TO EQUITY

The individual Progress Tracker is a space for students to be creative and to synthesize learning in their own words and drawings at the end of a lesson. It is not supposed to follow a prescriptive plan or structure and should be a low-stakes opportunity for students to make sense of what they are learning without the worry and anxiety that comes with knowing their work will be graded. Students have already engaged in discussion about this question, so the Progress Tracker provides an additional modality for students to express their understanding and reasoning in their own way. Encourage students to express what they have learned using a mode that makes sense for them.

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING PATTERNS

To press students to consider the *rate of change* and the numerical relationships in the data, ask students questions like:

- Has there been a steady change over time, or has most of the change occurred in a specific time period? Can you point to evidence from the data?
- Have there always been storms like this or has the rate (or frequency) of storms increased or decreased for a place? What is the evidence from the data?
- Does any data indicate a change in how long or how often something (e.g., drought, floods) are happening in a place?


Earth's Water System Model
Clouds
Water vapor
Temperature
In the air
Evaporation
Precipitation
Porterville
Navajo Nation
Vicksburg
Windom
Boston
Yakima
Lakes & reservoirs
Ponds
Rivers & streams
Snow
Glaciers & ice
Trees grass plants
Ocean
At the ground
Soil
Pumping (well)
Soaking in
Below the ground
Aquifers/ groundwater
Key
Places (Components)
Processes that move water (Interactions)
Changes to the system

Identify similarities and differences across case sites. Ask, *What are some of the similarities between the case sites?* Students may say:

Flood locations	Drought locations
Boston, Vicksburg, and Windom are flood locations. It seems like the amount of precipitation or number of storm events is increasing in areas where there are floods. The places are dealing with too much water at the surface or from above.	Porterville, Navajo Nation, and Yakima are all drought locations. It seems like the amount of precipitation over time isn't changing much for the areas of droughts or maybe going down a bit, but they are also running out of other sources of water, like groundwater or snowpack.
Similarities across all six sites	
It seems like the temperature is getting higher over time in all of the places.	

Once students have pulled out similarities, ask, *Did someone notice something different about a case site?* Example responses include:

- Boston has flooding related to storm surges and sea level, and no other site had that problem.
- Yakima and the Navajo Nation have decreasing snowpack, which is different from other sites.
- Porterville depends on groundwater, and they don't have that much anymore.

Encourage students to add similarities and differences across case sites to their Progress Trackers.

Transition to normal versus not normal. Bring students back to the lesson question. Say, *What would we normally expect for these places and how do we know it's really changing?*✱

Suggested prompts	Sample student responses	Follow-up questions
What did we figure out about this question?	The data is showing us that, from year to year, precipitation and rainfall vary a bit. It's normal to go up and down a little bit from year to year.	*So, what would we see on the graphs if it is normal?*
	If it is normal, then we would expect the average over time to stay about the same.	*Is that what we saw?*
	No, some places look like they are changing more than they did in the previous years. For example, this place is getting more and more rain than it did in the past 100 years.	*And how did you know it is getting more rain?*
	The trend line is going up.	

Suggested prompts	Sample student responses	Follow-up questions
Why is using multiple sources of data important to answer our question?	Some of the data wasn't quite clear, but when you look at a few types of data together, it helped us make sense. For example, Yakima's precipitation isn't changing much, but they are not getting as much water from snowpack as they are used to getting. If we only looked at precipitation, we might have missed that.	

ASSESSMENT OPPORTUNITY

Building towards: 2.C Analyze and interpret data about patterns in rates of change and numerical relationships to determine similarities and differences between drought and flood sites.

What to look for/listen for:

- Ideas about how some places are showing greater or lesser increase or decrease in precipitation and temperature.
- Ideas about how all places are showing temperatures going up, and importantly, most of this change in temperature is in recent years.
- Ideas about how precipitation is increasing and the rate of storm events is going up (happening more often) for flood places.
- Ideas about how drought places are experiencing a combination of less precipitation, less snowpack, and less groundwater. These places are experiencing more frequent "dry" conditions than before.

What to do: Students may struggle with some of the precipitation patterns. It might be helpful to use the Earth's Water System Model to help students understand that, even if one part of the water system for a place seems normal, another part of the system might not be. For example, precipitation in Porterville hasn't gone down drastically over the years, but they had a few extreme years of little rain coupled with decreasing groundwater, which ultimately led to people's wells drying up. The system model might help students make connections like this within a case site and also help support them in understanding similarities and differences across case sites.

Encourage students to update their Progress Tracker with any new ideas.

12 · NEXT STEPS

5 min

MATERIALS: Earth's Water System Model

Motivate next steps with temperature and precipitation. Display **slide U.** Say, *We're seeing changes in water for these communities, and precipitation in particular. The one thing they all have in common is rising temperatures. Look at our class model. We have arrows from the data for all these case sites for many of the processes we have on our model. What do you notice about evaporation?* Students should notice that we do not have data about the evaporation process in our system model.

Continue by asking, *What do we already know about how rising temperatures might affect Earth's water system?*

- Students will likely share ideas from Lesson 1 about how increases in temperature might cause evaporation of water to occur.

Ask, *Could we plan an investigation to test to see how temperature increases evaporation--to get some data? How could the same change in temperature cause wet places and dry places? What would we need to do?* Sample student ideas might include:

- Test temperature in a wet place and a dry place.
- Test different temperatures and see if they cause more evaporation.

ALTERNATE ACTIVITY	If students suggested evaporation-related experiments when they brainstormed Ideas for Investigation in Lesson 1, use this opportunity to surface those ideas again and ask students who suggested them to elaborate how the investigation could help the class understand how rising temperatures could affect evaporation.

Additional Lesson 2 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA	**CCSS.ELA-LITERACY.RST.6-8.7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).** Students integrate quantitative and technical information across text, video, histograms, and line graphs to develop a claim for how the data supports a change in temperature and/or precipitation for a community.
SUPPORTING STUDENTS IN MAKING CONNECTIONS IN MATH	**CCSS.MATH.CONTENT.6.SP.B.4 Display numerical data in plots on a number line, including dot plots, histograms, and box plots.** **CCSS.MATH.CONTENT.6.SP.B.5 Summarize numerical data sets in relation to their context, such as by:** • **CCSS.MATH.CONTENT.6.SP.B.5.B Describing the nature of the attribute under investigation, including how it was measured and its units of measurement.** • **CCSS.MATH.CONTENT.6.SP.B.5.C Giving quantitative measures of center (median and/or mean) and variability (interquartile range and/or mean absolute deviation), as well as describing any overall pattern and any striking deviations from the overall pattern with reference to the context in which the data were gathered.** • **CCSS.MATH.CONTENT.6.SP.B.5.D Relating the choice of measures of center and variability to the shape of the data distribution and the context in which the data were gathered.** Students work with variability within data and measures of central tendency (trend lines) to understand whether conditions in a place are normal or if they are changing.

LESSON 3: How would increased temperatures affect evaporation?

PREVIOUS LESSON

We developed a systems model to describe where Earth's freshwater is stored above, at, and below the surface. We analyzed and interpreted temperature, precipitation, and drought or flood data in our local community and six other places in the United States and figured out that water in these communities is changing over time, and all case sites showed rising temperatures.

THIS LESSON

INVESTIGATION

2 days

We wonder if increased temperatures are related to or causing more evaporation. We create closed bottle setups to test the relationship. We determine that increased temperatures can increase the evaporation rate, leading to an increase in water vapor in the atmosphere. We wonder how the water vapor would behave in a large, open system and observe two NASA water vapor and ocean surface temperature visualizations to determine that warmer temperatures at the surface increase evaporation, but the water vapor that enters the atmosphere does not move around evenly. We question what other changes to Earth's water system are happening due to rising temperatures.

NEXT LESSON

We will obtain additional scientific and technical information about other components of Earth's water system and how those components are changing as temperatures increase. We will figure out that all components and processes in the system have been affected. We will update our model and look ahead to explaining how rising temperatures can cause floods and droughts.

BUILDING TOWARD NGSS

MS-ESS3-1, MS-ESS3-3, MS-ESS3-4, MS-ESS3-5, MS-ETS1-2

WHAT STUDENTS WILL DO

3.A Analyze evaporation investigation data for patterns to provide evidence that increased temperatures cause an increase in evaporation leading to more water vapor entering the atmosphere.

3.B Modify a model - based on evidence - to match how a change in atmospheric temperature causes a change in evaporation in Earth's water system.

WHAT STUDENTS WILL FIGURE OUT

- Increased temperatures cause an increase in evaporation and more water vapor in the atmosphere.
- Evaporation happened in all cases, but more moist conditions had higher evaporation rates than drier conditions.
- The amount of water vapor in the atmosphere is not the same for every location and winds move the water vapor to different locations.
- Areas that are dry or have droughts may be getting drier when water vapor moves away from the location, while areas that are flooding may be getting wetter because more water vapor moves toward the location.
- Cooler ocean water and landforms like mountains may affect how much water vapor gets to a location, too.

Lesson 3 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	10 min		**SURFACE STUDENTS' PRIOR EVAPORATION EXPERIENCES** Reflect on past lab experiences with humidity and temperature.	A-B	
2	15 min		**COLLABORATIVELY PLAN THE EVAPORATION LAB** Plan an investigation to determine how temperature can affect evaporation rates over time.	C-F	*Temperature and Evaporation Investigation Planning*, *What Is Air?* (optional)
3	20 min		**CONDUCT THE TEMPERATURE AND EVAPORATION LAB** Create a data table in notebooks and conduct the bottle setup evaporation lab.	G-I	Temperature and Evaporation Lab
					End of day 1
4	10 min		**COMPARE BOTTLE SETUP DATA** Look for patterns in evaporation in heated versus unheated bottles.	I-J	Temperature and Evaporation class data chart (displayed)
5	5 min		**USING SCALED MODELS TO EXPLAIN AND PREDICT REAL-WORLD SYSTEMS** Consider benefits and limitations to the scaled bottles for studying systems too large to see, identifying an important difference of closed versus open systems.	K	
6	25 min		**WATER VAPOR VISUALIZATION AND DISCUSSION** Have students make observations from simulated water vapor and temperature data, tracing its origins and pathway across the United States. Facilitate a Building Understandings Discussion as the class updates the Earth's Water System model.	L-Q	computer and projector, NASA Water Vapor visualization, NASA Water Temperature and Vapor visualization, whiteboard or chart paper, dry erase or chart markers, sticky notes, Earth's Water System model
7	5 min		**NAVIGATION** Identify other potential effects of increased temperatures on other sources of water for the case site locations.	R	
					End of day 2

Lesson 3 • Materials List

	per student	per group	per class
Temperature and Evaporation Lab materials		• 2-L bottle (pre-cut with cap on) • humidity and temperature sensor • hook-and-loop fastener • 6-in. clay dish • 4 hand warmers (heated only) • 1 cup of wet or dry soil • 2 sticky notes • dark marker • timer • *Group Humidity and Temperature Lab*	• Temperature and Evaporation class data chart • extra sticky notes • towels or sponges for cleaning bottles
Lesson materials	• *Temperature and Evaporation Investigation Planning* • *What Is Air?* (optional) • science notebook		• Temperature and Evaporation class data chart (displayed) • computer and projector • NASA Water Vapor visualization • NASA Water Temperature and Vapor visualization • whiteboard or chart paper • dry erase or chart markers • sticky notes • Earth's Water System model

Materials preparation (45 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Prior to day 1, do the following:

- Prepare all materials following the lab investigation guidance below.
- Construct a data table for the evaporation investigation using chart paper and marker or on your class whiteboard.
    - Create a row for each bottle setup but organize the rows by "not heated" and "heated". There should be 4 setups for "not heated" and 4 setups for "heated", resulting in 8 rows for student groups to record their data. If students add conditions to test, add more rows.
    - Create columns for each group to record their temperature change (1st column) and humidity change (2nd column). Add a 3rd column and 4th column for averages across the two groups who tested the same bottle setup (i.e., trial 1 and 2).
    - You may want to use colors to distinguish between the "not heated" and the "heated" sections of the chart. This may help your students better organize and interpret the data (shown in the example to the right).
    - If reusing the chart between sections of science class, have students record their data on sticky notes to post into the "cells" of the chart. Then you can take a photo of the data table using your cell phone at the end of the day 1 class period, remove the stickies, and have a blank chart ready for the next class. Insert the photo of the data table into the Lesson 3 slide deck for later reference. If using a dry erase board, take a photo of the class data before erasing the data for the next class.
    - There is a virtual lab option (described below) that uses videos for data collection.

Prior to day 2, complete the following:

- Download and/or prepare to project the *NASA Water Vapor* visualization from https://youtu.be/UgKoTTLuMJs and the *NASA Water Temperature and Water Vapor* visualization from https://youtu.be/pR5PmtolZ5M.
- Have the Earth's Water System model ready for modification.

There is the option of deepening the discussion about freshwater natural resources following **slide Q**. More guidance is provided in the Natural resources guidance and extension opportunity below or refer to *Natural Resources Guidance and Extension Opportunities*.

Day 1: Temperature and Evaporation Lab

- **Group size:** There are 4 conditions to test, but each condition will be tested twice in order to average the data for the condition. That will result in 8 total bottle setups and 8 lab groups. Each group will be responsible for 1 bottle setup and will need to later average their data with the 2nd group testing their same setup.
- **Setup:**
  - Watch *Lesson 3 Bottle Setup Instructions* from https://youtu.be/icPVGYxXfb4 to see how to prepare the bottles for the investigation.
  - Prepare an empty 2-L soda bottle (with cap on) (1 per group) by cutting off the bottom using a hacksaw at first and then scissors.
  - Clean and dry the bottle if it was originally used for a beverage.
  - Attach a humidity probe to the inside of each bottle using sticky hoop-and-lock fastener material (e.g., velcro) to allow the probe's removal at the end of each class.
  - Gather 8 6-in. clay saucers for holding the earth materials (i.e., water, soil) below the soda bottle.
  - Gather about 8 cups of soil for the investigation.
  - Use 4 cups of soil to create wet soil in a separate container. Add water until the soil is fairly moist.
  - 4 cups of soil should remain dry and can be dried in advance by placing the soil in the sun. It does not need to be completely dry ahead of time.
  - Gather 16 hand warmers for the heated conditions. Each heated condition will receive 4 warmers.
  - Depending on your class schedule and the time available to you between classes, you will want to decide how best to efficiently distribute and clean up materials. It may be helpful to have a space in the classroom where students can obtain their dry and wet soil at one location. Alternatively, you may want to provide a "kit" at each lab table with the necessary materials. Regardless, plan in advance how to have your students obtain and clean up for the next group of students.
  - If the lab tables are made of stone or another poor insulator, this could potentially affect student lab results. Test out one setup before class to determine if this will affect the temperature readings. If during the testing period the temperatures decrease, a towel may need to be put under the pans during the lab.
  - To conduct a virtual lab, students can collect their data from videos of the lab. Assign students to 1 of 4 groups. Each group observes 2 bottle setups: dry and wet soil for either heated or non-heated. Assign the following videos to collect data from:
    - Group 1 watches the unheated, trial 1 video from: https://youtu.be/bXaBmcvEjHQ
    - Group 2 watches the unheated, trial 2 video from: https://youtu.be/rNiXRYpSTRw
    - Group 3 watches the heated, trial 1 video from: https://youtu.be/g477h_IU-3Y
    - Group 4 watches the heated, trial 2 video from: https://youtu.be/QMuk4E7h4cg
- **Notes for during the lab:** The hand warmers have a useful life of up to 10 hours, so the hand warmers can be reused for each class. If the hand warmers seem to be getting cooler, try to shake them and expose the inner materials to more air to spur the exothermic process. Soil can likely be reused from class to class, but have water on hand if you need to dampen the "wet soil" throughout the day.
- **Notes for after the lab:** At the end of the lab, it is important to air the bottles out and lightly shake them to remove any accumulated water before using in the next class. Likewise the humidity probe needs at least 5 minute to recalibrate to the room's humidity before use in the closed system.
- **Safety:** Use caution in preparing the bottles. For safety, start the cut with a hacksaw and then use scissors keeping your hands clear of the saw and scissors as you hold the bottle securely in place. Be cautious of the cut edge of the bottle and provide students with a thick towel or sponge to clean the bottle.
- **Disposal:** Water can be discarded. Soil can be discarded or reused. All other materials (bottles, humidity probes, saucers) can be dried, stored, and reused.
- **Storage:** Remove humidity sensors from the bottles and store in a room temperature location. If you are not using the humidity probe in the near future, remove the batteries and store batteries in a safe location near the probes. Dry the bottles and clay saucers for reuse.

		Temperature change °F	Humidity change %	Average temperature change °F	Average humidity change %
Not Heated	Wet Soil 1 -T1				
	Wet Soil 2 -T2				
	Dry Soil 1 -T1				
	Dry Soil 2- T2				
Heated	Wet Soil 1- T1				
	Wet Soil 2- T2				
	Dry Soil 1- T1				
	Dry Soil 2- T2				

Lesson 3 • Where We Are Going and NOT Going

Where We Are Going

In the previous lesson, students identified temperatures increasing in all case study locations. Students concluded that this change was likely affecting precipitation and wondered if it was also affecting evaporation. In this lesson, students investigate the relationship between temperatures and evaporation to draw a causal relationship that increased temperatures result in increased evaporation and more water vapor in the air. To do this, students set up and conduct an investigation to gather evidence using scaled models (bottle setups). They then investigate how these ideas they figure out play out in large-scale, open systems using visualizations of NASA data.

This lesson reinforces disciplinary core ideas previously built as part of *Storms Unit* with the bundle of ESS2.C The Roles of Water in Earth's Surface Processes provides an opportunity for students to use these ideas in a new context to answer a new question about how increased temperatures affect evaporation. By increasing global temperatures, we are adding energy to the system. Students gather evidence to support how this impacts the water cycling processes, particularly evaporation and precipitation and layer on complex movements of water vapor in the atmosphere by winds. This will help your students deepen their understanding of the dynamic nature of Earth's water system, which is influenced by changes in global temperature.

Furthermore, the second two discussion prompts on **slide Q** allow for students to share ideas about ESS3.A Natural Resources, including how humans depend on water from water cycling processes, and how changes to evaporation and precipitation affect what's available to human communities. Students will conclude that because of changes to evaporation, there is more water available to precipitate, but that it's not precipitating evenly, leaving some communities without as much water. Aim for students to conclude that the amount of water resources available to communities change when water cycling processes change.

Several crosscutting concepts will be advantageous to leverage in this lesson: Patterns, Cause and Effect; Scale, Proportion, and Quantity; and Matter and Energy. A crosscutting concept you'll want to attend to specifically is Cause and Effect since students will focus on articulating the causal relationship between temperature and evaporation by the end of this lesson. In Grades 3-5 students learned that events occurring together may or may not indicate causation. New in middle school is that students are expected to more clearly differentiate between causal relationships versus correlation (which are explicitly taught in the *Everest Unit* and the *Tsunami Unit*. If you've been working on causation versus correlation this school year, elicit from students what they have done in the past to decide if the relationship is causal or not. Use their prior knowledge of causation as a way to set-up, test, and evaluate the relationship between temperature and evaporation. If your students are new to causation versus correlation, use this lab to call their attention to the purpose of collecting evidence to more fully understand if a causal relationship is supported by the data. Other crosscutting concepts are called out for you in the Learning Plan at key moments in which their use could be beneficial for students. Discussion prompts to bring forward these crosscutting concepts are present in these moments in the Learning Plan and on slides.

Students conduct the lab investigation to better understand how rising temperatures affect water cycling processes and Earth's water system as a whole. Data from the lab is intended to help them modify the Earth's Water System model when a variable in the system changes (i.e., increased temperature). You may need to help students connect the independent variable in the bottle setup (heated/unheated temperature) and the dependent variables (air temperature and humidity/water vapor) to the large-scale atmospheric system.

Where We Are NOT Going

The level at which energy transfer is emphasized in this lesson may vary depending on your students' prior experiences with OpenSciEd units (e.g., *Cup Design Unit*, *Storms Unit*, *Homemade Heater Unit*). We have intentionally included a few touch points to energy that we believe are useful for student thinking, but we intentionally did not strongly connect to energy in case students had not experienced these units. We encourage you to do more with energy if you believe your students have a solid foundation to bring ideas of energy transfer to the explanation of temperature change and evaporation rates.

On day 2, students will observe water vapor visualizations to determine what might be happening with water vapor and where it might turn into precipitation. The concepts of wind patterns, landforms, and atmospheric rivers will not be established in this lesson, as it was a part of the *Storms Unit*. Current climate change research suggests that these wind patterns and global circulation systems are shifting as temperatures rise. The changes in atmospheric circulation, storm tracks, and wind patterns are not addressed in this lesson.

Students will be working with measurements of relative humidity. While this is a measure of the percentage of humidity levels relative to the maximum humidity at a given temperature, this does not show the actual amount of water vapor present in the air when comparing air as temperatures increase. While data could be presented in graphical form showing that the water vapor is indeed increasing in the atmosphere as temperatures increase, presenting this data at this time would negate the need for "figuring out" that warmer air allows for greater water vapor content. By looking at relative humidity, students have a clearer view of the impact of increased temperatures on evaporation rate.

LEARNING PLAN for LESSON 3

1 · SURFACE STUDENTS' PRIOR EVAPORATION EXPERIENCES

10 min

MATERIALS: None

Review ideas about evaporation shared at the end of the previous class. Say, *Last class we updated one side of our model to show the precipitation changes that were occurring in different locations—some places were getting more, some less, or the frequency or timing was just different from normal. What did we wonder about the other side of the model where we've represented evaporation?*

Listen for student ideas:

- *We thought if precipitation was different, that evaporation was probably different too.*
- *We thought increased temperatures could be affecting evaporation.*
- *We thought increased temperatures could be causing more evaporation.*✱

Surface students' prior knowledge about evaporation. Project **slide A**. Say, *We are starting to make predictions that warmer temperatures could be affecting evaporation. Some of you are claiming warmer temperatures may increase evaporation. Let's describe what we know right now about the relationship between evaporation and temperature.*

Give students 1-2 minutes to turn and talk about the questions on the slide.

- What do you think causes evaporation?
- What is happening at a particle scale when water evaporates? What causes the particles to do what they do during evaporation?
- Using these ideas, what do you predict will happen with evaporation in warmer temperatures? Why?

Facilitate a brief whole group sharing of their ideas. You may want to represent ideas on the class whiteboard.

Elicit the following key ideas from students:

- *Adding energy to the particles is what makes the particles turn from a liquid to a gas (or evaporate).*
- *Warmer temperatures means there are air particles with more energy.*
- *Air particles with more energy can transfer energy to water particles with less energy. This transfer of energy causes the water particles to spread apart, or evaporate.*

Listen for students saying "warmer air particles" and push them for what "warmer air particles" means in terms of energy. Likewise "cooler particles" and what that means in terms of energy.✱

Display **slide B**. Say, *How could we test this relationship between temperature and evaporation?*

Students may suggest ideas drawing on previous science labs or experiences outside school:

- Labs where they heated up water to watch it evaporate.
- Labs where they observed evaporated water condensing on a surface.
- Labs where they measured humidity inside a closed system.
- Simulations where they tested changes in temperature and humidity.

Say, *We're going to do a lab investigation today that may relate to some of these experiences you've had before testing evaporation. As we review the lab procedure, let's think about how the way we set it up will help us answer the question we're curious about, How would increased temperatures affect evaporation?*

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING CAUSE AND EFFECT

Listen for students to start using prior knowledge to make predictions that warmer temperatures cause more evaporation. When students bring up this connection, use probing questions to motivate needing evidence to support this causal relationship:

- What evidence do we have right now that warmer temperatures could cause more evaporation?
- What science ideas are you using [from previous learning] to draw these conclusions?
- How could we be more certain of this causal relationship between temperature change and evaporation?

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING ENERGY AND MATTER

Students should have completed the *Cup Design Unit*, the *Storms Unit*, or the *Homemade Heater Unit*, and should be prepared to use energy as a lens for explaining the relationship between temperature and evaporation. Consider adding prompts to activate students in using energy as they share initial ideas:

- When we learned about energy and particles before, what did we decide happens when energy is transferred to a particle?
- How can we use energy to explain what happens to particles when they evaporate?
- If the air temperatures are warmer, what does that tell us about the energy of those air particles?

2 · COLLABORATIVELY PLAN THE EVAPORATION LAB

15 min

MATERIALS: *Temperature and Evaporation Investigation Planning*, *What Is Air?* (optional)

ADDITIONAL GUIDANCE

Universal Design for Learning: There are several ways you might frame the investigation planning to elicit their prior experiences and recruit interest:

- If your students already experienced the *Storms Unit*, they completed a very similar lab. Draw upon your students' experience of that lab to decide together how to set up this lab and what to change. Note that they are doing something new in this lab by specifically testing an increased temperature as the independent variable.
- If your students have not experienced a lab like this before, you will want to involve them in the investigation planning to the extent that your materials and ability to adjust the procedures will allow.
    - If you have ample materials available and can adjust the procedures and conditions on the fly, invite more options for testing from students. Students may want to test a condition representing a coastal area, like Boston, with water as the surface material. (They may want to add ice to simulate Yakima, too).
    - If you have limited materials or less comfort adjusting the lab procedures and conditions on the fly, show students what you have and the procedures you have and invite them to reflect on how the lab is set up in ways that will allow them to answer their question (and the limitations of the lab, too!).

Determine the investigative question. Pass out 1 copy of *Temperature and Evaporation Investigation Planning* to each student. Explain to students that we can use this planning sheet to help us understand what we need to test and how to set up the investigation. Ask students to write our investigative question—*How would increased temperatures affect evaporation?*—on their handouts.✱

Demonstrate the lab setup and procedures. Show students the bottle setups you have available. Show students how they will assemble their bottle setups to give them a sense of how the lab will be conducted.

Map the bottle setups to the real world. Display **slide C** (and then **slide D**). Focus students' attention on how this particular investigation setup will help them answer their question. Facilitate a discussion about (1) how they can use this setup to study large scale systems✱ (2) how the different parts of the scaled model might map to the real world, and (3) how the bottle setups help them study the different case sites from Lesson 2.

Suggested prompts	Sample student responses
How can we use this setup to study things happening at the large scale in the real world?	We can heat up the bottles and watch evaporation happening inside them, which might be hard to study if we were trying to see it or measure it outside.
Let's think about the different parts we have. What are the parts of this setup that map to things in the real world? [direct students to their handout to record important parts]	Bottle, saucer/tray, soil, water, sensor, etc.
What do you think is the purpose of the 2-Liter bottle that is capped?	It could trap the air and close it off. We can see if the sample of air inside the bottle is warmer and watch if water evaporates. It may get trapped in the 2-L bottle and water might collect on the inside of the bottle.

✱ SUPPORTING STUDENTS IN ENGAGING IN PLANNING AND CARRYING OUT INVESTIGATIONS

Use *Temperature and Evaporation Investigation Planning* to help students develop this practice by identifying the question they are trying to answer, the data they need, and the procedures to collect the data.

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING SCALE, PROPORTION, AND QUANTITY

The first prompt on **slide C** is to encourage your students to use scale as a lens for thinking about how these scaled models could be used to study evaporation happening in large-scale systems. The purpose is to draw your students' attention to the idea that we can use scaled models to help us study systems too large or too small to see. You will return to the limitations of these scaled models for studying large-scale systems on day 2 (see **slide K**).

Suggested prompts	Sample student responses
What do you think is the purpose of the saucer?	To hold the dirt or soil.
What do you think is the purpose of the wet soil versus the dry soil?	The wet soil is like places with a lot of water or flooding. The dry soil is like places with drought.
*Project **slide D.** Now that you've thought more about the bottle setups, which case sites do our bottles map to best? Which do they not map to?*	Dry soil bottles map to Navajo Nation and Portersville. Wet soil bottles map to Vicksburg, Windom, and maybe Boston.

As the class maps the parts of the bottles to the real world, have your students record this mapping on their handout. Add rows as needed. The mapping might include:

Key parts of the bottle setups	Purpose (What it represents in the real world)
bottle	to contain the air which may be like the atmosphere
saucer	to contain the soil which may be like the surface of Earth
soil	the soil on the surface of Earth
water in wet soil	to show water in soil which may be like damp soil, flooded areas in places on Earth
dry soil	to show lack of water in soil, which may be like areas where there is a drought.
humidity and temperature sensor	[add after the discussion of the probe and what it measures]

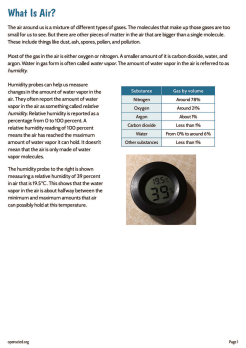
Focus students on what they are measuring with the sensor. Display **slide E.** Your students will need help to connect the humidity and temperature sensor to their question about evaporation. Engage them in thinking about how measuring humidity relates to evaporation.

Suggested prompt	Sample student response
We want to study evaporation, but I don't have a tool for that. I do have a humidity sensor that measures how much water is in the air and it gives us temperature too. How could we use this tool to answer our question about temperature and evaporation?	We want to know if increased temperature relates to evaporation so we need to see if warmer bottles have more evaporation. Humidity is how much water is in the air. Not sure how humidity connects to evaporation.
What exactly does humidity measure? When we say it's humid outside, what are we describing?	How much water is in the air.
And when we talk about water in the air, what do we mean by that?	How much water vapor is in the air.

Suggested prompt	Sample student response
The question we want to answer is about evaporation, not humidity. So how can we use this sensor that measures water vapor in the air to answer a question about evaporation?	Evaporation and humidity are related. Humidity shows us how much water is evaporating into the air. Evaporation means water goes into the air, and the more evaporation you have, the higher the humidity would be.
So let's confirm. How does this kind of sensor help us answer the question about how increased temperatures affect evaporation?	If we measure the humidity with different temperatures, it can show us if the humidity increases or not. If the humidity increases more in the bottles with a warmer temperature, that would mean there is more evaporation.

ADDITIONAL GUIDANCE

Building prerequisite understandings: Because of the focus of this unit, if students have not previously experienced the *Storms Unit*, it may be beneficial to develop an understanding of the concept of relative humidity by reading *What Is Air?*. Take a moment to read about relative humidity and what the sensor is measuring about water vapor in the air.



What Is Air?

The air around us is a mixture of different types of gases. The molecules that make up those gases are too small for us to see. But there are other pieces of matter in the air that are bigger than a single molecule. These include things like dust, ash, spores, pollen, and pollution.

Most of the gas in the air is either oxygen or nitrogen. A smaller amount of it is carbon dioxide, water, and argon. Water in gas form is often called water vapor. The amount of water vapor in the air is referred to as *humidity*.

Humidity probes can help us measure changes in the amount of water vapor in the air. They often report the amount of water vapor in the air as something called *relative humidity*. Relative humidity is reported as a percentage from 0% to 100 percent. A relative humidity reading of 100 percent means the air has reached the maximum amount of water vapor it can hold. It doesn't mean that the air is only made of water vapor molecules.

Substance	Gas by volume
Nitrogen	Around 78%
Oxygen	Around 21%
Argon	About 1%
Carbon dioxide	Less than 1%
Water	From 0% to around 4%
Other substances	Less than 1%

The humidity probe to the right is shown measuring a relative humidity of 39 percent in air that is 19.5°C. This shows that the water vapor in the air is about halfway between the minimum and maximum amounts that air can possibly hold at this temperature.

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Focus on the change we are testing and identify variables. Say, *Let's use what we know about independent and dependent variables to agree on what change we are trying to test and what we are going to measure to see if there is a difference.* Elicit ideas from students for the independent variable, dependent variables, and control variables. **Slide F** provides prompts for a Turn and Talk before discussing together as a class. Examples include:

- The one thing we are changing (independent variable) - increased temperature
- What we are measuring (dependent variables) - humidity or water vapor in air, temperature change in the air, water collecting on sides of bottle
- Control - Students will be testing the same set up with heated and non-heated, so those two groups will want to sample from the same amount of soil, bottle size, time, etc. The non-heated bottle is the "control" condition.

Introduce hand warmers and reflect on how well they represent increased temperatures. Say, *For the heated conditions I have hand warmers to use. I know that Earth is not heated by a whole bunch of hand warmers under the surface, but this is what we have to use. Let's think about how these will serve our needs, but also how they are different from the real world.*

Suggested prompts	Sample student responses
How are the hand warmers a good representation of how air gets heated?	If students have had the Storms Unit: Air is warmed or heated from the ground—when the ground warms up, it transfers energy to the air. Air is not heated directly from the sun. If students have not had the Storms Unit: They can warm up the clay saucer and soil and that might warm the air in the bottle too.
How are they not like the real world and how air gets heated?	Heat doesn't come from below, like the center of Earth. It comes from sunlight warming the surface.

3 · CONDUCT THE TEMPERATURE AND EVAPORATION LAB

20 min

MATERIALS: Temperature and Evaporation Lab, science notebook

Draw data tables in science notebooks. Instruct students to set up a data table that will allow them to record temperature and humidity every 2 minutes for 8 minutes total. **Slide G** is provided. Example:

	Start (0 min)	2 min	4 min	6 min	Final (8 min)	Change
Temp						
Humidity						

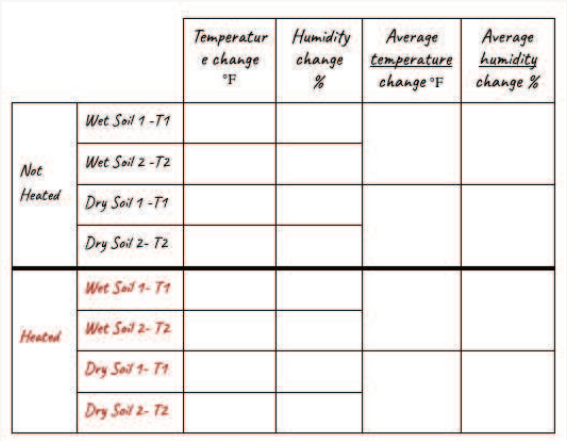
Introduce class evaporation data chart. Show students how they will post their 2 sticky notes for temperature change and humidity change to the class chart. The class chart can be drawn on the class whiteboard, chart paper, or projected over a wall or whiteboard using **slide H**.

Review the reason for 2 trials or test setups for the same condition and the process you want the two groups to do in order to average their results.

Group students into 8 different groups. Assign each group a different condition. Two different groups will test the same condition, which will represent 2 trials for that condition. Use the following conditions:

- Wet soil, not heated
- Dry soil, not heated
- Wet soil, heated
- Dry soil, heated

Distribute lab materials and conduct the lab. Provide guidance on how to obtain materials and clean up from the lab. Answer any questions that students may have about the lab. Make sure each group receives 1 copy of *Group Humidity and Temperature Lab* along with their materials.



		Temperature change °F	Humidity change %	Average temperature change °F	Average humidity change %
Not Heated	Wet Soil 1 -T1				
	Wet Soil 2 -T2				
	Dry Soil 1 -T1				
	Dry Soil 2- T2				
Heated	Wet Soil 1- T1				
	Wet Soil 2- T2				
	Dry Soil 1- T1				
	Dry Soil 2- T2				

blank class chart

✱ ATTENDING TO EQUITY

Universal Design for Learning: Larger tables filled with data can seem overwhelming to some students. Some students may benefit from a change in data *representation* by condensing the chart to show only the average differences in humidity and temperature change. By removing the unnecessary data, some students are better able to see patterns in a smaller dataset.

Once all groups have the required materials, allow students to start the lab. As students are working, circulate to make sure that the bottles are set up correctly and that there are no visible gaps between the 2-L bottle top and the tray.

Once students have completed the lab, have students clean and return materials following your instructions.

ADDITIONAL GUIDANCE

To conduct a virtual lab, students can collect their data from videos of the lab. Assign students to 1 of 4 groups. Each group observes 2 bottle setups: dry and wet soil for either heated or non-heated. Assign the following videos to collect data from:

- Group 1 watches the not-heated, trial 1 video from: https://youtu.be/bXaBmcvEjHQ
- Group 2 watches the not-heated, trial 2 video from: https://youtu.be/rNiXRYpSTRw
- Group 3 watches the heated, trial 1 video from: https://youtu.be/g477h_IU-3Y
- Group 4 watches the heated, trial 2 video from: https://youtu.be/QMuk4E7h4cg

Average and post data to the class chart. Have groups post their individual stickies to the class chart. Ask that the two groups testing the same conditions designate one member from each group to work together to average their data. Provide extra stickies for them to post the averaged data to the chart.✱

Before students leave class, inform them that they will get to look deeper into the whole class data in the next class period.

Take pictures of the class data table for analysis in the next class period. Insert pictures into **slide I.** Duplicate slide I, as needed, to insert pictures of the class data table.

		Temperature change °F	Humidity change %	Average temperature change °F	Average humidity change %
Not Heated	Wet Soil 1 -T1	↑ 0.7 °F	↑ 14%	↑ 0.1 °F	↑ 13.5%
	Wet Soil 2 -T2	↓ 0.5 °F	↑ 13%		
	Dry Soil 1 -T1	↑ 0.6 °F	↑ 5%	↑ 0.05 °F	↑ 4.5%
	Dry Soil 2- T2	↓ 0.5 °F	↑ 4%		
Heated	Wet Soil 1- T1	↑ 0.9 °F	↑ 24%	↑ 0.8 °F	↑ 25.5%
	Wet Soil 2- T2	↑ 0.91 °F	↑ 27%		
	Dry Soil 1- T1	↑ 0.7 °F	↑ 3%	↑ 0.5 °F	↑ 7.5%
	Dry Soil 2- T2	↑ 0.5 °F	↑ 12%		

sample data

End of day 1

4 · COMPARE BOTTLE SETUP DATA

10 min

MATERIALS: Temperature and Evaporation class data chart (displayed)

Say, *Last class we had the opportunity to collect temperature and humidity data over time as we increased the temperature in our bottle steps. Our question was how increased temperature affects evaporation. Now that we have the data, how should we analyze it to answer our question?*

Listen for students to identify that we need to analyze the data in a way that compares the heated and non-heated conditions to see if the heated conditions (increased temperature) seems to have different humidity outcomes.

Look for patterns in humidity data. Project **slide I** with the class data for their investigation. Give students 2 minutes to turn and talk about the following question:

- Compare the average temperature and humidity level change in the unheated bottles with the average temperature and humidity level change in the heated bottles. What patterns do you notice?

Bring students back together for a whole group discussion. Use this opportunity to check-in on what conclusions students are drawing from the data. Students should identify the following ideas:

- All conditions saw an increase in humidity, even the dry soil conditions.
- Wet soil conditions had a greater humidity increase than dry soil conditions.
- Heated conditions had a greater humidity increase than non-heated conditions.

ASSESSMENT OPPORTUNITY

Building towards: 3.A Analyze evaporation investigation data for patterns to provide evidence that increased temperatures cause an increase in evaporation leading to more water vapor entering the atmosphere.

What to look/listen for:

- All conditions saw an increase in humidity, even the dry soil conditions.
- Wet soil conditions had a greater humidity increase than dry soil conditions.
- Heated conditions had a greater humidity increase than non-heated conditions.
- Increasing humidity in the bottle is an indication of evaporation occurring, so a larger change in humidity indicates more evaporation occurred in the same period of time.

What to do:

- If students do not identify that the humidity increased in all bottles, ask students if we have any conditions in which humidity stayed exactly the same or decreased. If so, did anything unusual happen with temperature for that condition. Follow up specifically on the locations experiencing drought and what we can conclude about evaporation in these places - that it is still happening.
- If students do not identify that the heated bottles had higher humidity level changes, ask what differences they see between the two conditions (heated versus unheated). Connect back to students' ideas about what causes water to evaporate (adding energy) and what conditions had energy added to them.
- You may need to support students in the transition from humidity level changes to evaporation to evaporation rate. The concept of 'rate' is a change in one measure with another measure. In this case, it's a change in the quantity of water vapor in the air (humidity) over time (8 min). Ask your students, *Which condition had the greatest change in humidity in the same time period? What can we say about how fast evaporation was happening in this condition compared to the other conditions?*

Lead a whole group discussion about the results. Display **slide J.** Say, *Let's revisit our initial question and see if our data allows us to draw a conclusion.*

✱ SUPPORTING STUDENTS IN THREE-DIMENSIONAL LEARNING

Students should analyze the data to identify three important patterns that help them explain the connection between temperature and evaporation: (1) humidity increased in all conditions meaning evaporation occurs even in unheated conditions and those with dry soil, (2) wet soil conditions had greater evaporation, (3) heated conditions had greater evaporation.

Suggested prompts	Sample student responses
Our question was whether increased temperature affects evaporation. What can we conclude now with the data we have?	The heated conditions had more evaporation. If it's warmer, there is going to be more evaporation. [students bringing energy ideas] When we added energy using the hand warmers, the energy transferred into the system to the water and it evaporated.
What patterns did we notice that surprised us or that we weren't expecting?	We didn't think there would be much evaporation in the dry soil, but there was. Water is evaporating more everywhere in the warmer temperatures, even in dry soil places.
If there are increased amounts of water vapor in the air, how does that affect our water system model?	It should add more water in the air, and we should see more evaporation everywhere.
How does what we did here relate to the droughts and floods we're investigating?	It should increase the amount of precipitation, so shouldn't everywhere be flooding? The floods might just be more intense. Maybe the dry areas get drier because they run out of water to evaporate. If clouds stay in the same place then deserts should be getting more rain too, which isn't happening.

Say, *It seems like we have identified that it means that there might be more water vapor in the air, maybe more precipitation and flooding, but we aren't sure exactly what's happening with the drought places if there is evaporation but no precipitation.*

5 · USING SCALED MODELS TO EXPLAIN AND PREDICT REAL-WORLD SYSTEMS

5 min

MATERIALS: None

Generate ideas about what the bottles helped us see. Display **slide K**. Point out to students that they just used these small scale models to start drawing conclusions about what is happening in the different case study locations. Guide students through a brief reflection on the benefits and limitations of the bottles using the prompts on the slide. Give students 1-2 minutes for a Turn and Talk.

Bring students back together to share.

- Useful because...
  - The lab helped us get data to answer our question.
  - It made it easy to trap the air to measure the water vapor.
  - We could change different things to test it easily.
- Different or limiting because...✱
  - The lab did not have the same time frame.

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING SCALE, PROPORTION, AND QUANTITY

A limitation of using the bottles in the lab is that the bottles represent closed systems when the real-world system that students are investigating is actually an open system. Students have developed an idea of open and closed systems over the course of multiple OpenSciEd units and may recognize

- The lab used a heat source different from the real-world.
- The bottle trapped the air and kept it in one place.

Listen specifically for students to generate ideas about the closed system they tested in the lab and the open system of our atmosphere (e.g., no bottle holding air in place, winds moving air). If students do not bring this up, ask, *How might our observations of water vapor be different in the actual atmosphere where there is no bottle holding air in place?*

this limitation. Use these probes to listen for how students are making sense of phenomena they observe at one scale using the scaled models to study large-scale atmospheric systems.

6 · WATER VAPOR VISUALIZATION AND DISCUSSION

25 min

MATERIALS: science notebook, computer and projector, NASA Water Vapor visualization, NASA Water Temperature and Vapor visualization, whiteboard or chart paper, dry erase or chart markers, sticky notes, Earth's Water System model

Gather in a Scientists Circle. Arrange students in a Scientists Circle for the remainder of class. Have them bring their science notebooks with them to the circle. Say, *Scientists at places like NASA and NOAA collect a lot of data on water vapor in the atmosphere, and we just identified there may be differences between our bottle investigation and the real-world. Let's examine some of their data, combined with the data from our bottles, to see if that helps us figure out what's happening more clearly.*

Load the Water Vapor (only) visualization and explain what it represents. Say, *Scientists study the atmosphere with satellites and they check their satellite data with data from weather stations located at the surface.* Display **slide L**. Give students background about the NASA visualization they are about to observe.✱ For example, the visualization:

- is a computer simulation based on real-time data,
- is from a satellite perspective but uses both satellite data and ground observations from weather stations, and
- includes data for only 1 month in June 2014.

Have students consider how this data could help us better understand water vapor in the atmosphere as opposed to the bottles and any limitations or concerns.

Then show **slide M** and take a moment to see if other questions from the DQB might be answered with this new data.

Suggested prompts	Sample student responses
If we examine this visualized water vapor data, what should we pay attention to that might be different from the bottles?	Watch if the water vapor moves. If it moves around where it's coming from or going. We were wondering if it was a pattern, so we can look to see if the water vapor is only moving to a certain part of the country.
We had other questions on our DQB about water vapor. Do you think this data could possibly help us answer some of those questions?	We were wondering why one side of the United States has more flooding and the other has more drought? We were wondering if the drought in some areas was connected to areas where it's flooding? Accept all other related responses.

Observe water vapor across the United States. Project the *NASA Water Vapor* visualization from https://youtu.be/UgKoTTLuMJs over a class whiteboard, smart board, or chart paper. Make certain that all students are able to view the visualization. Point out that the United States is outlined with a white border. It may be helpful to identify large states, landmarks, or the location of your individual state before showing the visualization.

✱ SUPPORTING STUDENTS IN ENGAGING IN ANALYZING AND INTERPRETING DATA

Students make observations from simulated, or visualized, data. The data is derived from a computer model that was originally sourced from real-time satellite data and ground observations. The original data sets are massive, accounting for hourly and daily observations around the world. Students will view the visualized data for only part of this larger data set. Use this opportunity to share with students how scientists collect and use large data sets to visualize and communicate what is happening.

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING PATTERNS

During this discussion, ask students how visualizations, such as the ones they've been making observations about, are useful for identifying patterns over time (temporal relationships) or over space (spatial relationships). Have the students reflect on how decisions about data and how to represent data is part of the work of science. For example, a still image of a single snapshot in time would not have been an appropriate representation to use for trying to identify predictable patterns.

Watch the visualization for the first time. As students view the visualization, remind them to make mental notes of noticings. Once the visualization is complete, give students one minute to share their noticings with a partner.

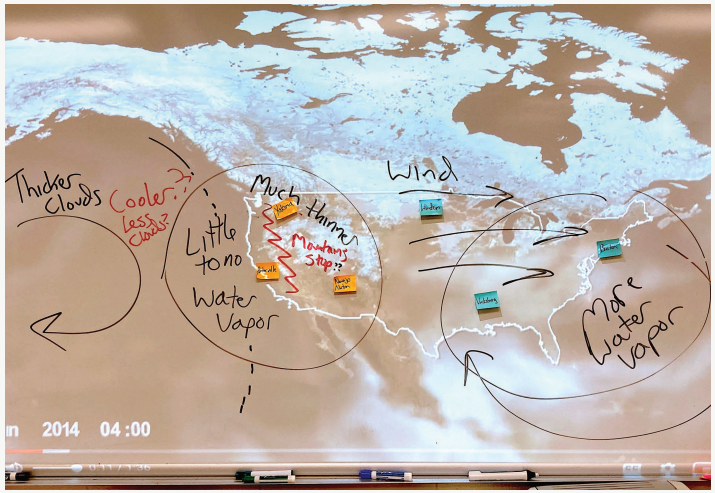
Decide on what to pay close attention to and how to annotate the class chart. Tell students they will watch the visualization again, but this time they will record, as a class, a few things on the whiteboard or chart paper background. Based on students' initial observations, decide together what to pay close attention to and how to record it. This could include

- recording the direction of water vapor movement with an arrow,
- recording where the vapor starts, and
- recording areas where there is a lot of water vapor and areas with the least vapor by circling the areas in different colors.

Place sticky notes of the case sites on the whiteboard before you replay the visualization.

Replay the visualization. Be prepared to stop and restart the visualization as needed to allow time for you or a student to record information on the whiteboard or chart paper background. This will become your class's annotated class map. Rewatch the animation as much as needed to document observations.

Facilitate a discussion from students' observations. Display **slide N**. Ask students to share what they noticed and invite students to use the class's annotated map to help them articulate their observations.



Suggested prompts	Sample student responses
What patterns are we noticing? ✱	Water vapor seems to mostly move west to east across the United States (left to right). The West Coast seems to have very little water vapor over it or over the ocean near it. Water vapor seems to start in the Gulf of Mexico or the middle of the country and move to the east.
Based on where there is water vapor, where would we predict precipitation to occur on the map?	It looks like precipitation would happen in the South and on the East Coast. The precipitation seems to be happening where there has been an increase in floods.

Suggested prompts	Sample student responses
Do our predictions line up with what we observed about data for our flood or drought story locations?	It looks like sometimes the thick white areas are moved by the wind over some flooding locations, so maybe there is a bunch of water getting to them at once. There is not a lot of water vapor shown near Navajo Nation or Portersville. It's like it's not there or moves away from there to the east.
What can we say about our flood locations?	They may be getting more precipitation because the increased water vapor is getting pushed to them by the winds.
What can we say about our drought locations?	The areas of drought don't have as much water vapor over them. It looks like the wind doesn't move the water vapor to some of our drought locations. Even though the drought locations are close to an ocean, they don't seem to be getting any of the water from it.
Some of those drought locations seem to have very little water vapor but it's not too far from the ocean. What could be preventing the water vapor from getting to states like Nevada and Arizona?	Something has to be stopping it. There is a mountain range there. Maybe the clouds hit the mountain ranges and can't go over them.

Say, *It's strange that there is so much water vapor on the East coast coming up from the Gulf of Mexico and the Atlantic, but on the West coast we're not seeing the same thing around the ocean. We do have access to some temperature data from where the water vapor starts over the oceans. If we look at temperature data and water vapor, what might we predict just based on our data from the bottles?*

Listen for students to suggest that any of the warmer locations will have more evaporation happening, therefore more water vapor entering the air.

View the temperature and water vapor visualization. Display **slide O**. Project the *NASA Water Temperature and Vapor* visualization from https://youtu.be/pR5PmtolZ5M. Allow students to make new noticings as they view the video. Replay the animation as much as necessary for students to record their observations. Open up a discussion to share noticings from the new visualization.

Suggested prompts	Sample student responses
What do you notice about this new visualization?	The water in the Gulf Coast seems much warmer than anywhere else. The ocean to the west of the West Coast is cooler than the East Coast. In areas where the temperature is higher, it seems to be constantly making water vapor.

Suggested prompts	Sample student responses
What do we think could be happening over here on the West Coast?	The West Coast has less water vapor coming over it because the Pacific is cooler. Maybe the Pacific Ocean also doesn't evaporate as fast because it's cooler than the Atlantic and Gulf of Mexico. [students who've had the Storms Unit] The mountains may be blocking some of the water vapor so it can't reach the Navajo Nation.
What new ideas do we have about the flood and drought locations?	With the winds blowing west to east, it makes sense that the water vapor may be blowing away from drought places and toward flood places. With the cooler ocean water on this side of the country there may just be less water vapor in the air to blow toward these places. In our bottle setups there was still evaporation happening in these places, but now that the system is open and winds are blowing it away, that may explain why they aren't getting very much rain.

Summarize the discussion by updating Progress Trackers and describing the relationship between temperature and evaporation. Project **slide P**. Give students a few minutes to quietly and independently summarize their new understanding in their Progress Trackers.

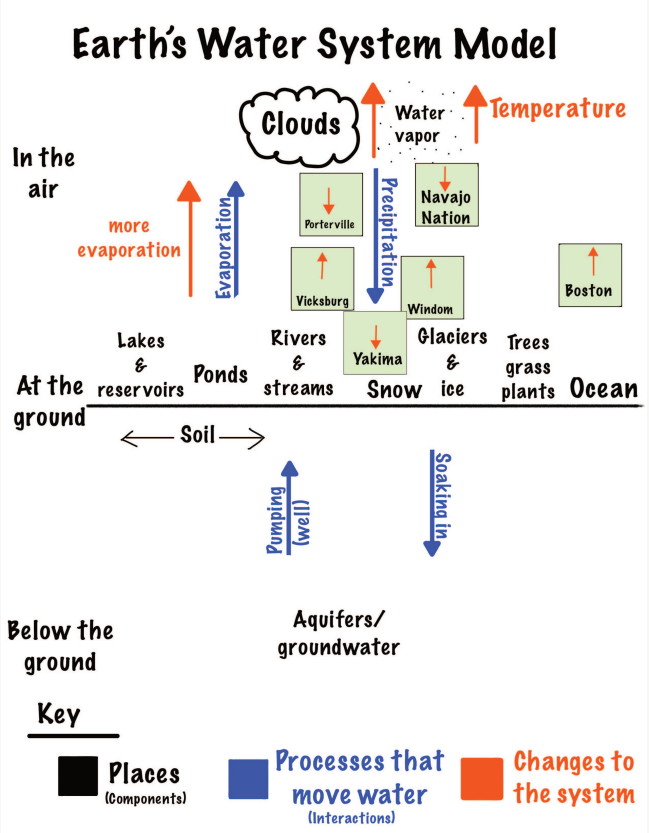
Give students time to discuss with a partner whether the new data supports that increased temperatures cause increased evaporation.

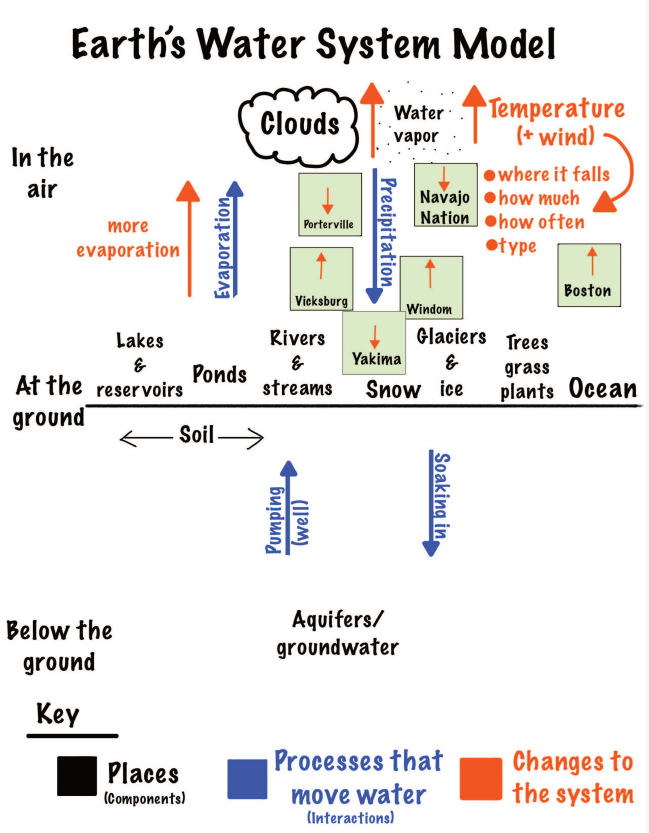
Update the class model. Display **slide Q**. Focus students' attention to the evaporation section of the model. Ask students, *What can we conclude about the effects of an increase in temperature on evaporation?*

Students should respond that an increased temperature causes increased evaporation, and this increases the overall amounts of water vapor in the atmosphere. Probe students about the causal relationship, listening for whether the data supports that changing temperature causes a change to evaporation.

When ready, modify the model by adding an up arrow to show that evaporation and water vapor is increasing, and replace the sticky notes that indicate that temperature is increasing with an up arrow. See the image below on the left for an example.

Modify what we know about precipitation changes. Direct students' attention to the precipitation side of the model. Guide students in revising the understanding of how the movement of water vapor in the atmosphere affects precipitation. See the image below on the right for an example.





Ask students, *There is more water vapor in the atmosphere overall, but it's not falling as precipitation everywhere. What new information could we add on the precipitation side? And how are we seeing this uneven precipitation impacting people's water resources.*

Students should respond that winds affect where the precipitation falls. They may also point to ocean temperatures, nearness to oceans, and landforms. Ask students to identify the ways precipitation is changing at the case sites. For example:

- Changes in where the precipitation falls
- Changes in how much precipitation falls
- Changes in how often precipitation falls
- Changes in the type of precipitation (ex. snow vs. rain)
- Changes how much water resources are available to people in those locations.✱

ADDITIONAL GUIDANCE

Natural resources guidance and extension opportunities:
The second two discussion prompts on **slide Q** will have students share their ideas about ESS3.A. Natural Resources. Because of changes to precipitation patterns, some communities are experiencing less replenishment of freshwater resources, while other communities are dealing with the opposition problem. To go further with ESS3.A consider adding a focused in class discussion using these prompts:

- How do humans depend on regular patterns in water cycling processes, like evaporation and precipitation?
- What problems are we seeing in our water resources when the patterns change?
- For people who get water from wells dug in the ground, how does their water source fill up? What happens when nothing is refilling it? How is this different from people who get their water from a city system? Where is the city getting its water, do we think?
- When there is less water available, who decides how it is shared among everyone who needs it?

Modify the model by adding an arrow pointing from the temperature box to the changes in precipitation. Other notes can be written in this area as students suggest them.

Summarize additional what we figured out ideas and add them to the Model Ideas list.

Model Ideas List

- Year-to-year variability in precipitation & temperature is a normal pattern.
- Data averaged over long periods of time show trends.
- Precipitation or heavy storm events are ↑ where there are floods.
- Precipitation, groundwater, and snowpack are ↓ where there are droughts.
- Temperatures are ↑ for all cases.
- ↑ temperatures = ↑ evaporation = ↑ water vapor in the atmosphere.
- Winds affect how and where precipitation falls.

ASSESSMENT OPPORTUNITY

Building towards: 3.B Modify a model - based on evidence - to match how a change in atmospheric temperature affects evaporation in Earth's water system.

What to look/listen for:

- Increased temperatures cause an increase in evaporation and more water vapor in the atmosphere.
- Students citing data from the bottle setups to support that this is a causal relationship.
- Students citing evidence from the NASA Water Temperature and Water Vapor visualization as additional evidence that increased temperatures cause more evaporation.
- Some students may bring their understanding of energy transfer from prior units to explain the causal relationship between increased temperature and increased evaporation.
- Students making suggestions for how to modify the model to show changes to evaporation (e.g., suggesting up arrows to show an increase) and changes in precipitation (e.g., suggesting that winds move water vapor in the atmosphere and where there may be more or less precipitation).

ASSESSMENT OPPORTUNITY

Continued from previous page...

What to do: If students do not agree on the causal relationship between an increase in temperature and an increase in evaporation, transition to thought experiments around other explanations. For example:

- Allow students to suggest other causes that would explain why there was more evaporation in the heated conditions. Use the prompt, *If an increase in temperature is not causing more evaporation, what other variables or factors can we identify in our bottles that would explain why the heated conditions had more evaporation?* Be prepared to test these new ideas.
- Have students track evidence from the bottle setups, visualizations, prior science learning, and out of school experiences that support that increased temperature causes increased evaporation. Chart evidence that supports or does not support this explanation.
- If students have prior learning of energy transfer, consider modeling at the particle scale the movement of particles in increased temperature scenarios, how those particles transfer their energy to water particles at the surface of Earth, and how water particles that gain enough kinetic energy to evaporate.
- If students struggle to suggest ideas for modifying the model, take a moment to suggest a few options for what could be represented and ask students which of those options best captures what they figured out and how they could communicate their new ideas to someone new to understanding these ideas.

7 · NAVIGATION

5 min

MATERIALS: None

Make predictions about other parts of the model. Say, *We've figured out that this higher temperature causes a change in evaporation and precipitation, which are important processes in our water system model. But if we look back at our cases, there are other sources of water in the communities other than precipitation. What other sources of water do these communities use that may be important to investigate further?* Students should identify the following additional water sources for the communities:

- East Porterville - aquifer
- Vicksburg - river
- Navajo Nation - aquifer, snowmelt
- Boston - ocean
- Yakima - snowpack, river
- Windom - river

Turn and talk about additional changes due to increased temperatures. Display **slide R**. Ask, *Could increased temperature be affecting aquifers/groundwater, snowpack, rivers and other sources as well? What do we predict?*Give students a minute to talk and then elicit predictions from students. If time permits, post sticky notes on the Earth's System Model with up arrows, down arrows, and question marks as students share their predictions.

Say, *We've made some predictions about how the increases in temperature and changes to precipitation might be affecting other parts of our model. Let's check these predictions against some more data and information next class period.*

LESSON 4: Are rising temperatures affecting anything else in Earth's water system?

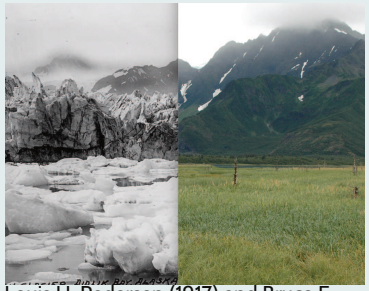
PREVIOUS LESSON

We created closed bottle setups to test the relationship between temperature and evaporation and concluded that increased temperatures cause an increase in evaporation. We wondered how the water vapor behaves in a large, open system. We observed NASA water vapor and temperature visualizations and determined that warmer temperatures at the surface increase evaporation, but the water vapor that enters the atmosphere does not move around evenly. We wondered what other changes to Earth's water system are occurring due to rising temperatures.

THIS LESSON

INVESTIGATION

1 day



Louis H. Pedersen (1917) and Bruce F. Molina (2005), obtained from the Glacier Photograph Collection/National Snow and Ice Data Center/World Data Center for Glaciology.

We obtain additional scientific and technical information about other components of Earth's water system and how those components are changing as temperatures increase. We discuss the sources of data, amount of data, and the information from scientists as we draw conclusions. We conclude that all components and processes in the system have been affected by a temperature rise. We update our model and add an entry to our Progress Tracker. We think we can now explain why communities are experiencing problems with precipitation and their water sources due to rising temperatures.

NEXT LESSON

We will use our key model ideas to build a cause-and-effect model to explain droughts and floods. Then we will apply this general model to explain how changes in temperature have an impact on our case site communities. We will revise our explanations using peer feedback.

BUILDING TOWARD NGSS

MS-ESS3-1, MS-ESS3-3, MS-ESS3-4, MS-ESS3-5, MS-ETS1-2

WHAT STUDENTS WILL DO

4.A Integrate scientific information with media and graphical displays of data to clarify how a small change in temperature affects components of Earth's water system.

WHAT STUDENTS WILL FIGURE OUT

- Changes to sources of water affect communities in different ways.
- A small change in temperature in the atmosphere can have big changes in Earth's water system.

Lesson 4 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	3 min		**NAVIGATION** Review predictions made in the previous class period about how components of the water system could be changing.	A	Earth's Water System model
2	20 min		**OBTAIN INFORMATION FROM TEXT AND VISUALS** Assign students to read about research conducted on a component of their system model. Then have students work in groups to share the information they have gathered from the text.	B-C	*Obtaining Information about Other Components*, *Changes to Snowpack*, *Changes to Sea Level*, *Changes to Glaciers and Land Ice*, *Changes to Streamflow*, *Changes to Groundwater*, sticky notes, marker
3	12 min		**FACILITATE A CONSENSUS DISCUSSION ABOUT OBSERVED CHANGES** Facilitate groups through sharing what they learned from their reading and come to consensus about how temperature change has changed components of the water system with different impacts on communities.	D-E, H-L	Earth's Water System model, Model Ideas list, markers
4	5 min		**UPDATE PROGRESS TRACKER** Individually reflect on what we figured out in this lesson.	F	
5	5 min		**NAVIGATION** Have students turn and talk to discuss how their understanding of the problem in these communities has changed since they first started learning about them.	G	

End of day 1

Lesson 4 • Materials List

	per student	per group	per class
Lesson materials	• science notebook • *Obtaining Information about Other Components* • *Changes to Snowpack* • *Changes to Sea Level* • *Changes to Glaciers and Land Ice* • *Changes to Streamflow* • *Changes to Groundwater*	• sticky notes • marker	• Earth's Water System model • Model Ideas list • markers

Materials preparation (15 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

The texts are slightly leveled to be accessible to below and on grade level readers. One text is designed to challenge above grade level readers. While all texts fall within a 810L-1000L lexile range, the Flesch-Kincaid score shows the slight differences in reading level. Additional modifications can be made to the texts to make them more accessible or more challenging depending on your students' needs.

- *Changes to Sea Level* Lexile range: 810L-1000L; Flesch-Kincaid Grade Level: 6.2
- *Changes to Streamflow* Lexile range: 810L-1000L; Flesch-Kincaid Grade Level: 6.4
- *Changes to Glaciers and Land Ice* Lexile range: 810L-1000L; Flesch-Kincaid Grade Level: 6.6
- *Changes to Snowpack* Lexile range: 810L-1000L; Flesch-Kincaid Grade Level: 7.0
- *Changes to Groundwater* Lexile range: 810L-1000L; Flesch-Kincaid Grade Level: 8.4

Refer to *Natural Resources Guidance and Extension Opportunities* for guidance on extending student learning about glacier resources, which are a key source of freshwater for human communities worldwide. Consider giving students *Glaciers and Water Supply* for home learning and a follow-up discussion of the prompts provided with the reading.

Lesson 4 • Where We Are Going and NOT Going

Where We Are Going

Students will have partially explored the relationship between temperature and precipitation during Lesson 2, and have developed conceptual understanding of the water cycle in *Storms Unit* that they will apply to their emerging understanding of Earth's water system. This lesson offers a deeper dive into temperature to better understand how it affects other components of Earth's water system over time around the world and not just at single case sites. It also gives students opportunities to reinforce ESS2.C learned in previous units, including that (1) most freshwater is in glaciers or underground; only a tiny fraction is in streams, lakes, wetlands, and the atmosphere (5th grade) and (2) that water continually cycles among land, ocean, and atmosphere via evaporation and precipitation, as well as downhill flows on land (6th grade in *Storms Unit*). The lesson also offers a moment to reinforce parts of ESS3.A that humans depend on Earth for many different resources, including freshwater, and that these resources are distributed unevenly around. In particular, glaciers as a global source of water for human communities can be explored more deeply using *Glaciers and Water Supply*.

In order to build new understanding about changes in the water system, students will obtain more information through reading scientific technical texts coupled with visual displays of data. In particular, they will consider the claims made by scientists and evaluate the data provided to support those claims.

Furthermore, students will use the lens of stability and change coupled with systems models throughout the lesson, which is demonstrated by the focus question they take up at the start, and during their analysis of data: *Are rising temperatures affecting anything else in Earth's water system?* As students discuss what they have investigated, you can help to facilitate students' use of these CCCs by guiding students to consider how a small change in temperature has led to large changes in the water system. The focus of this discussion is to help students build the element: "small changes in one part of a system might cause large changes in another part."

Where We Are NOT Going

Students will not yet provide a full explanation for changes to Earth's water system, though, they will gather the last piece of that understanding in this lesson that they can use to develop a full explanation in the next lesson.

Students will not explore the specifics of how data was gathered and calculated across both satellite and ground observations to produce the findings shared in each reading. This topic would make for an excellent extension opportunity for any student with high interest in how scientists use satellite data to make surface measurements. NASA offers ample resources should a student want to learn more.

LEARNING PLAN for LESSON 4

1 · NAVIGATION

3 min

MATERIALS: Earth's Water System model

Recall how increased temperatures affect precipitation. Ask 2-3 students to briefly share what they figured out in the previous lesson, and predictions they made about the water system. Listen for students to share things like:

- As temperatures increase, evaporation increases.
- Rising temperatures might affect groundwater.
- As temperatures increase, we might see changes in other parts of the system.

Display **slide A.** Ask students to describe the data sources that will help us check our predictions and how they will do so. Reach consensus that the data could help the class figure out if small changes in temperatures impact other components of Earth's water system.

Suggested prompt	Sample student response
What kinds of data do we want to look at?	Temperature and groundwater data. We should look at temperature and sea level data. We could examine data that shows temperature and the amount of water in rivers.
How will these data sources help us check our predictions?	We can look for the relationship between temperature and components of the water systems. If we see that rising temperatures are related to rising sea levels, then we will know our prediction is correct. We can look to see if changes in temperature affect other parts of Earth's water system.

Say, *I found information from different groups of scientists who study components of Earth's water system. These scientists make claims about how warmer temperatures are affecting the part of the system that they study. Let's look to see what claims and evidence they share and how their research matches or doesn't match what we predicted is happening. We really need to decide whether this small change in temperature is truly impacting all of the components like we think and then if this has any impact on people.*

2 · OBTAIN INFORMATION FROM TEXT AND VISUALS

20 min

MATERIALS: science notebook, *Obtaining Information about Other Components*, *Changes to Snowpack*, *Changes to Sea Level*, *Changes to Glaciers and Land Ice*, *Changes to Streamflow*, *Changes to Groundwater*, sticky notes, marker

Set the purpose for reading the text. Display **slide B**. Say, *We're pretty certain that this temperature change is causing more problems in different places of our model, but we're not certain how. What could be important to pay attention to as we read more about each component? How can we tell if the information is showing something normal or not normal?*

Listen for students to suggest:

- whether temperature is affecting that component,
- if water in that component is changing, like increasing or decreasing,
- if the component is changing how we thought it would be changing,
- if the scientists give data to support their claims, and
- if the scientists are looking at enough data over a long enough time period to be able to see a change or whether it's normal.

Display **slide C** and pass out 1 copy of *Obtaining Information about Other Components* to each student.✱ Students have previously engaged in similar reading strategies to obtain information during the *Maple Syrup Unit* and the *Palm Oil Unit*. Use the handout to preview the different information students should attend to and record as they read the text.

Assign students to read one of the texts.✱ Assign each student to read, annotate, and record their ideas to *Changes to Snowpack*, *Changes to Sea Level*, *Changes to Glaciers and Land Ice*, *Changes to Streamflow*, or *Changes to Groundwater*. Have students spend 10 minutes reading on their own.

ADDITIONAL GUIDANCE

Universal Design for Learning: Assigning students to the different texts based on the considerations below should support accessibility and *engagement* with the text. There are three considerations to account for when assigning students to the texts: (1) student interest and questions, (2) reading level, and (3) assigned case study in Lesson 2. See guidance callout for more information.

ADDITIONAL GUIDANCE

Pay attention to students' curiosities and questions when assigning texts. For example, if a student asked a question about sea level rise on the DQB, assign them to the text that would most align to their question.

Take care to assign students to the text that will be most accessible at their reading level. Consider partner reading with heterogeneous grouping as needed. The texts are slightly leveled to be accessible to below and on grade level readers. One text is designed to challenge above grade level readers. While all texts fall within a 810L-1000L lexile range, the Flesch-Kincaid score shows the slight difference in reading level. See the Materials Preparation section of this lesson for the Flesch-Kincaid score of each text.

Third, based on what you observed in students' analysis of data for the different case sites in Lesson 2, consider assigning students to texts that could help clarify some of their ideas and questions.

- Yakima, WA - Snowpack or glaciers
- Porterville, CA - Groundwater
- Navajo Nation, AZ - Streamflow, snowpack, groundwater
- Vicksburg, MS - Streamflow
- Windom, MN - Streamflow
- Boston, MA - Sea level rise

✱ SUPPORTING STUDENTS IN THREE-DIMENSIONAL LEARNING

As students read, annotate, and record notes from the texts, they should engage in all three dimensions. The *Obtaining Information about Other Components* handout will guide students to consider how to obtain and evaluate technical information from the text. The handout also focuses students on the question of how a small change in temperature could be affecting a component of the water system (stability and change). As students engage in the practice of obtaining and evaluating information and use the lens of stability and change, they work toward an understanding that water cycling components and processes are changing as a result of temperature rise.

✱ ATTENDING TO EQUITY

The numerical units and data displays used in the readings are different from those students are used to interpreting. If you notice students are struggling, suggest that they focus on what "negative" or "positive" numbers mean. If students are reading about aquifers, you can ask what a "negative trend" would indicate (water is decreasing). Or for snowpack, what "positive changes" mean (snowpack is increasing).

Convene small groups for a discussion. Continue to display **slide C**. Arrange students in small groups with the same assigned text. Have students (1) compare what they learned from each text, (2) update their own notes as they hear something new that they think is important from a member of their group, and (3) discuss a summary conclusion.

In the last 2 minutes, direct small groups to brainstorm what conclusion they want to share about their component with others in the class. Have one student write on a sticky note how temperature is affecting that component of the system and be prepared to add this to their class model.

ASSESSMENT OPPORTUNITY

Building towards: 4.A Integrate scientific information with media and graphical displays of data to clarify how a small change in temperature affects components of Earth's water system.

What to look/listen for:

- Conclusions should:
  - generally be similar to the claims made by the scientists but in students' own words,
  - describe how the component is changing (e.g., increasing, decreasing, etc.),
  - describe how temperature is related to the change in the component (e.g., melting ice, changing precipitation from rain to snow, causing a process to happen earlier, etc.), and
  - be supported by the data included with the text.

What to do: Encourage students to use the lens of stability and change as they read their text and examine the data, looking for what was considered normal and what has changed. If students struggle with interpreting the data in their reading with the information in the text, prompt them to brainstorm strategies they have used in the past to help them analyze data. If they don't offer the I^2 strategy, encourage them to use the I^2 strategy on the data display in their reading and then to compare their WIS and WIM statements with the text provided by scientists.

3 · FACILITATE A CONSENSUS DISCUSSION ABOUT OBSERVED CHANGES

12 min

MATERIALS: Earth's Water System model, Model Ideas list, markers

Facilitate a sharing of what was learned. Bring students together for a whole group discussion. Display **slide D**. Focus students on the first two questions on the slide.

- What did the scientists claim was happening and did their data support this claim?
- How did scientists' claims match or not match our initial predictions?

Have each group share for about 1 minute what they learned from their text. Ask them to also share what they concluded in terms of the relationship between temperature and changes to the component they investigated, posting their sticky note to the model.

Allow students from other groups to ask clarifying questions. The data visuals from the readings are included on **slides H-L** which students may want to display to the class as they share their conclusions.

Transition to a Consensus Discussion about how temperature affects the system and human communities that depend on the water system. Display **slide E**. Have the students connect back to the case sites from Lessons 1 and 2. Ask the following questions:

- How are changes to Earth's resources, like water, impacting communities we've looked at?
- How are these different water problems connected to each other?

KEY IDEAS

Purpose for this discussion: To develop a more comprehensive understanding that, while each community is having a slightly different problem, they connect because rising temperatures are changing Earth's water system. In particular, focus on building the following story:

- Communities depend on different water resources.
- These water resources are not evenly distributed, so each community has a slightly different problem.
- But all of their water problems seem to relate back to rising temperatures.

Listen for initially (question 1):

- Snowpack and glaciers in the mountains are getting less/smaller, and this affects places like Washington. Farmers and people rely on water when the snow melts, and there is less snow. And it's melting earlier in the year.
- Groundwater is not changing from temperature; but because places like Portersville are getting less rain, the groundwater is not refilling and people are still pumping from it, so it's becoming less as people use it.
- Vicksburg, Mississippi, and Windom, Minnesota, had really high streamflow because snow was melting earlier when rain was also coming to the area.
- Sea level is rising, so places like Boston that are right on the ocean are experiencing more flooding.
- Places like the Navajo Nation are experiencing problems with a lot of components, like less snow, dry rivers, and less groundwater, too.

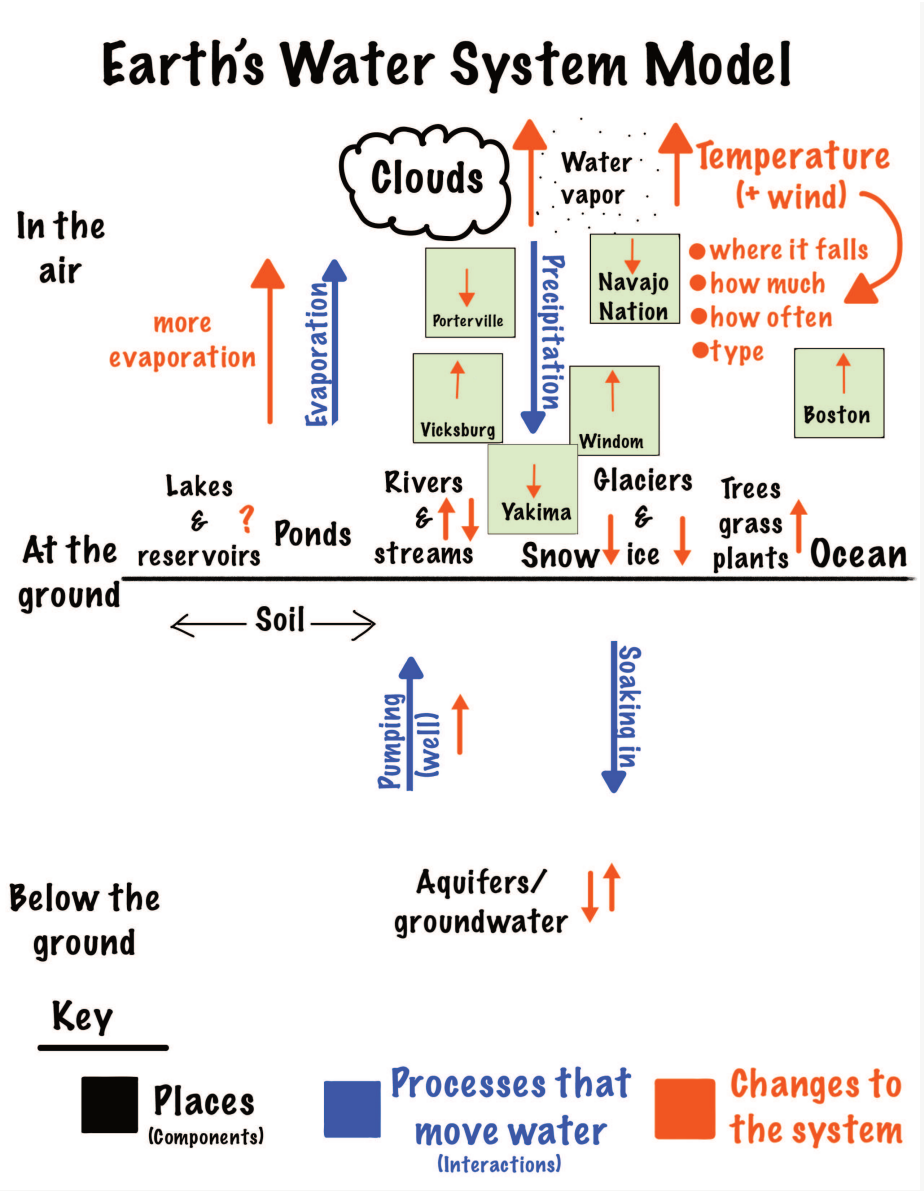
Push students to make connections across cases (question 2). Listen for:

- The temperature rise is affecting the whole water cycle or water system.
- Because our water system is all connected, changes in one part are affecting other parts.

As students share, remove sticky notes on the class's Earth's Water System model and replace them with arrows or symbols drawn directly on the model. Add new ideas to the Model Ideas list.

Model Ideas List

- Year-to-year variability in precipitation & temperature is a normal pattern.
- Data averaged over long periods of time show trends.
- Precipitation or heavy storm events are ↑ where there are floods.
- Precipitation, groundwater, and snowpack are ↓ where there are droughts.
- Temperatures are ↑ for all cases.
- ↑ temperatures = ↑ evaporation = ↑ water vapor in the atmosphere.
- Winds affect how and where precipitation falls.
- Changes to water sources (e.g., snowpack, groundwater) can affect communities in different ways.
- A small change in temperature can have a big impact on Earth's water system.


Earth's Water System Model
Clouds
Water vapor
Temperature (+ wind)
In the air
more evaporation
Evaporation
Precipitation
Porterville
Navajo Nation
where it falls
how much
how often
type
Vicksburg
Windom
Boston
Yakima
Lakes & reservoirs
?
Ponds
Rivers & streams
Glaciers & ice
Snow
Trees grass plants
Ocean
At the ground
Soil
Pumping (well)
Soaking in
Below the ground
Aquifers/ groundwater
Key
Places (Components)
Processes that move water (Interactions)
Changes to the system

4 · UPDATE PROGRESS TRACKER

5 min

MATERIALS: science notebook

Add an entry to the Progress Tracker for an individual reflection. Use **slide F** to guide students in adding an entry to their Progress Tracker below the previous one. Give students 5 minutes to quietly update their Progress Tracker, using words and drawings to show what they have figured out. Ask students to draw a line underneath their responses when they are done.

5 · NAVIGATION

5 min

MATERIALS: None

Take stock of the progress students have made. Display **slide G.** Say, *Wow. We started at the beginning just talking about a couple of places that were having droughts and floods, but this seems like a much bigger problem now. This change in temperature—just slight in some places—seems to really impact our water system. I'm wondering how these investigations have changed the way you think about the problem?* Give students 2 minutes to turn and talk to share how their understanding of the problem has changed now that they know more.

- How has your understanding of the problem changed since the first lesson? Any lingering confusions?✱
- How is the small rise in temperature affecting more than just droughts and floods?

ADDITIONAL GUIDANCE

Natural resources guidance and extension opportunities:
Glaciers provide freshwater resources to human communities around the world and are a source of water from hundreds to thousands of years ago. While glaciers are not a primary water source for the contingent United States, over a billion people worldwide rely on this freshwater resource, which is retreating or losing mass at a faster rate than replenishment in this warmer climate. The following is a home learning or extension opportunity that will engage your students in thinking about how human communities rely on glacier resources for water.

Home Learning or Extension Opportunity: Assign *Glaciers and Water Supply* as an at home reading or an extension activity in class. Use the prompts with the reading to discuss:

- How is the amount of glacier water changing as temperatures warm up?
- Think about what you've learned about changes to glaciers. How might these changes affect water supplies for people?

✱ ATTENDING TO EQUITY

Universal Design for Learning: Use this opportunity to support students in *action and expression* to monitor their progress on understanding the problem. In particular, asking questions to guide self-monitoring and reflection can support students in making sense of where they have gained knowledge and where they may still have lingering confusions.

Additional Lesson 4 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA

CCSS.ELA-Literacy.RST.6-8.2 Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

CCSS.ELA-Literacy.RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

CCSS.ELA-Literacy.RST.6-8.10 By the end of grade 8, read and comprehend science/technical texts in the grades 6-8 text complexity band independently and proficiently.

Students gather information from written text, images, and data depicting scientific research on different components of Earth's water system. Students must determine the central ideas, or claims made, and evaluate those claims using the explanations and data supplied in the text and visual displays.

LESSON 5: How are rising temperatures changing water stories in these communities?

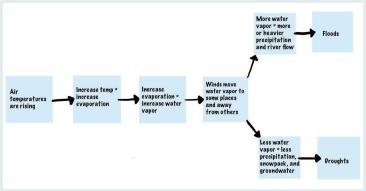
PREVIOUS LESSON

We obtained additional scientific and technical information about other components of Earth's water system and how those components are changing as temperatures increase. We concluded that all components and processes in the system have been affected. We updated our model and added an entry to our Progress Tracker. We thought we could explain how warmer temperatures cause droughts and floods.

THIS LESSON

PUTTING PIECES TOGETHER, PROBLEMATIZING

2 days



In this lesson, we use our key model ideas to build a cause-and-effect model to explain droughts and floods. Then we apply this general model to construct explanations, using evidence, about how changes in temperature are having impacts on the water stories in our case site communities. We peer review our explanations and revise them using the feedback from our peers.

NEXT LESSON

We will use our key model ideas to explain how changes in temperature have an impact on our case site communities. We will revise our explanations using peer feedback and apply our key model ideas in an Alaskan assessment transfer task.

BUILDING TOWARD NGSS

MS-ESS3-1, MS-ESS3-3, MS-ESS3-4, MS-ESS3-5, MS-ETS1-2

WHAT STUDENTS WILL DO

5.A Construct a scientific explanation based on valid and reliable evidence that changes in temperature can have impacts on the water sources available for communities.

WHAT STUDENTS WILL FIGURE OUT

- Small changes in one part of Earth's system can have big impacts on another part.
- Changes in atmospheric temperature are related to changes in the components and processes of Earth's water system.

Lesson 5 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	3 min		**NAVIGATION** Revisit student ideas connecting rising temperatures with changing precipitation patterns.	A	
2	15 min		**BUILD A CAUSE-AND-EFFECT MODEL** As a class, build a cause-and-effect model that connects rising temperatures to droughts and floods.	B	Key Model Ideas chart, pre-labeled sticky notes with model ideas, marker
3	8 min		**SET THE CONTEXT FOR EXPLANATIONS** Consider the audience, purpose, and key ideas we want to include in our explanation.	C-D	Earth's Water System Model, Model Ideas list
4	20 min		**CONSTRUCT AN EXPLANATION** Construct an explanation to explain how and why the water story in one community is changing.	E	*Initial Water Story Explanation*, *Peer Feedback Instructions*, *Data for All Case Sites*, assorted colored pencils, blank paper
					End of day 1
5	5 min		**REVIEW EXPLANATIONS** Review drafts of explanations from the previous class and add new ideas.	E	*Initial Water Story Explanation*, *Peer Feedback Instructions*, *Data for All Case Sites*
6	20 min		**PEER FEEDBACK** Explanations are traded with two different peers to receive feedback.	F-G	*Initial Water Story Explanation*, *Peer Feedback Instructions*, *Peer Feedback Guidelines*, assorted colored pencils
7	15 min		**REVISE EXPLANATION** Revise explanation based on peer feedback.	H	*Revised Water Story Explanation*
8	5 min		**EXIT TICKET** Reflect on learning and assess confidence in their explanation.	I	
					End of day 2

Lesson 5 • Materials List

	per student	per group	per class
Lesson materials	• *Initial Water Story Explanation* • *Peer Feedback Instructions* • *Data for All Case Sites* • *Peer Feedback Guidelines* • *Revised Water Story Explanation*		• Key Model Ideas chart • pre-labeled sticky notes with model ideas • marker • Earth's Water System Model • Model Ideas list • assorted colored pencils • blank paper

Materials preparation (20 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

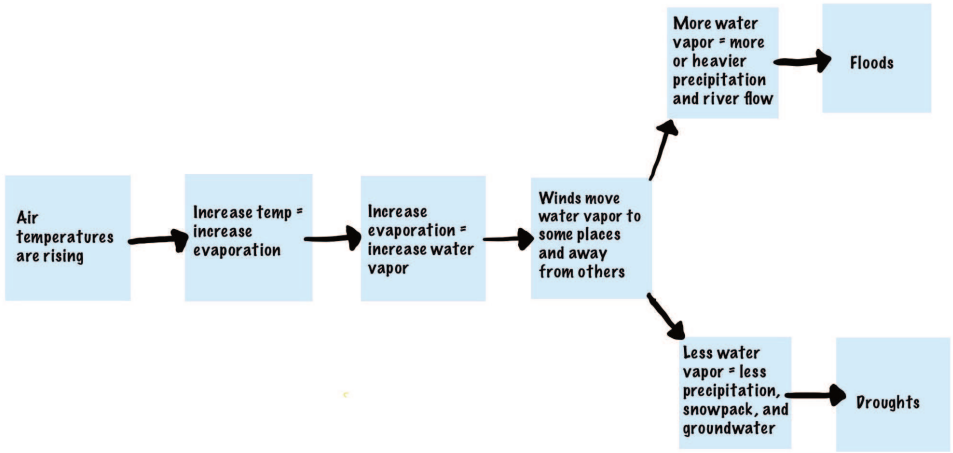
Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Have the Earth's Water System Model and Model Ideas list available for students to view.

Pre-label large sticky notes with shortened model ideas to use to build the cause-and-effect diagram. Examples of these might include:

- Air temperatures are rising.
- Increase in temperatures causes more evaporation and warm air holds more water vapor.
- Global movement of air is moving more water vapor to some places.
- Global movement of air is moving water vapor away from some places.
- More water vapor can cause heavier precipitation in some places, which also means more heavy storms and higher stream and river flow.
- Less water vapor can cause less precipitation in some places, which also means less snowpack and groundwater.

Also include one note with "Droughts" and one note with "Floods." The image to the right shows simplified versions of the ideas above.



The final slide of the slide deck, **slide E2**, can be used to help students bolster their explanations of changing water stories. It is particularly relevant for locations in which water resources are not replenishing as fast as people are using them. This applies directly to communities that are experiencing more frequent drought conditions, such as Porterville (groundwater) and Yakima (snowmelt and glaciers). If this option is selected, place slide E2 following slide E to help students prepare for including these additional ideas in their explanations. Adjust the teacher key to include science ideas your students have developed in connection to ESS3.A Natural Resources that you want to assess students progress toward.

Lesson 5 • Where We Are Going and NOT Going

Where We Are Going

The emphasis of this lesson is on students practicing constructing explanations to explain the phenomena at one of the water story case sites from Lesson 2. Students will pull together ideas from the Model Ideas list, the Earth's Water System Model, and valid and reliable data for a case site to write a scientific explanation. This task will require a synthesis across ideas and will also challenge students to put their thinking into a written explanation. Additionally, students will have an opportunity to review peer explanations, provide feedback, and revise their own. The peer review process will allow students to revisit, clarify, and improve their explanations.

As part of developing these explanations, students will continue to use the lens of stability and change, and in particular, how small changes in one part of a system can have larger impacts on other parts of the system.

Where We Are NOT Going

This lesson is focused on pulling together science ideas from Lessons 2-4 to develop a complete explanation of a case site. However, we are not yet transferring our understanding to new cases. We will do that with the Alaska transfer task in the next lesson.

LEARNING PLAN for LESSON 5

1 · NAVIGATION

3 min

MATERIALS: None

Convene in a Scientists Circle and frame today's work. Display **slide A**. Say, *We've figured out quite a bit about what is happening at these places that are having droughts and floods. How do we feel about these questions?*

- How are rising temperatures changing water stories in these communities?
- Have your ideas about droughts and floods changed or stayed the same since the beginning of the unit? Why or why not?

Ask students to share some of their ideas briefly. They will expand upon these ideas as they build the cause-and-effect model in the next step.

2 · BUILD A CAUSE-AND-EFFECT MODEL

15 min

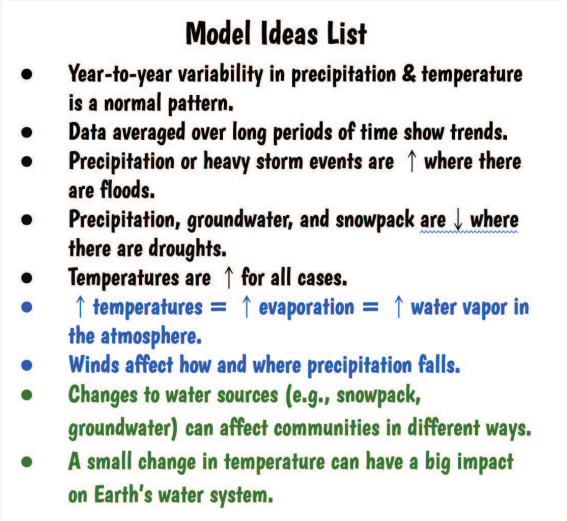
MATERIALS: Key Model Ideas chart, pre-labeled sticky notes with model ideas, marker

Prepare students to put together new ideas into a cause-and-effect model. Display **slide B** and the Key Model Ideas chart developed durings Lessons 2, 3 and 4. Say, *We had some ideas starting in Lesson 1 about ____, but we've figured out more ideas since then. Can we piece these ideas together to show a cause-and-effect relationship between them? How might we do that?*✱

Example student ideas might include:

- Put the ideas in order to show what happens first that causes the next thing to happen.
- Put arrows between the boxes to show which one causes the next thing to happen.

Place beginning and ending cards onto the board. Place a sticky note with "Air Temperatures are Rising" on the left side of the wall/chart or whiteboard, and the "Droughts" and "Floods" on the other side of the board or wall. Display the other pre-labeled sticky notes for all students to see and read. Give students a few minutes to read them. Then, have students turn and talk with a neighbor about what order they would put those sticky notes in to represent a relationship between rising temperatures and droughts/floods.

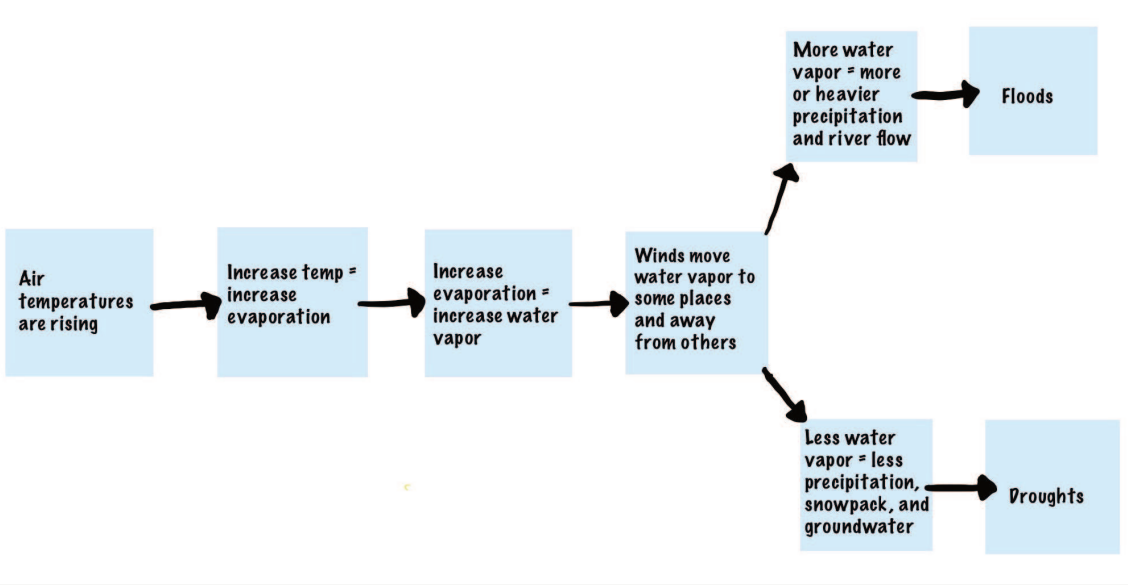


Begin building the diagram. Ask students to share out which sticky note would come after "Air Temperatures are Rising." Place the next sticky note to the right of the "Air Temperatures are Rising" sticky note, and draw an arrow with a marker (if using chart paper or a whiteboard as the background). Continue to build the cause-and-effect diagram by placing new sticky notes across the diagram until the diagram explains both droughts and floods. See the example at the beginning of the next page.

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING CAUSE AND EFFECT

Students have used cause-and-effect diagrams in previous OpenSciEd units, such as the *Everest Unit* and *Tsunami Unit*. If students struggle with ideas for how to show cause-and-effect relationships, prompt them with: *Remember when we did that in ___ unit? How did we represent the cause-and-effect relationship?* Or use prompts such as:

- *In Lesson 3, what did we figure out about what happens to evaporation when temperatures go up?* (let students respond) Then say, *So an increase in temperature causes an increase in evaporation?*



ALTERNATE ACTIVITY

If time allows, pre-print a set of cards for students to work with in small groups to build their own cause-and-effect diagram. This can be done as a card sorting activity where they order the cards in a sequence that can explain the relationship between rising temperatures and droughts/floods. Then build the classroom representation together, coming to consensus across the small group diagrams.

Say, *Wow, we have figured out a lot already about what is going on in our cases that we've been working with. How might we use our model to explain what is happening in each case site?* Give a few students an opportunity to share how they might use the model to explain one site.

3 · SET THE CONTEXT FOR EXPLANATIONS

8 min

MATERIALS: Earth's Water System Model, Model Ideas list

Consider the audience with whom we should communicate. Display **slide C**. Ask students, *Now that we have a model to explain what is happening, who might want to know why these communities are experiencing changes in their water stories?* Student ideas might include:

- people who live in the community,
- scientists who study climate,
- people who might be impacted because this community has changed (e.g., farmers can't grow crops so consumers might be impacted), and
- the general public.

Allow students choice in the audience they will target with their explanation.

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING STABILITY AND CHANGE

It might be helpful to explicitly introduce Stability and Change here by saying something like, *It surprised us that a small rise in temperature was related to all of these big changes in precipitation and Earth's whole water system. The audience may find this surprising, too. Why don't we add, "How could a small change in one part of the system have a*

Set the purpose for writing.✱ Motivate students to establish the purpose for why they might write something for this audience. Ask students, *What do you think this audience would want to know or better understand about what is happening?*

- Is this normal or not normal for this place?
- What does the data say about how things are changing?
- How or why is this happening in this community?

Consider how to include the model ideas needed to answer this question.✱ Say, *How might we take the ideas we have figured out and communicate them in a way so that our audience understands why floods are happening in some places and droughts are happening in other places? Would we need to include every model idea for every case site? Why or why not?*

Give students a few moments to consider this question and then have a few students share out important ideas to include in the explanation. Press them to identify how an explanation for droughts might use different ideas than one for floods. Example student responses might include:

- Places with floods need ideas about more water vapor in the air and more frequent heavy storms or higher stream or river flow.
- Places with droughts need ideas about less water vapor in the air, or less precipitation or snow, or groundwater.

Encourage students to consider what data they analyzed in Lessons 2-4 as part of their explanation of the case site. Say, *What data would be important to include to support our thinking?* Students might include ideas such as:

- How much rain a place is getting and the long-term trends for precipitation
- Data about long-term temperature trends
- Data about groundwater, snowpack, and storm frequency

Establish options for how to communicate with their audience. Display **slide D**. Provide students with options they can choose for communicating their explanations.✱ These options are:

- Write a headline for the site and give a news story that includes a scientific explanation of what's happening.
- Create an infographic that communicates how and why water is changing in the community.
- Allow students to suggest additional options and a rationale for why that format is helpful.

big impact on the community's water?" to our list. Explaining this may help the audience understand the problem better.

When students cite evidence from their case site locations, encourage them to include ideas about how as one part of the "normal," or stable, system changes, it impacts other parts of the system.

✱ SUPPORTING STUDENTS IN ENGAGING IN OBTAINING, EVALUATING, AND COMMUNICATING INFORMATION

As students think about how to construct their explanations for a case site, this is also a good opportunity to develop their thinking about how to communicate scientific information in writing. Encourage students to pre-think the ideas they want to communicate and how as part of developing the explanation.

✱ ATTENDING TO EQUITY

Universal Design for Learning: Offer students a choice of modalities for communicating their explanations, such as written or oral news stories. Students can also choose to *represent* their ideas in written or pictorial form.

4 · CONSTRUCT AN EXPLANATION

20 min

MATERIALS: *Initial Water Story Explanation*, *Peer Feedback Instructions*, *Data for All Case Sites*, assorted colored pencils, blank paper

Distribute *Initial Water Story Explanation* and *Peer Feedback Instructions*. Acknowledge that students made important progress toward this explanation through developing their models and model ideas in Lessons 2-4 and that this activity will give them an opportunity to share their thinking by writing and/or drawing their explanation.

Remind students that their role is to use data and their model ideas to create a clear and convincing communication to others to (1) explain how or why something is happening and (2) support the how or why with evidence.✱ Display **slide E**. Students should review the first column of *Peer Feedback Instructions* to see how their peers will review their work.

Tell students they can (1) choose the case site they want to explain, (2) choose their intended audience, and (3) choose their format for communicating their explanation. However, all explanations need to focus on (1) how or why something is happening, drawing upon the science ideas and (2) being supported by evidence.

✱ SUPPORTING STUDENTS IN ENGAGING IN CONSTRUCTING EXPLANATIONS AND DESIGNING SOLUTIONS

Students use the class model, model ideas, and Progress Trackers to construct a first draft of an explanation for one case site location. Each case site has a unique explanation. If students get stuck, encourage

Divide students to work on explanations for their case sites. Ideally, students would be assigned to the same location as they did in Lesson 2, since they are familiar with those sites. However, students could explain a different case location if they want a challenge or need an extension opportunity. If students choose pictorial ways of representing their explanations, provide them with colored pencils and blank paper to do so. Give students about 15 minutes to work on their explanations.✱ Encourage students to look back at the data from Lessons 2-4, such as *Data for All Case Sites* as well as at the causal model the class constructed earlier in the lesson.

ADDITIONAL GUIDANCE

Natural resources guidance and extension opportunities:
If you want students to include ideas from ESS3.A Natural Resources in their explanations, move slide E2 to follow slide E and facilitate a brief discussion with students prior to their writing explanations. Discuss how some water resources are being used by people faster than the resources replenish themselves from natural processes. Brainstorm how this idea could help explain changes to water resources for some communities. Make sure to avoid 'blaming' residents of those communities for using water; rather, focus on comparing the time it takes to refill glaciers and aquifers compared to the regular use of water by human communities that depend on those resources.

ALTERNATE ACTIVITY

Building Prerequisite Understanding: If your students need additional support for writing a scientific explanation before they engage in this activity independently, choose one of these two options:

- Option 1: Use column 1 from *Scoring Guidance for Case Site Explanations* and display a draft of an initial explanation for either Porterville or Vicksburg. As a class, practice providing peer feedback on the initial explanation. Then let students work independently on the other five case sites.
- Option 2: Co-construct an explanation for your local community together first. This would allow you to model how to write a good explanation by (1) deciding the main idea (or headline) for your local community's water story, and (2) co-constructing the explanation of your local precipitation and water source patterns supported by data. After co-constructing an explanation for your local community together, have students write an explanation for another case site.

them to review the models and Progress Trackers since they are helpful sensemaking tools for explaining the phenomenon.

✱ ATTENDING TO EQUITY

Supporting Emerging Multilingual Learners: To support Emerging Multilingual Learners and/or other students who need additional support with writing in science, consider providing sentence starters. If the whole class needs support, consider posting a list of sentence starters on chart paper for everyone to use. If only some students need support, write sentence starters on strips and put them in an envelope that you can provide to students who would benefit from additional support.

Example sentence starters:

- The sources of water used by this community include...
- The temperature data shows a long-term pattern of...
- The precipitation data shows a long-term pattern of...
- The other data show...
- This means...
- When temperatures rise, evaporation is affected by...
- This community's water story is affected by...

End of day 1

5 · REVIEW EXPLANATIONS

5 min

MATERIALS: *Initial Water Story Explanation*, *Peer Feedback Instructions*, *Data for All Case Sites*

Review explanations. As students come into class, give them time to review their explanations and add any new ideas or revise any parts of the explanations before beginning peer feedback. Encourage students to use the class causal model as they read through their explanation fully and check two aspects: 1) Did they include all the important science ideas and evidence, and 2) Did they communicate the ideas clearly so that others can follow their explanation?

6 · PEER FEEDBACK

20 min

MATERIALS: *Initial Water Story Explanation*, *Peer Feedback Instructions*, *Peer Feedback Guidelines*, assorted colored pencils

Discuss the key elements on which to give peer feedback. Display **slide F**. Review the "Peer feedback" column of *Peer Feedback Instructions*. Review the key elements of the explanation as a class. Share instructions for how to provide feedback:

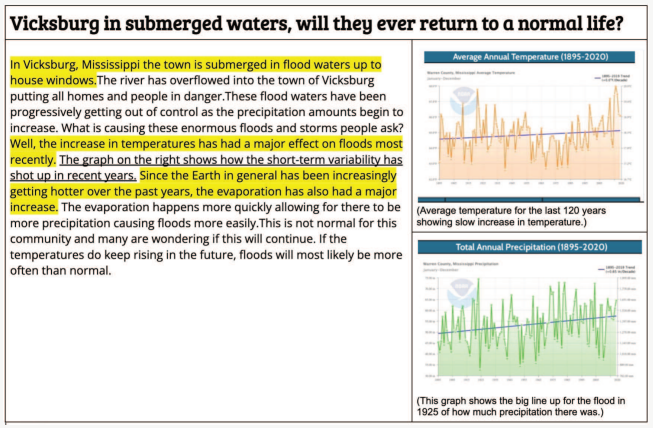
- Underline places that explain how or why.
- Circle evidence that is used.
- Use colored pencils or pens to mark up peer work and write legibly.
- If students made an infographic or other visual representation, peers can use sticky notes to add comments and suggestions.
- If there is another protocol used in your classroom for providing feedback, substitute that protocol if desired.

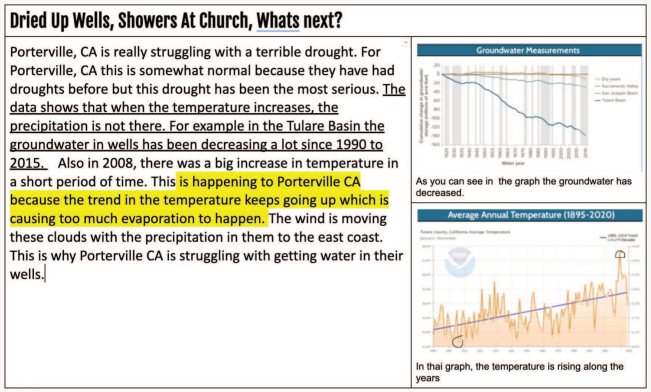
Discuss as a class how to provide useful feedback.✱ Display **slide G**. Review elements of quality peer feedback on *Peer Feedback Guidelines* in the student edition. Give examples of productive and unproductive feedback.

Examples of productive feedback	Examples of unproductive feedback
"Your explanation said that less snow means less water for the community. I think you should add details about why snow matters to this community and how they use the water source."	"I like your explanation."
"Your explanation provides really clear patterns from the data for the community, but it doesn't explain how temperature and precipitation are related, and why that matters for this community."	"I agree with everything you said."

Provide peer feedback for the same case site. Give students 3-4 minutes to provide feedback within the same case site group. These peers analyzed the same data. This will provide students with feedback from a similar perspective.

Provide peer feedback for a different case site. Rotate partners. Give students 3-4 minutes to provide feedback on a different case site. These peers analyzed the slightly different data and wrote a different explanation. They can provide feedback from a more neutral perspective.





✱ SUPPORTING STUDENTS IN ENGAGING IN ARGUMENT FROM EVIDENCE

Students will provide and receive critiques on their water story explanations. This is a good opportunity for students to practice giving clear and constructive feedback to peers. It is also an opportunity for them to prioritize which feedback they can respond to (or not) and why they might do so. If students have been giving and receiving feedback already during the school year, consider fading the scaffolds provided in *Peer Feedback Guidelines* to allow students to independently practice this element of arguing from evidence.

ALTERNATE ACTIVITY

If time is short, complete only one round of peer feedback. Choose a peer from a different case site to provide feedback on a different place.

7 · REVISE EXPLANATION

15 min

MATERIALS: *Revised Water Story Explanation*

Discuss how to respond to peer feedback.✱ Display **slide H**. Discuss how students take these steps when receiving feedback:

- Read the feedback carefully. Ask someone else to help you understand it, if necessary.
- Decide if you agree or disagree with the feedback and reflect on why you agree or disagree.
- Revise your work to address the feedback.

Individually draft a revised explanation and reflection on what was revised and why. Distribute a copy of *Revised Water Story Explanation* to each student. Give students time to write a new explanation, incorporating their own and the peer feedback.✱

ASSESSMENT OPPORTUNITY

Building towards: 5.A Construct a scientific explanation based on valid and reliable evidence that small changes in temperature can have big impacts on the water sources available for communities.

What to look/listen for:

- a "how" explanation that draws upon science ideas and is supported with evidence, including:
  - how temperature, precipitation, and water sources change in the communities,
  - how those changes are connected to one another in Earth's Water System Model, and
  - how changes in one or more components of the system can impact changes in another part of the system.
- Look for evidence that students have revised their explanation, based on peer feedback, by comparing the first draft and the revised explanation and reviewing their reflections on what feedback they used and didn't use.

What to do: Have students submit their revised explanation along with the first draft explanation that has their own revisions, as well as peer feedback. If students struggle to include model ideas, cue students to reference the class's Earth's Water System Model and their Progress Trackers. If students struggle to include all of the interactions among parts of the system, encourage them to review the blue and orange parts of the system model. If students struggle to include evidence from investigations, direct them to their science notebooks to remember the evidence that they gathered from Lessons 2, 3, and 4.

Use *Scoring Guidance for Case Site Explanations* to assess students and provide feedback to them on their explanations and revisions.

HOME LEARNING OPPORTUNITY

If time is short, assign home learning to complete the revised explanation. If possible, provide feedback on students' written explanations for their case site prior to day 2 of Lesson 6 so that they have the opportunity to use these written explanations, the peer feedback, and your feedback to inform their explanation for the Alaskan case in that lesson.

✱ SUPPORTING STUDENTS IN ENGAGING IN ARGUMENT FROM EVIDENCE

Students receive critiques about their explanations and respond to peer feedback and questions by determining how to add elaboration and detail and revising their explanation accordingly.

As an extension opportunity for this practice, ask students to explain one piece of feedback they used, one piece of feedback they didn't use, and why.

8 · EXIT TICKET

5 min

MATERIALS: None

Close with an Exit Ticket. Take a moment to ask students how confident they feel about writing scientific explanations. Use **slide I** to present the question, *On a scale of 4 (totally independent) to 1 (need lots of help with this), how are you feeling right now about writing a scientific explanation? Briefly explain what makes you feel that way and what help you could use as you develop this practice.* Direct students to respond on the bottom or back of the page where they wrote their scientific explanation.✱

✱ SUPPORTING STUDENTS IN ENGAGING IN CONSTRUCTING EXPLANATIONS AND DESIGNING SOLUTIONS

Students will construct another explanation on day 2 of the next lesson. Gathering information about students' comfort with the practice now can help better scaffold their explanations in the next lesson.

Additional Lesson 5 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA

CCSS.ELA-LITERACY.W.7.1: Write arguments to support claims with clear reasons and relevant evidence.

- **CCSS.ELA-LITERACY.W.7.1.B: Support claim(s) with logical reasoning and relevant evidence, using accurate, credible sources and demonstrating an understanding of the topic or text.**
- **CCSS.ELA-LITERACY.W.7.1.C: Use words, phrases, and clauses to create cohesion and clarify the relationships among claim(s), reasons, and evidence.**

CCSS.ELA-LITERACY.W.7.2.B: Develop the topic with relevant facts, definitions, concrete details, quotations, or other information and examples.

When students are recording their first draft and revised explanations, they are writing an explanation, conveying their understanding of key science ideas, and drawing on evidence from investigations. While we are not calling it a "claim," students are developing a how or why account for the phenomenon and backing up that explanation using evidence and reasoning from class investigations.

LESSON 6: How are rising temperatures connected to two seemingly different phenomena?

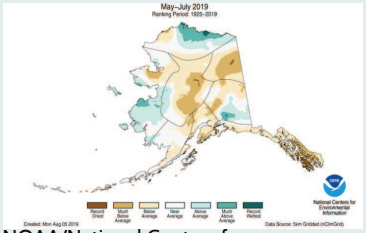
PREVIOUS LESSON

We used our key model ideas to build a cause-and-effect model to explain droughts and floods. Then we applied this general model to explain how changes in temperature have an impact on our case site communities. We revised our explanations using peer feedback.

THIS LESSON

PUTTING PIECES TOGETHER, PROBLEMATIZING

2 days



NOAA/National Centers for Environmental Information

In this lesson, we learn about another community in Alaska and apply our key model ideas in an assessment transfer task to explain what is happening in that community. We notice that some other indicators are also changing in our atmosphere, and we are curious if that is related to the temperature changes, too. We revisit our Driving Question Board and develop new Ideas for Investigation.

NEXT LESSON

We will build on our understanding of the composition of air to determine if changes happening in the air are related to the rising temperatures. We will discuss and analyze data and develop a better understanding of parts per million. Using this understanding, we will find the percent change in the concentration of these gases over a 100-year period. We will compare any increases or decreases in the concentration of these gases over time. We will notice that some gases remain stable, some change very little, while other gases change a lot.

BUILDING TOWARD NGSS

MS-ESS3-1, MS-ESS3-3, MS-ESS3-4, MS-ESS3-5, MS-ETS1-2

WHAT STUDENTS WILL DO

6.A Compare graphs and charts depicting a changing climate in Alaska looking for similarities and differences to determine that trend lines and patterns across Alaskan claims are caused by increasing temperatures.

6.B Analyze graphs and charts from multiple claims to identify the similarities and differences in patterns to determine that changes in the environments are caused by increasing temperatures.

WHAT STUDENTS WILL FIGURE OUT

- Small changes in one part of Earth's system can have big impacts on another part.
- Changes in atmospheric temperature are related to changes in the components and processes of Earth's water system.

Lesson 6 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	6 min		**NAVIGATION AND CELEBRATION** Celebrate progress made on explaining the case sites and navigate to the transfer task.	A	
2	3 min		**REVISIT THE ALASKA HEADLINE** Look back at the headline from Lesson 1 about Alaska. Determine what we would need to figure out if the Alaska case site is related to increases in temperature.	B-C	Cause-and-Effect diagram
3	17 min		**INTRODUCE AND LISTEN TO CLAIMS** Introduce the account of Gordon Brower, an Iñupiaq whaler. Record the claims and data we need to investigate further.	E-F	*Transcript: Alaskan Whaler Interview* (optional), Alaskan Whaler Interview, Claims and Data We Might Need T-chart
4	16 min		**INVESTIGATE NEW GRAPHS FROM ALASKA** Read about wildfires and look at new Alaskan graphs in groups. Use *Alaska Graph Notes* to record any connections between the graphs and the claims.	G-H	*Alaska Graph Notes*, *What Causes Wildfires?*, *Alaska Graphs*
					End of day 1
5	25 min		**BEGIN ASSESSMENT** Use *Revised Water Story Explanation* and *Alaska Graph Notes* to complete *Alaska Wildfires and Sea Ice*.	I	*Alaska Graph Notes*, *Alaska Wildfires and Sea Ice*, *What Causes Wildfires?*, *Revised Water Story Explanation*, *Alaska Graphs*
6	8 min		**REVISIT OUR DRIVING QUESTION BOARD** Look back at the DQB and brainstorm what may be causing temperatures to rise.	J	*DQB Check-In*, Initial Consensus Model (Lesson 1), Earth's Water System Model, DQB, Ideas for Investigation chart
7	12 min		**DEVELOP NEW QUESTIONS AND IDEAS FOR INVESTIGATION** Determine areas of the model where we are less certain, and brainstorm questions and ideas for investigation around that area.	K-L	*Alaska Wildfires and Sea Ice*, Cause-and-Effect diagram (from Lesson 5), initial models (from Lesson 1)
					End of day 2

Lesson 6 • Materials List

	per student	per group	per class
Lesson materials	• science notebook • *Transcript: Alaskan Whaler Interview* (optional) • *Alaska Graph Notes* • *What Causes Wildfires?* • *Alaska Wildfires and Sea Ice* • *Revised Water Story Explanation*	• *Alaska Graphs* • *DQB Check-In*	• Cause-and-Effect diagram • Alaskan Whaler Interview • Claims and Data We Might Need T-chart • Initial Consensus Model (Lesson 1) • Earth's Water System Model • DQB • Ideas for Investigation chart • Cause-and-Effect diagram (from Lesson 5) • initial models (from Lesson 1)

Materials preparation (20 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Have the Earth's Water System Model and Model Ideas list available for students to view.

For day 1:

- Test *Alaskan Whaler Interview* video at https://youtu.be/6oQYlSAO3_E.
- Create a T-chart. Label the left side of the T-chart "Claims" and the right side "Data we might need."

For day 2:

- Prior to day 2, type all questions from the DQB into *DQB Check-In*. Add additional rows as needed to the table.
- Confirm that students have easy access to the Driving Question Board, Cause-and-Effect diagram, Earth's Water System Model, and the Ideas for Data and Information We Need chart.

Lesson 6 • Where We Are Going and NOT Going

Where We Are Going

This lesson introduces students to another case site in Alaska that is experiencing reduced amounts of single- and multi-year sea ice. Students will apply their model ideas to this additional site to explain why the community is experiencing reduced sea ice levels. The additional case site serves as an assessment opportunity and transfer context. Here students will draw from ideas developed in Lessons 2-5 but with the addition of a new climate impact: wildfires. Students will use data over the Alaskan headline and claims from an indigenous whaler to compare to their scientific explanation of one case site and determine if the diminishing sea ice and wildfire claims are connected, even though they are seemingly different phenomena.

Where We Are NOT Going

Even though wildfires may occur in other case site locations, that data will not be utilized for the assessment. This will allow students to make sense of the data already given, in addition to only the Alaskan graphs and charts.

While there are other effects of rising temperatures that are also contributing to the increased wildfires in Alaska, we will only look at lightning strikes and changing drought index conditions. Other factors that are contributing to wildfires via increased temperatures, such as a shortening snow season and the increased drying of duff during the summer months, will not be discussed in this lesson. For more information about other contributing factors in a condensed format, see the International Arctic Research Center publication at https://uaf-iarc.org/alaskas-changing-wildfire-environment/.

Some experts are now pointing out that there has been an increase in precipitation in the last 30 years in Alaska. This short-term trend does exist, but we are choosing to focus on the long-term trend that shows a decrease in overall precipitation over the last century. This is because even though there is an increase in precipitation due to the increasing temperatures, the increase in precipitation is not enough to offset the more massive increase in wildfires and fire fuel availability caused by the rising temperatures. The explanation of this more complex interaction is more consistent with high school level expectations for engaging in the Crosscutting Concept of System and System Models and the high school performance expectation HS-ESS3-6, as it would likely involve the representation of the changes through computational relationships.

The history of Iñupiaq people and their relationship with natural resource use is an important one that involves the weighing of short term needs and long term effects. In future lessons, students will make the connection between fossil fuel use and rising average temperatures globally, which is having poignant, direct effects on this region of Alaska. To learn more about this relationship and to hear more from Gordon Brower and others, please visit https://www.thresholdpodcast.org/season02-episode08 .

LEARNING PLAN for LESSON 6

1 · NAVIGATION AND CELEBRATION

6 min

MATERIALS: None

Say, *We've made a lot of progress on our case sites! We can explain why these changes in precipitation have been occurring, and then created headlines and explanations to help others understand what is happening in those locations. Let's consider what we have learned so far.*

Turn and talk about progress on our ideas. Project **slide A**. Ask students to turn and talk about the following questions:

- How has your understanding of the problems of droughts and floods changed?
- What are some big takeaways for you so far in our study of this problem?

Give students 2 minutes to discuss their ideas with a partner. Ask students to share their ideas with their partners. Anticipated student responses are below:

- There are normal short-term fluctuations in precipitation, but long-term there is a (decrease) or (increase) in extreme precipitation events. Long-term data shows that rising temperatures are changing how much freshwater is available and where it can be found on Earth.
- The rise in temperature is causing changes in the water cycle. It is causing more precipitation in some areas and less in others.
- Changing temperatures cause changing precipitation patterns.
- Changes in temperature affect many aspects of the water cycle, which varies in impact, depending on where you are.
- These seem like different "events" that happen at random, but they are all really connected to each other. Even if one community is experiencing one kind of water problem, it is connected to the problems happening in other communities and all caused by rising temperatures.

2 · REVISIT THE ALASKA HEADLINE

3 min

MATERIALS: Cause-and-Effect diagram

Project **slide B**. Say, *We have seen patterns with increasing temperatures and precipitation across the United States. Let's look back at our headlines, specifically one from Alaska. This headline focused on wildfires. Do you think the headline could be explained using our Cause-and-Effect diagram?*

Give students a moment to read the headline and allow students to respond. Below are some anticipated student responses:

- It could be related to increasing temperatures because it mentions a heat wave.
- Wildfires might be related to the droughts because it says "dry," but we aren't sure.
- Alaska is normally cold, but wildfires in Alaska don't make sense because it's snowy all the time in Alaska. These could possibly be related to the increase in temperature.

ADDITIONAL GUIDANCE

Many students who have not lived in or studied Alaska may believe that Alaska is covered in snow and cold year-round. While some areas do remain colder, this is not true for the entire state. If students have this preconception, take a moment to ask them to describe what they picture summer in Alaska looks like. Accept all responses, and discuss seasonal trends that occur with temperatures in the summer as you move away from the Equator to help students understand that seasonal warming also occurs in Alaska. Consider showing one of the many YouTube videos that exist showcasing Alaska in the summer to help students understand that there are many areas of Alaska that are not snow covered in the summer, and that some areas can get quite warm. Ask students if these areas could also be susceptible to wildfires, and if some of the same patterns that we saw in our case sites could also be occurring here to navigate into **slide K**.

Say, *It sounds like these could be related, but we may need additional data to figure out if it is related to our increasing temperatures. Let's see if we can use data to determine if these claims could be related.*

Create a Claims and Data We Might Need chart. Project **slide C**. Direct students to create a Claims and Data We Might Need T-chart in their notebooks. Explain that as a class we can use this chart to keep track of the claims and data we need to evaluate our headline.

Project **slide D**. Ask students to turn and talk with a partner about the following question:

- What does the headline claim is happening in Alaska?
- What data would we need to determine if the changes in Alaska are due to temperature increases and precipitation changes?

As students are discussing, display the Claims and Data We Might Need class chart that matches the chart in their notebooks. Allow students to share out the claims from the headline and data they might need with the class. As students share, have them record the claims and data in their notebooks, and also record the claims and data on the class chart. Students should identify the following claims:

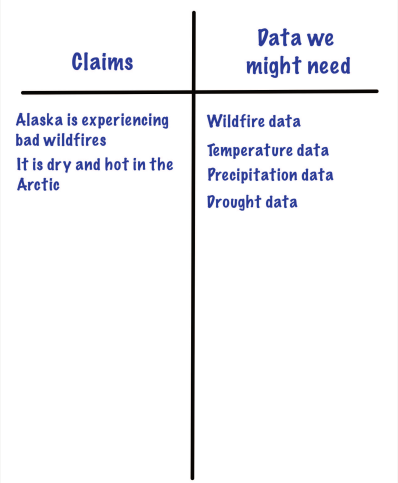
- Alaska is experiencing bad wildfires.
- It is dry and hot in the arctic.

The following data we might need should be identified:

- Data over wildfires
- Temperature data
- Precipitation data
- Drought data

Students might also mention that we need to know more about what causes wildfires. If students also mention this idea, add this to the charts as well.

Say, *OK, so it sounds like we need to look at data from Alaska to determine if these claims are related to our case sites. Interestingly, though, these are not the only changes that are being reported in Alaska. Our headline is from the southern part of Alaska. Very different changes are being reported in the northern part of Alaska.*



ADDITIONAL GUIDANCE

If your students were curious about wildfires in Lesson 1 and added questions to the DQB and ideas to the Ideas for Investigation chart, make sure to resurface those questions and ideas at this time. Have students share their question again and the data or information they wanted to gather to learn more about the problem.

3 · INTRODUCE AND LISTEN TO CLAIMS

17 min

MATERIALS: science notebook, *Transcript: Alaskan Whaler Interview* (optional), Alaskan Whaler Interview, Claims and Data We Might Need T-chart

Introduce the Alaskan oral account. Say, *To understand what is happening in regions like the Arctic, we can gain knowledge from those that have lived there for thousands of years. Many tribes, such as the Iñupiaq have knowledge going back thousands of years and they have kept records of what they have observed over time. They have reported changes that may or may not be connected to wildfires, precipitation changes, and increasing temperatures. The Iñupiaqs' accounts provide an important historical record to help us understand what is normal and what is changing there.*

✱ ATTENDING TO EQUITY

Universal Design for Learning: Some students may struggle with listening to the podcast and recording ideas in their notebooks at the same time. You can support *representation* and perception of the information by adjusting the timing of the

ADDITIONAL GUIDANCE

Please present this interview to students not as a story about outdated observations, unbased claims, or ways of thinking about the world but as a legitimate, living body of knowledge. This knowledge and observation set is not lesser than but rather a complement to Western scientific ways of knowing. Humans have always been driven by noticing, recording, and understanding patterns and by understanding our perspective and belonging within a larger system. In addition, whenever we consider cultural identities, Indigenous ancestral knowledge, and meaning-making practices, it is important to avoid framing them as static and homogenous instead of recognizing that all people have multilayered and multicultural identities. It can be easy to tokenize Indigenous stories. The goal is to respect but not oversimplify differences in this knowledge and the Western ways of knowing.

Explain to students that we have an oral account of the changes that are occurring in the northern part of Alaska from an Alaskan whaler whose ancestors have lived in the Northern Slope for thousands of years. Explain to students that because whaling is central to life in the Northern Slope, detailed accounts about whaling and sea ice conditions have been kept by those that live there over time.

Remind students that this is an oral account detailing what has happened to the area over time, so we will need to record the claims as they are told to us. Instruct students to draw a line under the claims we have already identified to create a new section in their charts. Explain that they will record any claims they hear in their Claims and Data We Might Need charts under this line.

Listen to the podcast. Play the *Alaskan Whaler Interview* at https://youtu.be/6oQYlSAO3_E. Remind students before pressing play to record claims as the podcast is playing. Once the video is over, they will write down any data they think we might need to figure out if that claim is related to increasing temperatures and precipitation changes. If students would like to follow along with the video, they can use the *Transcript: Alaskan Whaler Interview*.✱

Share claims and data we might need with the class. Project **slide E.** At the conclusion of the video, give students 2 minutes to revisit the claims on the left side of the chart and write down their ideas for data we might need on the right side of the chart. Allow students to share their ideas with a partner before going public. Students should share the following claims from the video:

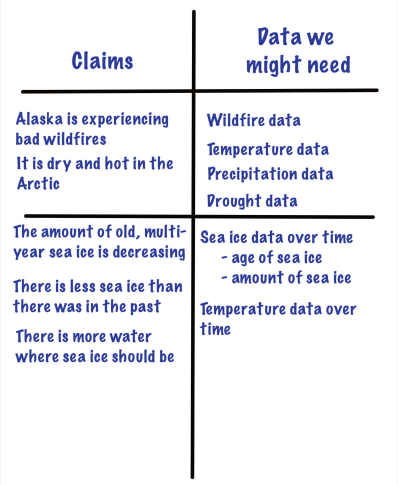
- The amount of old ice is decreasing.
- There is less sea ice than there was in the past.
- There is more water where the sea ice should be.

As students share, explain that sometimes this older ice is referred to as multi-year sea ice, since it is around for more than one year. Add multi-year sea ice next to where old sea ice is written to help students make this connection on future graphs.

Draw a line under the headline claims and data that was previously identified on the class chart. Write these new claims as they are shared by students on the class chart, and instruct students to also add them to their notebooks.

After identifying the claims made in the video, ask students what data might be needed to investigate these claims. Students should bring up the following data:

- Data for the age of sea ice over time
- Data for the amount of sea ice over time
- Data for temperature over time
- Data for the amount of precipitation over time



podcast and listen to it twice. On the first pass, allow students to only listen. On the second pass, pause the podcast every minute or two and give students time to write. This will allow those students to fully listen to the interview and write while it is paused. A transcript is provided as an alternative to the auditory information and can be located in *Transcript: Alaskan Whaler Interview*.

Add the data sources students have identified to the class chart and ask students to add them to their notebooks as well. If students do not identify precipitation and temperature data, ask them what they think might be causing these changes in sea ice, and what we would need to compare the sea ice data to.

Project **slide F.** Say, *We seem to have two very different sets of claims, one set of claims from our headline and one set of claims from our video. Do we think these changes in Northern Alaska are also related to the claims made by our headline?* Allow students to respond. Accept all responses.

Ask students, *If we were to look at our data, could we use the data to determine if these claims are related?* Students should respond that looking at data will help us determine if there is a relationship between the claims in the Northern and Southern part of Alaska.

Say, *It sounds like we might think that these claims are related, but we need to look at the data to determine what might be causing these changes. We have identified some data that we think could be helpful, and I think I have most of this data you want to look at. Let's spend some time looking at the data I have in groups and see if it can help us explain the Alaskan claims.*

4 · INVESTIGATE NEW GRAPHS FROM ALASKA

16 min

MATERIALS: *Alaska Graph Notes*, *What Causes Wildfires?*, *Alaska Graphs*

Go over Alaskan graphs and wildfire handouts. Project **slide G**. Point out the two different handout examples on **slide G.** Explain to students that they will read about wildfires first. After that, each group will receive a set of graphs that they identified as "data we might need."

Project **slide H** and review *Alaska Graph Notes*. Direct students to look at the individual recording page example on the slide. Explain to students that as they analyze the reading and the graphs, they will record any connections they find to the claims. This will help them determine if the Alaskan whaler claims and headline claims are related or not. Go over each column and explain what should go in each space. Encourage students to discuss their ideas about the claims with their partners. Let students know that tomorrow they will be given an assessment where they have to explain what is occurring in the claims and how the claims might be related to their case site.

Distribute a copy of *Alaska Graph Notes* and *What Causes Wildfires?* to each student. After students have completed their wildfire row, distribute *Alaska Graphs* to each group. As students work on their graph analysis, circulate to each group. Encourage students to work together to record their ideas on their charts. Remind them that their notes on the charts can be used as a tool on their assessment to help determine if these claims are related, and if these claims are also related to their individual case site from Lesson 5.

Collect handouts. At the end of class, collect *Alaska Graph Notes*, *What Causes Wildfires?*, and *Alaska Graphs* from students. Review *Alaska Graph Notes* before the next class period to check student understanding. Provide individualized feedback for students on *Alaska Graph Notes* prior to beginning the assessment on Day 2.

ASSESSMENT OPPORTUNITY

Building towards: 6.B Compare graphs and charts depicting a changing climate in Alaska looking for similarities and differences to determine that trend lines and patterns across Alaskan claims are caused by increasing temperatures.

What to look for/listen for:

- Increasing wildfires can be partially attributed to the decrease in precipitation.
- The increase in temperatures contributes to the increase in wildfires, changes in precipitation, and decreases in sea ice age and amount.
- The drier than normal conditions in Alaska contribute to wildfires increasing and can be explained by decreasing precipitation.
- The two sets of claims are related. The changes seen are all caused by increasing temperatures.

ASSESSMENT OPPORTUNITY

Continued from previous page...

What to do:

- This handout is meant as a formative assessment before *Alaska Wildfires and Sea Ice*.
- If students are not making the connections above, touch base with the student(s) at the beginning of the next class period. Ask students if any of the graphs are related and then how those graphs would also be related to any of the data from the other claims.
- Focus on the temperature graph as a causal mechanism, and ask students if the increase in temperatures would contribute to any of the other changing graphs and how the increase in temperatures would cause those changes to occur.
- Alternatively, another strategy would be to cut out each graph and lay them next to each other in a partnering fashion. Ask students if the graphs are similar or share a trend line or relationship. This can help students see patterns of change across multiple graphs.

ALTERNATE ACTIVITY

Graphs can be posted in an online format for students to access and review between class sessions, or copies can be given to students who want to look at the data again before their assessment on day 2.

If students would like more time to complete *Alaska Graph Notes*, students can take *Alaska Graph Notes* home to work on the data analysis. If students have taken *Alaska Graph Notes* home and there isn't time to do a full formative check and provide teacher feedback on the work they completed at home, ask students to place *Alaska Graph Notes* on their desks as they enter class and as *Alaska Wildfires and Sea Ice* is distributed. Conduct a quick check of ideas by looking at the students' responses to the last question. If students still identify that the claims are all connected, there is likely a connection made between graphs on the first section of *Alaska Graph Notes*. After students begin to read and complete *Alaska Wildfires and Sea Ice*, a more thorough check can be done by going from student to student to look at *Alaska Graph Notes*.

Alternatively, additional time could be given on day 2 for students to work together in groups to finish the graph analysis before beginning the assessment. A quick check-in with each group to note what is documented on their charts and listening to student ideas can give a good glimpse into student ideas before engaging in the assessment.

End of day 1

5 · BEGIN ASSESSMENT

25 min

MATERIALS: *Alaska Graph Notes*, *Alaska Wildfires and Sea Ice*, *What Causes Wildfires?*, *Revised Water Story Explanation*, *Alaska Graphs*

Pass back *Alaska Graph Notes* to students. As students review the feedback, pass out *Alaska Wildfires and Sea Ice* and *Revised Water Story Explanation*.

Go over part 1 of the assessment. Project **slide I**. Walk through the assessment with students. Point out that part 1 of the assessment is asking students to explain any potential connections between the data and claims from our last class period. Direct students to use their notes from *Alaska Graph Notes* to help, and let them know that there are class copies of *What Causes Wildfires?* and *Alaska Graphs* available if they would like to reanalyze any of the graphs and information.

✱ ATTENDING TO EQUITY

Universal Design for Learning: During *Alaska Wildfires and Sea Ice*, some students may benefit from having graphs from Day 1 to help write their explanations. For some students, providing a visual *representation* of the data can be helpful for comprehending the similarities and differences in the graphs

Go over part 2 of the assessment. Explain that part 2 of the assessment is focused on explaining how the increasing wildfires and decreasing amounts of multi-year sea ice are or are not related. Tell students that *Revised Water Story Explanation* was returned to them so that their explanations are available for their use during this assessment, as well as any teacher-provided feedback on their explanations. Remind students that they can use the class's Model Idea list, Earth's Water System Model, and any of their notes from their Progress Tracker as they work through the assessment.

Conduct assessment. Allow students 25 minutes to finish the assessment.✱

ASSESSMENT OPPORTUNITY

Building towards: 6.B Analyze graphs and charts from multiple claims to identify the similarities and differences in patterns to determine that changes in the environments are caused by increasing temperatures.

What to look/listen for: See *Alaska Wildfires and Sea Ice Key* for information regarding assessment guidance.

What to do:
To revisit part 1:

- Review the claims and graphs from *Alaska Graph Notes*, *What Causes Wildfires?*, and *Alaska Graphs*. Ask students what connections might be seen among the graphs and wildfire information.
- Focus on the temperature graph that shows an increase in temperature. Compare graphs from both claim sets to the temperature graphs for any similarities or patterns that may be present.
- Ask students if these patterns are across all graphs, or if all the claims might have a similar cause.

To revisit part 2:

- Direct students to the graphs. Ask if any of the graphs have anything in common, and how they are different.
- Cut out the graphs and place different graphs next to each other. Ask students if one graph is related to another graph, and how they may be related.
- Help students compare the temperature and precipitation data for the case site and Alaska, and then look for similar graphs that might share the same trend lines.
- Look at the graphs that have opposite trend line directions from the temperature graphs, and determine if there is a connection between increasing temperatures and the graph trend lines.
- Ask students if one of the graphs could cause a change in another graph.

they had written about in *Initial Water Story Explanation*. Some students may be hesitant to ask for this support, even though it may be helpful. Consider distributing copies of *What Causes Wildfires?* to students who may benefit from seeing the graphs during the assessment.

6 · REVISIT OUR DRIVING QUESTION BOARD

8 min

MATERIALS: *DQB Check-In*, Initial Consensus Model (Lesson 1), Earth's Water System Model, DQB, Ideas for Investigation chart

Collect the assessment. Project **slide J**. Collect *Alaska Wildfires and Sea Ice* and all other materials from students. Say, *We just spent some time explaining new phenomena with multi-year sea ice and wildfires. We have really learned a lot! Let's look back and see if we can answer any of our DQB questions.*

Complete a DQB check-in. Distribute a copy of the *DQB Check-In* to students with student questions added. Instruct students to work with a partner to determine which questions they have fully answered, partially answered, and not answered yet by placing a checkmark in the appropriate column. Give students roughly 7 minutes to complete this activity.

Discuss answered questions with students. Bring students back together around the Driving Question Board. Ask students to share what questions they believe we have made progress on or have answered. As students share, confirm that the rest of the class agrees that progress has been made. If the class agrees, add a small checkmark to the bottom corner of the sticky note or move the sticky note to an area of the board that can be designated for "answered questions."

7 · DEVELOP NEW QUESTIONS AND IDEAS FOR INVESTIGATION

12 min

MATERIALS: *Alaska Wildfires and Sea Ice*, Cause-and-Effect diagram (from Lesson 5), initial models (from Lesson 1)

Say, *At the end of our assessment, we considered if these trends would continue in the future and tried to support that with data. Let's talk to our partners about what we think will happen in the future and what data we think supports our ideas.*

Project **slide K.** Ask students to turn and talk about the questions on the slide:

- What trends did we notice on our graphs?
- Do you think this trend in data will continue to head in the same direction in the future?

After a couple of minutes, bring the class back together. Discuss the questions and trends as a class, and speculate as to what might be causing these trends. Some example prompts and responses are provided below.

Suggested prompts	Sample student responses
We looked at a lot of different graphs from Alaska, listened to an oral account, and looked at data from our individual case sites. What trends did we notice on our graphs and in the oral account?	Some graphs showed increasing or decreasing precipitation. There were also graphs from some sites that showed an increase in flooding, where other sites had an increase in drought conditions. One graph showed an increase in wildfires in Alaska. One graph showed a decrease in Alaskan sea ice amount and sea ice age. All of the graphs showed an increase in temperatures. The oral account and the graphs all showed a connection to increasing temperatures. Accept all other relevant responses.
So, you're saying that the graphs showed an increase in temperatures across all case sites and Alaska?	Yes.
Did that also connect to the changes people are experiencing in the Northern Slope of Alaska?	Yes. The multi-year sea ice is being affected by the increased temperatures.
Interesting. Do you think this trend in increased temperatures will continue to happen in the future?	Maybe. It seems to be going in one direction, but maybe at some point, it has to turn back down.
Does that also mean that the trends in precipitation data may also continue to change?	It may continue to change if the temperature keeps changing.

Add "climate change" to the Word Wall. Say, *It sounds like we may expect this trend of temperatures increasing to continue in the future, and the precipitation trends may also continue. When we see long-term precipitation and temperature trends changing for a place, we have a name for this trend. It's called "climate change."*

Remind students that the word *climate* references the long-term weather patterns of a place, often measured by temperature and precipitation (from Lesson 2), and *climate change* refers to the changes we observe in those long-term patterns. Add "climate change" to the Word Wall (example definition: a change in the average conditions--such as temperature and precipitation--in a place over a long period of time).

ADDITIONAL GUIDANCE	Definitions for climate change often include human activities as the cause. For now, do not include human activities in the definition as students will explore this concept more in the next lesson set 2. Students will revise this definition in Lesson 11.

Say, *We have identified this trend in rising temperature and changing precipitation as climate change. Let's look back at our Cause-and-Effect diagram to figure out what part of our model this "climate change" is happening in.*

Revisit the consensus model for temperature increase ideas. Orient the class to look at the initial consensus model and the Earth's Water System Model. Orient the class to look back at the Cause-and-Effect diagram. Ask students to consider where the temperature increase and precipitation changes are happening. Direct students to determine that these changes are happening in the air, as indicated by the sticky note before the "increases in temp" sticky note.

Ask students what changes might be happening to the air to cause increasing temperatures. Ask students to look back at their initial models and review any ideas or potential causes already listed on the class initial consensus model. Add any additional ideas students may have for what is causing temperatures to rise. Students may generate ideas such as "more greenhouse gases" or "fossil fuels being burned." As the ideas/potential causes are being reviewed and added, ask students about how they might be causing the temperatures to increase. Example questions are below:

- You mentioned X. What does X do?
- What is the difference between X and another possible cause on our model?
- How much of X do you think is in the air?
- Is all air like that?
- What would X do if it increased or decreased?

Say, *It seems like we have several ideas about what is causing these air temperatures to increase and cause our climate to change. What new questions do we have about any of these possible causes or what is happening for the air temperatures to increase?*

Add any new questions to the DQB. Project **slide L.** Give students a moment to consider any new questions that they have. Give the student a sticky note and allow them to add those questions to our DQB. After new questions have been added to the DQB, ask students, *Do we have any ideas for investigation or data sources that might help us figure out the answers to our new questions?*

Add any new ideas for investigations or data we might need to the Ideas for Investigation chart. Say, *OK. It seems like we can all agree that something is happening in the air to make the temperatures increase, but we aren't sure what that is or what is causing it.*

Ask students to share their ideas and add them to our Ideas for Investigation and Data we Might Need Chart. Point out that based on their questions and ideas for investigation, we will need to figure out more about what is in the air and what it is doing to make temperatures increase in our future class periods.

Additional Lesson 6 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA

CCSS.ELA-LITERACY.W.7.1: Write arguments to support claims with clear reasons and relevant evidence.

- **CCSS.ELA-LITERACY.W.7.1.A: Introduce claim(s), acknowledge alternate or opposing claims, and organize the reasons and evidence logically.**
- **CCSS.ELA-LITERACY.W.7.1.B: Support claim(s) with logical reasoning and relevant evidence, using accurate, credible sources and demonstrating an understanding of the topic or text.**
- **CCSS.ELA-LITERACY.W.7.1.C: Use words, phrases, and clauses to create cohesion and clarify the relationships among claim(s), reasons, and evidence.**

CCSS.ELA-LITERACY.W.7.2.B: Develop the topic with relevant facts, definitions, concrete details, quotations, or other information and examples.

When students are recording their first draft and revised explanations, they are writing an explanation, conveying their understanding of key science ideas, and drawing on evidence from investigations. While we are not calling it a "claim," students are developing a how or why account for the phenomenon and backing up that explanation using evidence and reasoning from class investigations.

LESSON 7: Are there any changes in the air that could be related to rising temperatures?

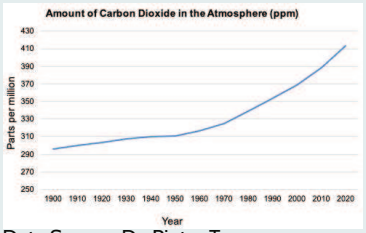
PREVIOUS LESSON

We used our key model ideas to explain how changes in temperature have an impact on our case site communities. We revised our explanations using peer feedback and applied our key model ideas in an Alaskan assessment transfer task. Finally, we were curious as to what would be causing the temperatures to change.

THIS LESSON

INVESTIGATION

1 day



Data Source: Dr. Pieter Tans, NOAA/GML (gml.noaa.gov/ccgg/trends/) and Dr. Ralph Keeling, Scripps Institution of Oceanography (scrippsco2.ucsd.edu/)

We recall our understanding about the molecules that make up air and look at data that shows the concentration of those molecules over time. We continue wondering if changes in the air are related to the rise in temperatures. By looking at the data, we build our understanding of the meaning of parts per million and figure out how to find the percent change in the quantity of these gases over time. We notice that some gases have not changed at all, some have changed very little, while other gases show an unusual increase over the 100-year period. Based on these new findings, we wonder if the gases that are rising are related to or causing the temperatures going up.

NEXT LESSON

We will figure out if the gases that are increasing in the atmosphere are causing the temperature to rise. We will do this by comparing movement of different atmospheric gas molecules and apply that to energy transferred in the atmosphere.

BUILDING TOWARD NGSS

MS-ESS3-1, MS-ESS3-3, MS-ESS3-4, MS-ESS3-5, MS-ETS1-2

WHAT STUDENTS WILL DO

7.A Apply mathematical concepts of percent to understand the proportion and quantity of and stability and/or change in the concentration of gases in the atmosphere over time.

WHAT STUDENTS WILL FIGURE OUT

- The atmosphere is made from different concentrations of gases.
- Some gases have not really changed over time, but some show an unusual increase.
- Carbon dioxide and methane are a small percent of the atmosphere but are increasing at a high rate.

Lesson 7 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	6 min		**COMPARE THE MIXTURES OF GASES IN THE ATMOSPHERE** Have students recall and review the composition of gases that make up the atmosphere.	A-C	Earth's Water System Model
2	6 min		**BUILDING UNDERSTANDINGS DISCUSSION ABOUT PARTS PER MILLION** Facilitate a deeper discussion about the data displaying gas composition in parts per million. Support students in their reasoning to understand how amounts of gases are measured and converted into percentages.	D	plastic bag, whiteboard or chart paper, markers
3	15 min		**ANALYZE CHANGES IN COMPOSITION OF GASES IN THE AIR** Distribute graphs for students to analyze changes in gases over time. Then have students work in partners or small groups to calculate the percent change for each gas and draw initial conclusions.	E-F	*Concentration of Gases in the Atmosphere Over Time*, calculator
4	15 min		**FACILITATE A BUILDING UNDERSTANDINGS DISCUSSION AND ADD TO DQB** Bring students together to discuss new findings and add to the DQB.	G-H	sticky notes, markers, whiteboard or chart paper, DQB, Model Ideas list
5	3 min		**NAVIGATION** Prime students to further explore the causal link between gases that are on the rise and temperature change.		

End of day 1

Lesson 7 • Materials List

	per student	per group	per class
Lesson materials	• science notebook • *Concentration of Gases in the Atmosphere Over Time* • sticky notes • markers	• calculator	• Earth's Water System Model • plastic bag • whiteboard or chart paper • markers • DQB • Model Ideas list

Materials preparation (10 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Have a large plastic bag on hand. This will be used to capture air as a visual to engage student thinking.

Alternate start to Lesson 7: In pilot studies of the anchor phenomenon and initial models to explain them, most students identified "pollution", "carbon dioxide", and "greenhouse gases" as the cause of temperature change. However, it is possible that students may believe that the Sun is getting warmer or closer to Earth or that the ozone hole is related to warming temperature. If your students identified these as possible warming mechanisms, explore them more using the Extension Opportunity located in *Exploring Possible Causes of Warming*.

Lesson 7 • Where We Are Going and NOT Going

Where We Are Going

From early in the unit, students likely shared questions about how things in the air or gas molecules could be related to or causing the rise in temperature. Students may have already known about "pollution" or "carbon dioxide emissions" or even "greenhouse gases." In this lesson, students further explore how rising concentrations of gases in the atmosphere are related to rising temperatures, and in the next lesson, they will make sense of how those gases *cause* an increase in temperature. This lesson will have students explore the concentration of some permanent gases that make up our atmosphere and observe that some gases have increased at an unusual rate over time, while others have remained mostly stable. In order to make sense of the increase, students first need to develop an understanding of "parts per million." When looking at the total concentrations of gases by parts per million, both methane and carbon dioxide appear to be insignificant gases. By calculating the percent change, students then see that, while those gases are small in concentration and total quantity in the atmosphere, their percent change over time is unusually high, while other more abundant gases have changed very little. By the end of this lesson, students should wonder if the unusual increase of carbon dioxide and methane is actually *causing* the rising temperatures in the atmosphere.

Throughout this lesson, students will engage with mathematical reasoning about the phenomena. Students calculate and use percent to understand gas concentrations and their change over time. Two crosscutting concepts—Scale, Proportion, Quantity & Stability and Change—should be used by students to support their reasoning.

Where We Are NOT Going

This lesson does not explore the cause(s) of the changes in the concentration of these gases (Lesson 10) or which gases are considered greenhouse gases and their role in rising temperatures (Lesson 8). These ideas will be taken up in subsequent lessons. If students ask questions about these ideas, encourage them to add those questions to the DQB but avoid exploring them until later lessons.

There are interesting patterns to explore with changing water vapor and oxygen over time. Unfortunately, time does not permit for deeper investigation of changes in these two gases.

- Water vapor: With respect to water vapor, because overall atmospheric temperatures have risen, scientists have also observed an increased percent of water vapor. Because water vapor is variable by geographic location, it is challenging to estimate "global average." If students are curious about the increase in water vapor, return to the ideas that students figured out in Lesson 3.
- Oxygen: Scientists have measured that atmospheric oxygen is declining over time. For the purposes of this lesson, oxygen is treated as a relatively "stable" gas because it has changed less than 1% over time. The science to explain this change is still tentative as scientists make sense of complex natural and human-generated causes for the decline. The change in oxygen concentration over time would make for an interesting extension opportunity for high interest learners should they express more curiosity about the decline.

LEARNING PLAN for LESSON 7

1 · COMPARE THE MIXTURES OF GASES IN THE ATMOSPHERE

6 min

MATERIALS: Earth's Water System Model

ALTERNATE ACTIVITY

Alternate start to Lesson 7: In pilot studies of the anchor phenomenon and initial models to explain them, most students identified "pollution," "carbon dioxide," and "greenhouse gases" as the cause of temperature change. However, it is possible that students may believe that the Sun is getting warmer or closer to Earth or that the ozone hole is related to warming temperature. If your students identified these as possible warming mechanisms, explore them more using the Extension Opportunity located in *Exploring Possible Causes of Warming*.

Navigation into the lesson. Display **slide A.** Say, *So far we have seen that there have been an increase in droughts or floods in different places. We also saw that in Alaska we have an increase in wildfires and a decrease in multi-year sea ice. We also figured out that all our case sites show increasing air temperatures. Let's think about what we figured out about how these events and data seem to be connected.*

Suggested prompts	Sample student responses
What did we figure out is happening to the temperature?	The temperature is changing; increasing over time.
What do we now know about the relationship between temperature and what we are seeing with droughts, floods, wildfire, and sea ice?	That the changes in temperature has something to do with the increased droughts, floods, wildfires, sea level rise, and sea ice melting.
And where in Earth's Water System Model are the increases in temperature happening?	We see this happening in the air.

Remind students that the last lesson looked at a portion of the model to consider what might be happening in the air. The class determined areas of uncertainty and developed new questions, along with ideas for investigating those questions. Explain that since a lot of questions are about the air, the class should start to look at the air, what is there, and what is changing.

Say, *Last class we had some ideas about what makes up the air already that we've learned about before, and it seems like something in the air is changing. Before we start to tackle our new questions, let's recall what we already know about the air, and what we think it's made of, so we can then figure out what is possibly changing.*

Turn and talk about the composition of gases in the atmosphere. Display **slide B**. Ask the students to recall the gases that are found in the air. Students should recall ideas from the following units: *Storms Unit*, *Bath Bombs Unit*, and *Maple Syrup Unit*.

Record student responses and discuss relative composition. Bring students back together for a brief whole group sharing. Ask students to share ideas as you record a public record. Students will likely mention oxygen, nitrogen, carbon dioxide, and water vapor. Ask for ideas about which gases are most abundant in the atmosphere. Students may recall from previous units that nitrogen and oxygen are the most abundant and that carbon dioxide makes up only a small amount.

Share percentages of gases in the atmosphere. Display **slide C**, which shows the percentages of the main gases making up the atmosphere: nitrogen, oxygen, carbon dioxide, water vapor, and other trace gases. Ask students to compare the chart to their responses. Students should notice/confirm that the graph shows a higher percentage of nitrogen, oxygen as the second highest, and that carbon dioxide, water vapor,

and other gases make up a very small percentage of the atmosphere.

Say, *Looking at this data, we know more about the composition of the atmosphere. However, from our conversations, there are still things that are unclear. What are we still unclear about?*

- Listen for ideas:
  - We still aren't sure why the temperature is increasing, or if it is related to global warming and climate change.
  - We aren't sure if something in the air is changing that could be causing temperatures to go up.

ADDITIONAL GUIDANCE	If ideas about global warming, climate change, or what might be changing in the air do not come out from the conversation above, direct students back to the DQB and the questions they developed at the end of Lesson 6 to identify these areas of uncertainty.

2 · BUILDING UNDERSTANDINGS DISCUSSION ABOUT PARTS PER MILLION

6 min

MATERIALS: science notebook, plastic bag, whiteboard or chart paper, markers

Facilitate a discussion of parts per million and what that means as a unit of measurement. Continue to display **slide C**. Tell students that the pie chart is one way to show the concentration of gases that make up our atmosphere by percent. Say, *OK, so we know that there are percentages of these gases in the atmosphere, but how did scientists figure out these percentages anyway? It seems challenging to measure gas molecules in something as large as the atmosphere. Scientists have really interesting ways to make these measurements using a unit called "parts per million."* Display **slide D**, which contains a data table in percent and parts per million.

Give students time to turn and talk. Using the prompt on **slide D**, give students one minute to turn and talk about their ideas before facilitating a whole group discussion.

Suggested prompts	Sample student responses
One way that scientists measure gases is in "parts per million." What do you think "parts per million" means?	Each part is a molecule, so if you look at a million molecules, how many of them will be a different gas? Out of a million total gas particles, a certain amount of them are carbon dioxide, nitrogen, and so on.
What if, instead of one million parts, there were two million parts? Ten million?	There will be twice as many carbon dioxide particles.

Use the plastic bag to demonstrate sampling air. Open the bag wide to fill with air and then seal the bag so that it's partially inflated. Say, *This bag has a sample of air molecules in it. Let's imagine that there are one million air molecules in it, though there are actually many, many more! If we had a million air molecules in the bag, how many do we think would be nitrogen, according to our data here?* Use the bag to help facilitate an understanding that, for every million molecules, a certain portion of them will be each kind of gas.✱

Practice representing parts per million as a fraction and percent. Using the data table, have students work in partners to practice moving between parts per million and percent. Ask partners to pick one gas from the table to write as a fraction in their notebook or on scrap paper.

✱ SUPPORTING STUDENTS IN ENGAGING IN USING MATHEMATICS AND COMPUTATIONAL THINKING

Use the plastic bag as a visual to engage in ratio reasoning. Support students in discussing how to measure a particular gas in a given air sample. For a sample of one million gas molecules, on average 780,000 of 1,000,000 will be nitrogen molecules and only 410-411 will be carbon dioxide. Use this difference to emphasize how abundant some gases are in the atmosphere, while other gases seem somewhat insignificant. Calculating percents from parts per million is a secondary skill compared to being able to understand the mathematical meaning of the value of "parts per million" and the use of this unit to draw a conclusion about the quantities of different gases in the atmosphere.

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING SCALE, PROPORTION, AND QUANTITY

Use this opportunity to emphasize the vastly different quantities of gases in the atmosphere, in particular, carbon dioxide making up very little of the overall mixture of gases. You can help students scale their

Suggested prompt	Sample student response
How could we write parts per million as a fraction?	For example, carbon dioxide is 411 ppm. 411 ppm as a fraction is 411/1,000,000.

Say, *We just figured out that parts per million or ppm can be written as a fraction. Some graphs show percentages instead of ppm. How does the data showing ppm compare to data representations showing percentages? Let's figure that out. Discuss with your partner how to turn the fraction into a percent. You don't have to do it. Just explain to your partner how you would convert these fractions into a percent.*

Bring students back together and check that they have an understanding that percent and parts per million are different ways of accounting for quantities and concentrations of gases in the atmosphere. Practice conversions together on the whiteboard or chart paper as needed.

Say, *Now we're ready to see if anything is changing in the atmosphere. Seems like nitrogen and oxygen are pretty important gases for our atmosphere and most everything else is in actually quite small amounts. Let's see if anything is going on with these different gases that could be related to temperature change.*✱

understanding of the immensity of the atmosphere by connecting this concept to everyday processes they know change the molecules found in the air. For example, every living thing gives off carbon dioxide into the atmosphere, yet carbon dioxide remains a small overall amount of the total gases.

3 · ANALYZE CHANGES IN COMPOSITION OF GASES IN THE AIR

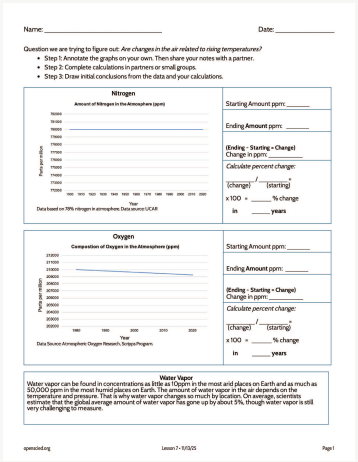
15 min

MATERIALS: *Concentration of Gases in the Atmosphere Over Time*, calculator

Recall what we're trying to figure out and the data we need to do this. Say, *Let's remind ourselves of what we're trying to figure out. Our question is: Are there any changes in the air that could be related to rising temperatures? Now that we know what is in the air, what else do we need to answer our question? In other words, what additional data do we need to see if anything is changing?* Listen for students to suggest:

- *Data showing gases since the temperature started rising.*
- *Data showing gases over time.*
- *Data showing any change in the gases.*

Guide students to the idea that we need data that shows whether the gases are changing over time—for example, data showing the amount of each gas over a certain period of time.✱


Name: _____ Date: _____

Question we are trying to figure out: *Are changes in the air related to rising temperatures?*

- Step 1: Annotate the graphs on your own. Then share your notes with a partner.
- Step 2: Complete calculations in partners or small groups.
- Step 3: Draw initial conclusions from the data and your calculations.

Nitrogen

Amount of Nitrogen in the Atmosphere (ppm)

Starting Amount ppm: _____

Ending Amount ppm: _____

(Ending − Starting = Change)
Change in ppm: _____

Calculate percent change:

(change) / (starting) x 100 = _____ % change

in _____ years

Data based on 78% nitrogen in atmosphere. Data source: UCAR

Oxygen

Composition of Oxygen in the Atmosphere (ppm)

Starting Amount ppm: _____

Ending Amount ppm: _____

(Ending − Starting = Change)
Change in ppm: _____

Calculate percent change:

(change) / (starting) x 100 = _____ % change

in _____ years

Data Source: Atmospheric Oxygen Research, Scripps Program.

Water Vapor

Water vapor can be found in concentrations as little as 10ppm in the most arid places on Earth and as much as 50,000 ppm in the most humid places on Earth. The amount of water vapor in the air depends on the temperature and pressure. That is why water vapor changes so much by location. On average, scientists estimate that the global average amount of water vapor has gone up by about 3%, though water vapor is still very challenging to measure.

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Prepare students for data observations. Say, *Yes, we need to see if the amounts of these gases are changing and, if so, by how much. We have some data for a few gases in the atmosphere. These are graphs that show the concentration of each gas in the atmosphere over a period of 100 years. We don't have data for every gas, but do have it for some of the most abundant ones, like nitrogen, oxygen, and carbon dioxide.*

Pass out 1 copy of *Concentration of Gases in the Atmosphere Over Time* to each student. Use **slide E** to give students direction for working with a partner on their analysis. Get students started on step 1.

- Individually, students will annotate their handout with noticings, writing their ideas onto the graphs. They can also document wonderings.
- With a partner, students will discuss their noticings and add additional notes.
- Students should notice that the labels of the axes are parts per million (*y*-axis) and years (*x*-axis). They should also notice that the scales on both axes are different for each graph because their concentrations differ and the time period differs slightly. For example, data for oxygen is only given from 1980 until 2020.
- They should also see that there is no graph for water vapor and that the information is given in text format.

Before students begin step 2 to make calculations, bring the students back together for a whole group check-in about their noticings.

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING STABILITY AND CHANGE

When students begin their analyses of the data and calculate percent change, encourage students to use the crosscutting concept of Stability and Change as a lens for explaining what is happening to gases over time. Students should know that fluctuations within a normal range can be considered stable (Lesson 2) but that an overall trend in one direction could indicate a change in the normal pattern. Prompt students to think about whether the data supports a stable pattern or a changing pattern.

Suggested prompts	Sample student responses	Follow-up questions
What do you notice about the concentration of the gases over time?	Some gases are changing a lot more than other gases.	*How did you determine that?*
Did anyone notice the data given for oxygen. How is that graph different from the other graphs?	There is no data before 1980 recorded on the graph.	*Why do you think that is the case?*
What is different about water vapor?	There isn't a graph. It's really hard to measure and changes so much from place to place.	*What did we already learn about water vapor in the atmosphere?*

Say, *Now we need to see how much the gases have changed over time and if the changes are big or small. To do this, we will calculate the percent change of each gas in the air over time.*

Prepare students to find the percent change over time to complete step 2 on their handout. Display **slide F** with an example calculation to complete together.

- Subtract to find the change (Ending ppm-Starting ppm).
- Divide the change by the starting ppm.
- Then multiply by 100.
- Ex: (360-300)/300 = 0.20 x 100 = 20% change.

Prepare students to determine the rate of percent change. Tell students, *Let's say this change occurred over 10 years. Scientists would want to know how much the concentration of these gases changed each year. This gives scientists the rate of change and helps predict future changes in the concentration of gases in the atmosphere. How can we determine the percent change in one year?* (We would have to divide the percent change by the number of years). So let's figure it out:

- Ex: 20/10 = 2% change per year.

Students calculate the percent change. Display **slide E** again, and direct students to complete steps 2 and 3 on their handout with a partner or small group. Provide each group with a calculator. Water vapor is given to students (5%). When the students get to step 3, suggest that students use +/-/= to show increasing, decreasing, or staying the same.

4 · FACILITATE A BUILDING UNDERSTANDINGS DISCUSSION AND ADD TO DQB

15 min

MATERIALS: science notebook, sticky notes, markers, whiteboard or chart paper, DQB, Model Ideas list

Discuss and categorize the gases by how much they have changed. Gather in a Scientists Circle with the DQB visible. Display **slide G**. Work as a class to categorize the gases by which ones are changing the most and which are changing the least based on the percent change.✱

Create a chart with the headings shown below. Decide on how to agree on what constitutes a change versus what is stable over time. Then work together to agree upon which gases belong in each column.

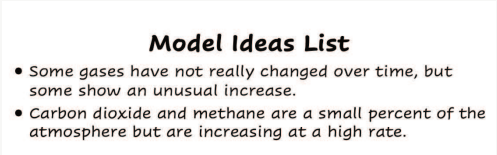
Not really changing	Changing a little	Changing a lot
Nitrogen *Oxygen*	*Water vapor*	*Carbon dioxide* *Methane*

✱ SUPPORTING STUDENTS IN THREE-DIMENSIONAL LEARNING

As students share their conclusions about the change in atmospheric gases over time, encourage them to use both scale and quantity lens, as well as stability and change lens, to support their conclusions. They can reference their calculations for percent change to support their conclusions, too. One of the most perplexing ideas that

Add to the Model Ideas list. Start a new model ideas list or continue to add to your existing chart from Lesson Set 1. With your class, co-construct summary ideas from this lesson to add to your class chart. Example ideas may include:

- Some gases have not really changed over time, but some show an unusual increase.
- Carbon dioxide and methane are a small percent of the atmosphere but are increasing at a high rate.
- Students may want to add an idea similar to, "The atmosphere is made from different concentrations of gases," which is also fine.



KEY IDEAS

Purpose of the discussion: to identify that a few gases in the atmosphere are changing over time.

What to look/listen for:

- students identify that nitrogen and oxygen are mostly stable and not changing over time,
- students identify that carbon dioxide and methane are increasing by a high percentage,
- students classify water vapor as "changing a little," and
- students conclude that, while carbon dioxide and methane make up a small quantity of gas in the atmosphere, the change over time for both types of gas is unusually high.

ASSESSMENT OPPORTUNITY

Building towards: 7.A Apply mathematical concepts of percent to understand the proportion and quantity of and stability and/or change in the concentration of gases in the atmosphere over time.

What to look/listen for: See Key Ideas above.

What to do: If students struggle to draw conclusions, do the following. Draw a two-column chart. Label the left column "Abundance in the atmosphere" and the right column "Percent change over time." In the left column, have students list the gases from most to least abundant (i.e., nitrogen, oxygen, water vapor, carbon dioxide, and methane). In the right column, have students list the gases from greatest to least change over time (i.e., methane, carbon dioxide, water vapor, oxygen, and nitrogen). This should help students see that the most abundant gases are the most stable, while gases in smaller quantities are changing the most over time. This will help students understand the relative proportions of gases and how their quantities are changing over time.

Problematize what we have figured out. Say, *We see that methane and carbon dioxide are increasing the most. But so what? How could gases that are so small in amount in the atmosphere really matter? And it seems really strange that carbon dioxide , the gas we exhale and that plants use to make food, could be related to temperature change anyway? Now that we do know some gases are changing in the atmosphere, this may prompt new questions for you. Look back at any wonderings you had today, or even previously, and let's see if we can get new questions on our DQB that we need to answer now.*

Add new questions to the DQB. Display **slide H**. Give students sticky notes and a few minutes to record new questions they have. Facilitate students in adding and categorizing those questions on the DQB. Just as with the original DQB, ask students to read their questions one at a time and make connections to other students' questions. Categorize the questions and add labels to the categories.

Questions that could come up for discussion (add to DQB):

- Pollution-related questions: Is it pollution? Are CO_2 and methane bad gases or if these gases are part of the "normal" composition of air, then why is the rise in CO_2 bad? We know from previous lessons that plants need carbon dioxide to make food.
- Methane-related questions: What about methane? Is it needed?
- Crosscutting concept-related questions: How could a gas that is only a *small fraction* of the air in the atmosphere *cause* temperatures to rise? Is it causing temperatures to rise? (Focus is on deciphering causation version correlation.)

should emerge through this work is that the most abundant gases in the atmosphere are stable, while the gases in smaller quantities are changing at an unusually high rate. This should prompt questions from students about whether gases in such low abundance matter enough to affect temperatures.

5 · NAVIGATION

3 min

MATERIALS: None

Summarize what we have figured out. Tell students that we have figured out that carbon dioxide and methane in the atmosphere are both rising at an unusually high rate compared to the other main gases that are staying mostly the same or slightly changing. Say, *We are wondering if gases that are rising are related to the temperatures going up? Right now we only see that they could be related (correlated), but we'd need more information to understand if carbon dioxide and methane are causing a temperature change. It's really strange that gases that we can't even see with our eyes, and ones that are in such a small amount overall, could possibly be causing these unusual changes on Earth. Any ideas about how these gases could cause this to happen?*

Students might suggest these initial ideas:

- They absorb sunlight.
- They act like a blanket.
- They have something to do with the greenhouse effect.
- They are bad for our environment.

Additional Lesson 7 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN MATH

CCSS.Math.Content.6.RP.A.2: Understand the concept of a unit rate a/b associated with a ratio a:b with b ≠ 0, and use rate language in the context of a ratio relationship.

Through discussion and calculations, students apply grade-appropriate mathematical concepts of unit rate and ratio reasoning to describe and explain measurement of and change in atmospheric gases. For example, students parse descriptions of quantities that use rate language (like "parts per million") and practice converting parts per million to fractions and percentage. To better understand change in gas concentration, students calculate a "percent change" over a time period of 100 years, then determine the rate of "percent change" per year. In each case, the ratio reasoning supports students in making sense of how amount and change over time can communicate very different things about what is happening to gases in the atmosphere. For example, looking at the amount alone may mislead someone to conclude that carbon dioxide is insignificant, while calculating percent change would lead to a different conclusion.

If students need extra support with ratio reasoning or representations, consider offering math support, like targeted questioning or anchor charts on ratio language or graphing on the coordinate plane, so that students can demonstrate their understanding of key science concepts through mathematical language and representations. Support may focus on helping students to identify ratio language like "per" or two quantities separated by the word "to" and translating these ratios to make sense of how one quantity is compared to another (for example, making sense of "carbon dioxide molecules per million gas molecules" to mean how many carbon dioxide can be found in a sample of one million particles). To further support students' understanding of unit rate, provide familiar examples of unit rates such as speed or heart rate.

LESSON 8: Are changes in carbon dioxide and methane related to or causing temperatures to increase?

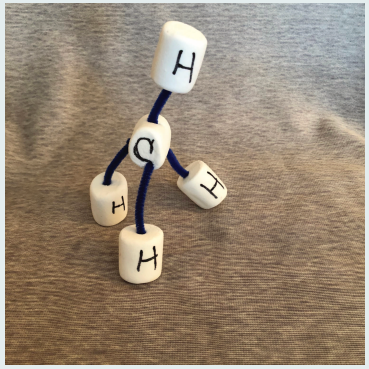
PREVIOUS LESSON

We discussed our previous understanding of the composition of air and analyzed graphs and charts showing the concentration of gases that make up the air. We developed a better understanding of parts per million and figured out how to calculate the percent change in their concentration over time. We noticed that, over a 100-year time period, some gases remained stable, some changed very little, and other gases in the atmosphere changed a lot.

THIS LESSON

INVESTIGATION

2 days



We use molecular models to investigate the way molecules move in response to energy transferred from Earth to molecules in the air that warm our atmosphere. We investigate this idea further by using an interactive showing how molecules move when this energy is absorbed. Using these ideas and the ideas from a reading, we figure out that, because greenhouse gases absorb, vibrate, and release energy, they keep our atmosphere warm. We apply these ideas to what we learned about GHGs increasing in our atmosphere to figure out that increasing GHGs are why temperatures are currently increasing. We wonder if this is normal.

NEXT LESSON

We will carry out an investigation and find that gas can be trapped in ice. We will find out about how scientists use ice core samples from locations on Earth that have very old ice to determine the amounts of carbon dioxide in the air over time. We focus on carbon dioxide and examine carbon dioxide data from ice cores dating back 800,000 years. We notice carbon dioxide naturally fluctuates up and down, but the current levels are outside of the normal high range for carbon dioxide.

BUILDING TOWARD NGSS

MS-ESS3-1, MS-ESS3-3, MS-ESS3-4, MS-ESS3-5, MS-ETS1-2

WHAT STUDENTS WILL DO

8.A Develop and use a model to describe how greenhouse gas molecules respond to energy transfer from Earth to the atmosphere and cause the temperatures to rise.

WHAT STUDENTS WILL FIGURE OUT

- GHGs are gas molecules in the atmosphere that absorb, vibrate, and release energy back into the atmosphere. This keeps Earth at a livable temperature.
- As the amount of GHGs increases in our atmosphere, they cause the atmosphere to get warmer.

Lesson 8 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	10 min		**NAVIGATION** Surface students' prior knowledge about what happens when things warm up and how these ideas may apply to the atmosphere and air molecules as temperatures rise.	A	chart paper or white board, markers, optional slides
2	10 min		**THE MOTION OF GAS MOLECULES** Demonstrate the motion of gas molecules and students observe the similarities and differences in the way gas molecules move.	B-D	pre-assembled marshmallow molecule models
3	17 min		**USE AN INTERACTIVE TO UNDERSTAND MORE ABOUT GASES IN THE ATMOSPHERE** Set up the interactive and do an analogy map as a class. Predict which gas or gases will respond more to the energy transferred based on students' observations of molecular models. Use the interactive to explore how gas molecules in the air respond to this energy transfer.	E-G	*Important Gases in the Atmosphere*, PhET Energy and Air Molecules interactive, computer and projector
4	8 min		**DISCUSS OBSERVATIONS FROM THE INTERACTIVE** Share observations from the interactive and chart results.	H	
					End of day 1
5	10 min		**BUILDING UNDERSTANDINGS DISCUSSION** Compare our observations from the interactive and molecular models to the groupings from Lesson 6. Lead a Building Understandings Discussion and record model ideas.	I-J	
6	12 min		**READING GASES THAT VIBRATE** Read *Gases that Vibrate* with a partner, highlighting important ideas.	K	*Gases that Vibrate*, highlighter
7	20 min		**SUMMARIZE AND UPDATE PROGRESS TRACKER** Summarize important ideas from the reading. Update Progress Tracker with models and model ideas.	L-M	colored pencils, Model Ideas list, markers
8	3 min		**NAVIGATION** Navigate to the next lesson by asking if students think that increasing GHGs in the atmosphere are just part of a normal cycle.	N	*Concentration of Gases in the Atmosphere Over Time* from previous lesson, Driving Question Board, Ideas for Investigations Board
					End of day 2

Lesson 8 • Materials List

	per student	per group	per class
Lesson materials	• *Important Gases in the Atmosphere* • science notebook • *Gases that Vibrate* • highlighter • colored pencils • *Concentration of Gases in the Atmosphere Over Time* from previous lesson		• chart paper or white board • markers • optional slides • pre-assembled marshmallow molecule models • PhET Energy and Air Molecules interactive • computer and projector • Model Ideas list • Driving Question Board • Ideas for Investigations Board

Materials preparation (45 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

There is one reading in this lesson that is not leveled, but should be accessible to most students. Based on seven readability formulas, the text ranged between 6th-and 7th-grade readability. The text should be modified for below grade level readers as needed by shortening sentences and replacing some vocabulary (e.g., replace "cylinder" with "jar").

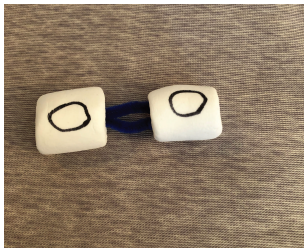
- *Gases that Vibrate* Lexile range: 810L-1000L; Flesch-Kincaid Grade Level: 6.4.

Test the PhET interactive from https://phet.colorado.edu/sims/html/molecules-and-light/latest/molecules-and-light_en.html?openSciEd.

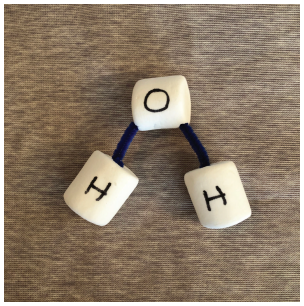
Day 1: Molecules in Motion

- **Teacher Demonstration**
- **Setup:**
  - At least 24 hours before, and no more than 48 hours before, make the marshmallow models; lay out to dry 15 regular sized marshmallows to make one set of molecular models. Laying them out to dry will make them less sticky, allow you to write on them easily, and discourage students from eating them. Laying the marshmallows out too long will make it difficult to insert the pipe cleaners.
  - Use scissors to cut pipe cleaners into 2.5" pieces. You will need 15 2.5" pieces for the set of molecules.
  - Once marshmallows have dried for at least 24 hours and not more than 48 hours, assemble molecular models as shown in the *Marshmallow Model Assembly* video located at https://youtu.be/j0nlo3BTQeo and according to the table below.
  - Use a sharpie to write the atomic symbol on the marshmallows as shown in the images below. You may want to write the symbol on two sides of the marshmallow so that it is visible from several directions.

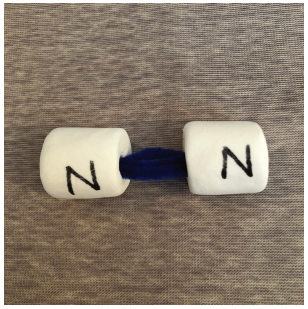
Oxygen gas
2-marshmallows
2-2.5” pipe cleaners
(two for one bond)



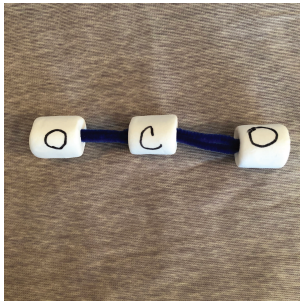
Water
3-marshmallows
2-2.5” pipe cleaners
(one for each bond)



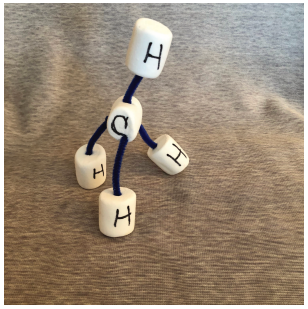
Nitrogen gas
2-marshmallows
3-2.5” pipe cleaners
(three for one
bond)



Carbon Dioxide
3-marshmallows
4-2.5” pipe cleaners
(two for each bond)



Methane
5-marshmallows
4-2.5” pipe cleaners
(one for each bond)



- **Notes for during the demonstration:** Move molecules gently so that they don’t come apart. The pipe cleaners are hard to reinsert once they come out. See the *Marshmallow Model Assembly* video located at https://youtu.be/j0nlo3BTQeo for a demonstration.
- **Safety:** Students should not eat the marshmallows.
- **Disposal:** These models can be discarded in the trash can or saved for later use. Allowing the models to dry completely is OK, but if pipe cleaners come out of the marshmallows, it will be difficult to replace them.
- **Storage:** If stored in an airtight container and marshmallows are not completely dry, they may become sticky over time.

Lesson 8 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students will investigate that greenhouse gas molecules behave differently than other atmospheric gas molecules when energy is transferred to them. In previous units they have learned that (1) a group of particles with a higher average kinetic energy are at a higher in temperature; (2) particles with more kinetic energy can transfer energy when they collide with particles with less kinetic energy; (3) heat is the transfer of thermal energy from one object to another; and (4) when the sun warms Earth's surface particles, there is a transfer of energy from the surface particles to the air particles above them through conduction, and that warmer air rises (convection), which is part of the reason the atmosphere is warmed up. Thus, prior to this lesson students will have familiarity with energy transfer in the atmosphere by two mechanisms - conduction and convection.

However, students will expand their understanding of energy transfer beyond conduction and convection. They learn that energy also leaves Earth's surface in a different way and moves back toward space. This energy interacts with some molecules in the atmosphere. Some air molecules absorb this energy, which causes these molecules to vibrate, and release the energy in all directions. Some of the energy is redirected back into our atmosphere. We call these molecules, greenhouse gases, or GHGs. This interaction between energy and GHG molecules is what causes the greenhouse effect. For this reason, the concentration of GHGs is proportional to temperature. Because the amount of GHGs in our atmosphere is increasing, more energy is released throughout the atmosphere, creating a situation where overall kinetic energy of atmospheric particles increases: temperatures are rising.

In this lesson we do not use "heat" as a noun, but instead we use "thermal energy transfer" or "transfer of thermal energy" This is consistent with **PS3.S Definitions of Energy:** *The term "heat" as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of that thermal energy from one object to another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects.* Heat is often used to identify a "form" of energy but it is the *transfer* of thermal energy from warmer objects to cooler objects. We will use "heated" or "warmed" and "heating" or "warming" to describe what we would detect when thermal energy is transferred into an object or part of a system.

Where We Are NOT Going

Students will investigate atmospheric molecules and how the bonds between the atoms are flexible—but they will not learn about chemical bonding. They will learn through a reading that energy causes GHG molecules to vibrate, but they will not go on further to learn about resonance. Infrared light interacts with the GHG molecules, but the terms/phrases—electromagnetic radiation, radiation, and infrared—are not part of this lesson.

In your prior learning, you may have seen "heat" used as a synonym for 'infrared radiation.' More accurately, infrared is considered a form of light. At this grade level, we make no attempt to use the term electromagnetic radiation to describe infrared radiation. Infrared radiation has a longer wavelength than the visible light our eyes can detect but we can feel energy being transferred from this light to our skin for example, as it interacts with matter in our skin heating it to a higher temperature. No attempt is made to address what is different about light of different wavelengths in this unit.. One mechanism by which energy is transferred is infrared radiation, which travels across empty space without needing matter as medium, which is different from the other two mechanisms that can transfer thermal energy via particle collisions or bulk particle movement- conduction or convection. Students will see that the energy transfer in this lesson is different from conduction and convection but will not learn about radiation. Instead, this lesson intends to lay the groundwork for future learning about radiation in high school.

LEARNING PLAN for LESSON 8

1 · NAVIGATION

10 min

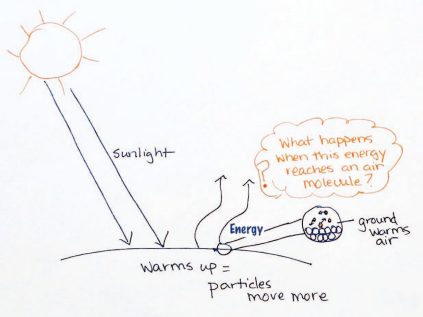
MATERIALS: chart paper or white board, markers, optional slides

Remind students where we left off. Say, *We left the last class wondering about these gases that are increasing in our atmosphere. Are these gases related to the temperature increasing or possibly even causing the temperature change? First, let's remind ourselves of what we already know about when things warm up and temperatures increase.*

Turn and talk about prior ideas about molecules and temperature. Display **slide A**. Say, *We learned in Cup Design Unit* and *Homemade Heater Unit about what happens when things warm up. And, we learned in Storms Unit how the sun interacts with the ground to warm the air molecules in the atmosphere. Turn and talk to your partner about other ideas you may already have that could help us explain what's going on with temperatures in the atmosphere and whether gases could be related.*

Listen for students to recall:

- When molecules move more they have more energy which can be transferred to other molecules.
- The surface of Earth is warmed by the sun.
- The air is then warmed by conduction and convection.
- When air molecules start moving more, the air has a warmer temperature.



Discuss and diagram students' knowledge about how air molecules could be related to temperatures. Say, *I heard in your conversations that the Sun warms Earth and tha*t the ground warms *the air. Let's represent our thinking in a model to see what we already know about temperature and warming up.* Start a diagram like the one shown to the right. Document your students' existing knowledge in a diagram on chart paper or the white board.

Introduce a different way for energy to transfer. Say, *You learned in previous units that energy transfers by conduction and convection. Those ways both require matter to carry the energy--like in the air or water. Do you think energy from the sun can transfer or move without matter?*

Suggested prompts	Sample student responses	Follow-up questions
Do you think energy can move without matter?	No	*Why do you think that?*
	Yes	*Can you give an example?*
Can you give an example of when the energy from the sun transfers or moves without matter?	Well, the energy from the sun gets here from outer space and there is a lot of space that has no matter.	*What is your evidence that the energy gets to Earth from the sun?*

Continue by saying, *So, there must be other ways energy travels that doesn't require matter. This is another way that the Sun warms Earth and Earth warms the atmosphere. In this lesson, this is the process of energy transfer that we will be talking about.*

ADDITIONAL GUIDANCE

Radiation is the transfer of energy that does not require matter. Light moves in this way. The transfer of light does not require a medium (matter) like sound or water waves do. If your students are familiar with the term radiation or if you have used that term with them, you may want to use it here. Radiation is a concept that is beyond the middle school standards and first appears in the high school standards.

Continue by saying, *What happens when the energy from the warm Earth reaches an air molecule? Do you have any ideas? And how could that relate to temperature?*

Suggested prompt	Sample student response
What happens when the energy from Earth reaches an air molecule? And how does that relate to temperature?	Maybe it makes the molecules move faster and the temperature goes up. If the temperature is going up, then there must be more energy in the air. And if there is more energy, molecules are likely moving faster.

Identify a key question to guide the next activity. Write the question near the diagram, *What happens when energy reaches an air molecule?*

Say, *We're thinking that when energy reaches those molecules it could cause them to move more. Let's try this out with a few of the molecules we've been investigating.*

2 · THE MOTION OF GAS MOLECULES

10 min

MATERIALS: pre-assembled marshmallow molecule models

Set up the investigation of atmospheric gases. Display **slide B**. Say, *We get that the ground transfers energy ,warming the air. We know this is the way the air in the atmosphere normally gets warmed. But what we're wondering about is what happens to this energy when it reaches the air molecules. We suspect they might move more. Let's do some tests with the different molecules we've been studying. I have some molecular models that we can use. What are some ways we could simulate adding energy to those molecules?*

Listen for students to suggest:

- Move them faster.
- Move them more.
- Wiggle them.
- Bounce them around.

Say, *Let's try a few of those things and make some observations.* Distribute one copy of the handout, *Important Gases in the Atmosphere* to each student.

Show students the molecular models. Display **slide C**. Hold up one of the marshmallow and pipe cleaner models to demonstrate. Call attention to the way the atoms in the molecules are connected in your marshmallow model. Tell students that these connections are not rigid. Remind students of the models they used in the *Bath Bombs Unit* unit.

ADDITIONAL GUIDANCE

It is important that the molecular models you use have flexible "bonds." In other words, do not use wooden sticks or hard plastic rods to connect the atoms together into a molecule. Instructions are provided to make these molecular models from regular size marshmallows and pipe cleaners. Molecular models that use springs to connect the atoms together are also acceptable but are more expensive. The atoms within the molecule must be free to move and wiggle relative to other atoms in the molecule. This is more like the natural world. Be sure to use the regular size marshmallows because the mini ones are not heavy enough to move in the molecule.

Set up to demonstrate the motion of the following gases: O_2, N_2, CO_2, H_2O, and CH_4. Say, *These represent the molecules of the gases we worked with in our last lesson, and we also recognize these as common gases that make up the atmosphere.*

Display **slide D** and say, *Let's test adding energy to these gas molecules.* Move the molecules so that they bounce off of surfaces or other molecules. Ask students to watch how the molecules and the atoms in the molecules move. If the molecule you are moving has an atom in the center, hold that atom as you move the molecule.

ADDITIONAL GUIDANCE

Remind students that they learned about molecular models in the *Bath Bombs Unit* and what they learned about the small numbers that appear as subscripts. These numbers help them know how many of each atom are in the molecule. Symbols without a number mean that there is only one of that atom in the molecule. If there are numbers lower and to the right of the symbol, that tells them the number of atoms that are in the molecule. You may want to suggest that, if carbon (C) is part of the molecule, it usually appears in the center of the molecule. Therefore, CO_2 would be represented as O--C--O instead of C--O--O. However, do not be overly concerned that the structure is perfect. Getting the right number and type of atom is what is important for this activity. Also, we do not want students to overly focus on the bonds. It's OK for them to notice that nitrogen with a triple bond has less wiggling than the molecules with single bonds, but students do not need to understand why there are triple, double, or single bonds.

This should only take a few minutes for students to see what the atoms in the molecules are doing. Encourage students to record their observations on the handout as they observe you moving each molecule. They can use words and phrases like "moves a lot," "doesn't move much," "moves the most," and "vibrates" or "wiggles."

Share out and record what we noticed about movement of the molecules. Ask students to share out what they noticed about the movement of the different molecules. Listen for ideas, such as:

- all the molecules can move more if you just move them fast in the air,
- in some molecules, the atoms seem to wiggle,
- CH_4 atoms moved or wiggled the most,
- O_2 and N_2 atoms wiggled the least, and
- H_2O and CO_2 atoms wiggled a lot, too.

Say, *If we categorize these molecules into two groups—those that wiggle a lot and those that don't wiggle very much—where would we put each molecule?* As students share, record the molecule formulas into two groups on the whiteboard or chart paper. The groups should be like this:

Molecules that wiggle a lot	Molecules that <u>DO NOT</u> wiggle much
(H_2O, CO_2, CH_4)	(N_2, H_2)

Set up the key questions to motivate observation from an interactive. Say, *We agree that when energy reaches these molecules, they all move more. But we also noticed that some molecules can also wiggle, and others don't do that as much. Does this wiggling matter? And also, what happens to that energy after it causes the molecules to wiggle and move?*

Suggested prompt	Sample student response
Does being able to wiggle when energy reaches the molecule matter?	They are the same gases that are going up so maybe there is something there that's important.
What happens to the energy next?	It turns into movement maybe? It keeps going. I don't know but it can't just disappear.

Say, *OK, let's test a few more things about these molecules and energy. Let's see if we can find out if the wiggling is important, and what happens to the energy after it causes the molecules to wiggle.*

ALTERNATE ACTIVITY

The previous activity is written as a teacher demonstration. If you think your students would benefit from manipulating the molecular models in groups rather than observing in a demonstration, consider supplying additional marshmallow and pipe cleaner models for students to work with in small groups. This of course will take more time but students may benefit from physically interacting with models rather than observing them.

3 · USE AN INTERACTIVE TO UNDERSTAND MORE ABOUT GASES IN THE ATMOSPHERE

17 min

MATERIALS: *Important Gases in the Atmosphere*, PhET Energy and Air Molecules interactive, computer and projector

ADDITIONAL GUIDANCE

In this interactive, Earth is represented by a flashlight that most students will initially connect to the sun. It's important to take time here to help students connect the flashlight to energy transfer from Earth. You may have to take extra time ensuring that your students understand what each part of the interactive represents. Consider supplementing the interactive with an additional NASA simulation to help students understand what the flashlight is representing: https://climate.nasa.gov/climate_resources/188/graphic-the-greenhouse-effect/. This shows sunlight reaching Earth's surface, but then energy reflecting back into the atmosphere, which is what the flashlight is representing in the interactive (not the sunlight itself).

Additionally, students may not be familiar with packets or bundles of energy and may be most familiar with energy as a wave. These bundles of energy are photons of infrared light. The ideas that light can be modeled in these different ways (as a wave or as a photon) are above middle-school grade levels, however, and there is no need to go into this level of detail here. Your students will get this science content in high school.

Set the purpose for the interactive. Say, *It seems we have figured out that the molecules in the atmosphere can move in different ways when energy reaches them. Then what? Where does the energy go and does the wiggling seem to matter?*

Introduce the interactive and give students guidance. Project the *PhET Energy and Air Molecules* interactive from https://phet.colorado.edu/sims/html/molecules-and-light/latest/molecules-and-light_en.html?openSciEd. Display **slide E** (optional setup to the interactive can be found on slides E1-E3). Say, *I found an interactive that shows energy interacting with these molecules, but it is a little different than what you are used to seeing. It shows energy represented by packets of energy coming from an energy source that looks like a flashlight. Before we make observations, let's map the interactive to what we are trying to figure out in the real world.*

Complete the table below on the board to help students map the analogy of the flashlight in the interactive to the real-life representation that they are studying. Leave this up for students to see as they work with the interactive.

✱ ATTENDING TO EQUITY

Universal Design for Learning: Some students may struggle with using an interactive and recording ideas on a handout at the same time. You can support *representation* and perception of the information by encouraging students to only focus on going through the interactive first and to make some general observations that they share with a partner. After the initial pass with the interactive, tell students to try out the interactive with one molecule, pause and record observations, and then move to the next molecule. Having time at the beginning to only work with the interactive will allow students to make general observations first and then record their ideas on the next pass through the interactive.

Feature of the Interactive	...is like...	Feature of the real world
flashlight		Earth after it is warmed by the sun
bundle or packet of energy coming from the flashlight		energy coming from Earth to warm the atmosphere

Predict which molecules will interact more when energy is transferred. Display **slide F** and let students make predictions. Use the graphics on the slide to help students remember that the flashlight represents a warmed Earth surface. Mention that the molecule and thickness of the atmosphere are not to scale.

Display **slide G** and say, *As you use the interactive, describe on the handout how each molecule behaves when it encounters a bundle of energy. Think about where that energy goes after the encounter. Use the questions on the slide to help you focus your work and record everything on the handout. Use the back of the page if you need more room. You may use sketches, words, or both in your descriptions.*

Use the interactive to investigate interactions of energy with molecules of the atmosphere. Make observations from the interactive together, in partners, or individually. Allow students 10 minutes to make observations of each of the molecules they have been working with. They should record their observations on the handout that they have been using, *Important Gases in the Atmosphere*, and describe carefully the way each molecule interacts with the packets of energy that come from the flashlight. Encourage them to observe what happens to the energy after it encounters the molecule. Also, if students want to tally how much energy goes through and how much goes off in another direction, encourage them to do that on their handout.✱

Listen and probe student ideas. Use this opportunity to gauge how students are making sense of molecular behavior when the molecules encounter energy. Probe their ideas to understand what they are thinking and how they are reasoning with this new information.

Suggested prompts	Sample student responses	Follow-up questions
What are you seeing with the interactive?	The energy bundles don't seem to do anything to some of the gases. It goes straight through.	*Which ones? Why do you think these gases are not affected?* *What happens to the energy? Where does it go next?*
	Some molecules really move and vibrate when the bundle of energy hits them.	*Which ones? Why do you think these molecules are the ones that really move and vibrate?* *What happens to the energy after it makes the molecule move and vibrate? Where does this energy go next?*

4 · DISCUSS OBSERVATIONS FROM THE INTERACTIVE

8 min

MATERIALS: None

Share observations of molecule movement. Display **slide H**. Ask, *What did you notice about these molecules when energy is transferred to the molecule? Describe how those molecules behave and what happens to the energy.*

[page-beak]
Listen for students to share these ideas:

- In some molecules, the energy went straight through them.
- In some molecules, the energy seemed to get absorbed or stopped but then shot out in other directions.
- Some molecules can move more than others, or wiggle, because the atoms in the molecule can move.
- These molecules are also the ones that vibrate when energy moves to them. (from interactive)
- Some energy seems to be coming off of the ones that vibrate in a lot of different directions.

Revise the two-column chart on the board to note how the molecules interacted with energy. Ask students to note which molecules send energy in all directions and which let it pass through. Record using a checkmark or other symbol in a different color. Their answers should correspond to the ones shown in the chart.

Molecules that wiggle a lot	**Molecules that <u>DO NOT</u> wiggle much**	✓ Energy went out in all directions
(H_2O✓, CO_2✓, CH_4✓)	(N_2, H_2)	

Wrap up class and preview day 2. Say, *Tomorrow we will continue to make sense of what you have figured out today about what happens to these molecules when energy is transferred to them.*

End of day 1

5 · BUILDING UNDERSTANDINGS DISCUSSION

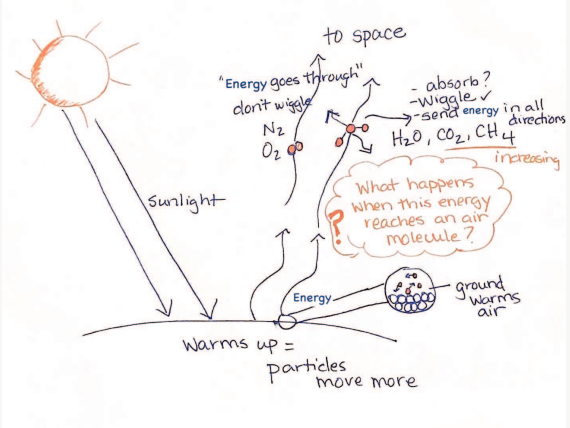
10 min

MATERIALS: science notebook

Navigate in from day 1. Display **slide I** and the chart from the previous day about which molecules move the most. Have students turn and talk with a partner about what they noticed about how the different gases that make up the atmosphere acted when energy was transferred to them. Students should note that H_2O, CO_2, and CH_4 vibrated or wiggled and moved more when energy was transferred to them. From the interactive, those molecules also released that energy in all directions, while the ones that wiggled less let energy go straight through.

Lead a Building Understandings Discussion and update model. You may want to project the interactive and have the molecular models available so that you or the students can demonstrate throughout this discussion. Say, *We have figured out several things about these gases. Let's make a list of ideas that we have figured out. Can someone offer an idea that you have figured out about gas molecules in our atmosphere?* Use the dialogue below to guide your discussion.

Display **slide J**. As student share, record their ideas on the model.✱



✱ SUPPORTING STUDENTS IN DEVELOPING AND USING CAUSE AND EFFECT

Students use evidence gathered through multiple means to figure out that GHG molecules absorb, vibrate, and release energy. It is important to emphasize this mechanism as what *causes* the atmosphere to warm. Understanding that GHGs are the cause is an important part of understanding the problem of global warming and climate change, as well as understanding and developing solutions to mitigate these problems.

KEY IDEAS

Purpose of this discussion: Use evidence from the data in Lesson 6, the molecular model investigation, and the interactive to reason that the gases that are increasing in our atmosphere are the same gases that absorb and release energy in the atmosphere. This sets students up to wonder if this is causing rising temperatures.

Listen for these ideas:

- CO_2 and CH_4 are increasing in our atmosphere.
- H_2O, CO_2, and CH_4 are able to move more than N_2 and O_2.
- H_2O, CO_2, and CH_4 vibrate or wiggle when energy is transferred to them.
- N_2 and O_2 do not vibrate or wiggle when energy is transferred to them. The energy goes through the molecule into space.
- H_2O, CO_2, and CH_4 release the energy after they vibrate. The released energy leaves the molecule in all directions. They let some go through to space.
- This method of transferring energy is different from convection and conduction because matter is not moving to transfer the energy.

Suggested prompt	Sample student response
What happened when energy reached the molecules?	Some went through. It caused some to vibrate and those that vibrated shot it out in random directions.
OK, so for the ones that the energy went straight through, where does it go next?	It just keeps going out to space.
It seems that other gases started vibrating when the energy reached them. What happened?	Not all the energy did that. Some went straight through. But sometimes it caused them to shake or wiggle.
Then what? Where did the energy go?	It shot back out in all directions.
How did what you noticed about the molecules in the simulation compare to how we grouped the molecules after observing the marshmallow models in the last lesson?	Give students 1-2 minutes to discuss in pairs and then share their ideas with the whole group.

Bring students back together and document on the chart and/or model which gases are increasing and which are staying stable and how that maps to the gases that wiggle.

Molecules that wiggle a lot	Molecules that <u>DO NOT</u> wiggle much
(H_2O✓—, CO_2✓↑, CH_4✓↑)	(N_2—, H_2—)

✓ Energy causes vibration
↑ Amounts increasing
— Amounts staying mostly the same

Set the purpose for getting more information. Say, *It seems that some of these gases are special—the atoms in the molecule are able to wiggle—and we know that the amount of motion is related to the amount of energy the molecule has. They seem to do different things with energy. Some let the energy go straight through and some send it in all directions. Let's gather more information to see how this relates to our questions about rising temperatures and whether getting more of these gases could be related.*

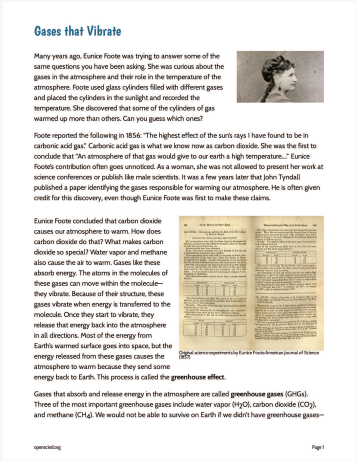
6 · READING GASES THAT VIBRATE

12 min

MATERIALS: *Gases that Vibrate*, highlighter

Distribute the reading (*Gases that Vibrate*). Display **slide K** and pass out 1 copy of the reading to each student. There are two versions of the reading: The handout version is for printing and for students to write on and attach to their notebooks, and a second copy is included in the reading section of the Student Edition.✱
Review the procedures for close reading. Remind students of their purpose by saying, *As you read, think about how these gases relate to temperatures and whether having more of them matters.*

Allow students 10 minutes to read the article.


Gases that Vibrate

Many years ago, Eunice Foote was trying to answer some of the same questions you have been asking. She was curious about the gases in the atmosphere and their role in the temperature of the atmosphere. Foote used glass cylinders filled with different gases and placed the cylinders in the sunlight and recorded the temperature. She discovered that some of the cylinders of gas warmed up more than others. Can you guess which ones?

Foote reported the following in 1856: "The highest effect of the sun's rays I have found to be in carbonic acid gas." Carbonic acid gas is what we know now as carbon dioxide. She was the first to conclude that "An atmosphere of that gas would give to our earth a high temperature..." Eunice Foote's contribution often goes unnoticed. As a woman, she was not allowed to present her work at science conferences or publish like male scientists. It was a few years later that John Tyndall published a paper identifying the gases responsible for warming our atmosphere. He is often given credit for this discovery, even though Eunice Foote was first to make these claims.

Eunice Foote concluded that carbon dioxide causes our atmosphere to warm. How does carbon dioxide do that? What makes carbon dioxide so special? Water vapor and methane also cause the air to warm. Gases like these absorb energy. The atoms in the molecules of these gases can move within the molecule—they vibrate. Because of their structure, these gases vibrate when energy is transferred to the molecule. Once they start to vibrate, they release that energy back into the atmosphere in all directions. Most of the energy from Earth's warmed surface goes into space, but the energy released from these gases causes the atmosphere to warm because they send some energy back to Earth. This process is called the **greenhouse effect**.

Gases that absorb and release energy in the atmosphere are called **greenhouse gases** (GHGs). Three of the most important greenhouse gases include water vapor (H_2O), carbon dioxide (CO_2), and methane (CH_4). We would not be able to survive on Earth if we didn't have greenhouse gases—

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✱ ATTENDING TO EQUITY

Supporting Universal Design for Learning: This is informational text. For some students, such as Emerging Multilingual Learners or students who need reading support, creating an audio recording as an alternate *representation* of this text that these students can listen to as they follow along on the reading can help students access the text.

ALTERNATE ACTIVITY

Extension Opportunity: Students who have clearly mastered the content and do not need the reading to solidify the science ideas in the article, may benefit from this extension opportunity. For these students, direct them to the original Phet simulation at: https://phet.colorado.edu/sims/html/molecules-and-light/latest/molecules-and-light_en.html. This version of the interactive has additional information that accelerated students will enjoy exploring. Encourage students to begin with the Light Spectrum Diagram by clicking on the button at the bottom right of the interactive and then study the diagram. Students can explore the effect of different energies of light on several different molecules of gas in our atmosphere--many more than were in the interactive they previously explored. Encourage these students to ask questions about the interactive and then research to find the answers. Example questions they may explore are:

- Why are microwave, infrared, and ultraviolet all called light?
- Why is light represented as a bundle of energy rather than a wave?
- Why do the different kinds of light cause the molecules to behave differently?

The content the students will explore in this extension is beyond middle school standards. However, some students that are curious or ready to learn more will benefit from this challenge.

7 · SUMMARIZE AND UPDATE PROGRESS TRACKER

20 min

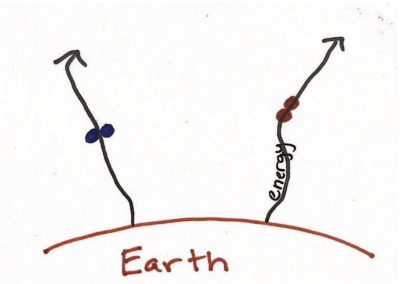
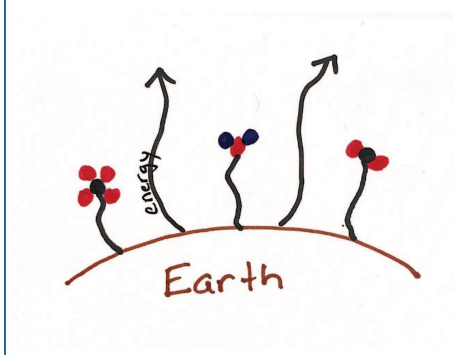
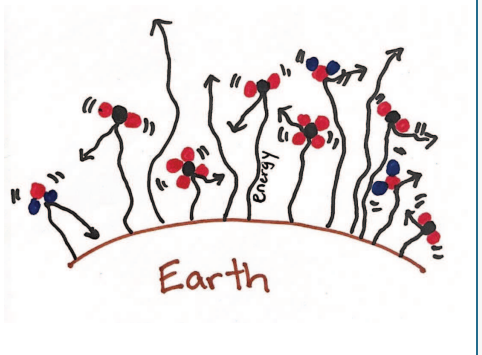
MATERIALS: science notebook, colored pencils, Model Ideas list, markers

Summarize as a class the important ideas from the reading. Display **slide L**. Ask students to share new ideas they learned from the reading and from the lesson. Say, *We have figured out a lot about these gases in our atmosphere and how the atmosphere is getting warmer. Let's make a list of big ideas from this lesson that we think are important for answering the lesson question—Are changes in carbon dioxide and methane related to or causing temperatures to increase?—and explaining how this happens.*

Some important ideas may include:

- A woman first described carbon dioxide gas as contributing to rising air temperatures.
- Carbon dioxide, water vapor, and methane are all important greenhouse gases.
- Energy from Earth does not make N_2 and O_2 vibrate (see diagram below).
- Energy from Earth is absorbed by greenhouse gases in the atmosphere (see diagram below).
- When a GHG molecule absorbs energy, it vibrates and releases that energy into the atmosphere (see diagram below).
- We do not have to worry about H_2O increasing in the atmosphere because precipitation will take care of it.
- Because of their ability to absorb and release energy, GHGs cause our atmosphere to be warm enough for life.

As students share their ideas, update your existing model to show new ideas about how these gases connect to atmospheric temperature.

Energy from Earth does not make N_2 and O_2 vibrate and the energy goes straight through to space.	Some energy from Earth is absorbed by greenhouse gases in the atmosphere.	When a GHG molecule absorbs energy, it vibrates and releases that energy into the atmosphere in all directions. This warms up the air.
		

Record Key Model Ideas. As students share, start summarizing important ideas and add to the Model Idea list. List only the ideas that students agree on from this discussion. Some ideas may include:

- GHGs are gas molecules in the atmosphere that absorb, vibrate, and release energy back into the atmosphere. This keeps Earth at a livable temperature.
- As the amount of GHGs increase in our atmosphere, they *cause* the atmosphere to get warmer.
- More GHGs = warmer temperatures; less GHGs = cooler temperatures.

Emphasize the proportional relationship between GHGs and temperature when adding model ideas. Take a moment to write this sentence in your notebooks: As GHGs in the atmosphere go _____, temperature goes _____. Have students individually complete this sentence to show their understanding of the proportional relationship between GHGs and temperature. Use the dialogue below to help guide the discussion once students have had a chance to complete the sentence on their own.

Model Ideas List

- Some gases have not really changed over time, but some show an unusual increase.
- Carbon dioxide and methane are a small percent of the atmosphere but are increasing at a high rate.
- GHGs absorb, vibrate, and release energy back into the atmosphere.
- As the amount of GHGs increase in our atmosphere, they cause the atmosphere to get warmer.

Suggested prompts	Sample student responses
Can we think of a rule we can use that helps us know how the amount of GHGs affects temperatures?	GHGs make our atmosphere warm.
Can you use your idea to make a rule for what happens to temperatures when the amount of GHG changes? Use your completed sentence to help you.	If GHGs go up, the temperature will go up!
And, is there a relationship when GHGs go down or decrease? Can you state that in a rule?	If GHGs decrease, the temperature will go down.
Those rules seem to be important relationships that we should add to our model ideas list.	

Word Wall. Add "greenhouse gas" to the class Word Wall using a definition that makes sense to students.

ADDITIONAL GUIDANCE

The idea that GHGs are good or bad may come up in this discussion, and it is an important idea for students to consider. If students do not bring it up, ask, *Are GHGs good or bad?* Some students may say that they are bad because they are causing our atmosphere to get warmer. Others may recognize that GHGs are what keep our planet at a temperature suitable for life. Students should see that we must have GHGs to live on Earth but that too much GHG in the atmosphere is causing it to warm more than normal and that warming is causing problems.

ASSESSMENT OPPORTUNITY

Building towards: 8.A Develop a model to describe how greenhouse gas molecules respond to energy transfer from Earth to the atmosphere and cause the temperatures to rise.

What to look/listen for: As a formative assessment opportunity, listen for the key ideas listed below to assess the class's understanding of the important ideas they have figured out through using molecular models, working with the interactive, and the reading.
Key ideas:

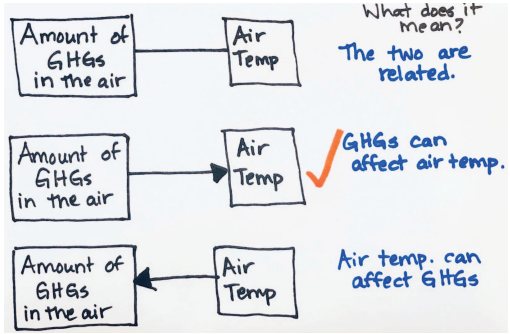
- The amount of GHGs in the atmosphere *causes* temperature changes in the atmosphere.
- Increasing GHGs *cause* atmospheric temperatures to increase.
- Decreasing GHGs *cause* atmospheric temperatures to decrease.

Students should understand that the two are not just related but that they now have a causal mechanism to explain the temperature rise.

What to do: Listen for accurate ideas, as well as inaccurate or incomplete ideas, when students are sharing. Try to hear from as many students in your class as possible. If you hear an inaccurate or incomplete idea, ask the student to explain their thinking, cite evidence from the interactive or reading, or challenge them to add details to push their thinking forward or make them realize inaccuracies. Ask students that are not sharing to paraphrase accurate ideas that another student has shared.

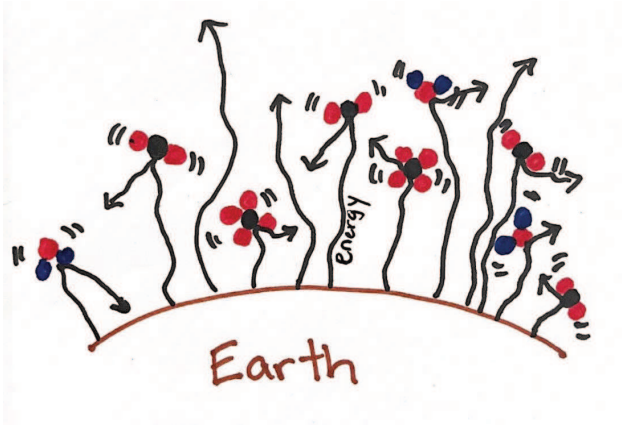
You will have an additional opportunity for assessment as students individually update their Progress Tracker in the following activity.

If students struggle to understand the causal mechanism for temperature change, facilitate a deeper discussion to explain the relationship between GHGs in the atmosphere and atmospheric air temperature. Write "Amount of GHGs in the air" and "Air temperature" on the board, drawing a box around each one. Have the class share ways to represent the connection between the two boxes. For example, if they simply draw a line between the two, what does this communicate about how the two are related? If they use an arrow, what are the ways they can draw the arrow, and if they draw the arrow in this direction, what would that mean? Ask students to use their evidence from their investigations to decide the best way to represent the relationship between the two, indicated with an orange checkmark in the example image.



Update Progress Tracker with these ideas and a sketch to help explain this process. Display **slide M**. Say, *These are some pretty complex ideas. I think a model would be useful to help explain this process. Do some of you have some ideas of how to represent this process of energy transfer to greenhouse gases and the atmosphere?* Allow a few students to share ideas of what they will include in their models and how they are thinking about representing important features. Encourage students to use the sketches that the class agreed on to represent parts of their models.

Continue by saying, *You may use words or sketches (or both!) to answer the lesson question. Use the model ideas you have written down to model how GHGs warm the atmosphere. Then explain how increasing GHGs are making us warmer. You can do this in words, sketches, or you may want to add words to your initial model of how GHGs warm the atmosphere.* Example student responses are shown below.

Question	What I figured out in words/pictures
Are changes in carbon dioxide and methane related to or causing temperatures to increase?	• *GHGs are gas molecules in the atmosphere that absorb, vibrate, and release energy back into the atmosphere. This keeps Earth at a livable temperature.* • *As the amount of GHGs increases in our atmosphere, they cause the atmosphere to get warmer.* 

ASSESSMENT OPPORTUNITY

Building towards: 8.A Develop a model to describe how greenhouse gas molecules respond to energy transfer from Earth to the atmosphere and cause the temperatures to rise.

What to look/listen for: Review students' Progress Trackers. Look for the model ideas that are listed above. Students should represent in a model that GHGs absorb, vibrate, and release energy into the atmosphere. Look for labels or pictures that connect this released energy to the cause of atmospheric warming. Students should use words, pictures, or both to indicate that increasing amounts of GHG in the atmosphere is what is causing our atmosphere to get warmer.

What to do: Provide quiet time for students to work individually on their Progress Trackers. Monitor their work, and, if students are struggling with representing important ideas in their models, call attention to the model ideas and sketches you did with the class during the discussion. They can use these as a starting point for their models. Collect student notebooks or Progress Trackers before they attach them to their notebooks so you can review them.

Allow students time to update their Progress Trackers. Give students quiet time to update their Progress Trackers but stop them 2 minutes before class is over so that you can take them through the navigation routine.

8 · NAVIGATION

3 min

MATERIALS: *Concentration of Gases in the Atmosphere Over Time* from previous lesson, Driving Question Board, Ideas for Investigations Board

Summarize the lesson. Display **slide N**. Say, *When we started this lesson, we were wondering if the gases that were increasing in the atmosphere were related to temperature changes. We know now that these are called greenhouse gases. And, we know that these gases are causing the temperature to rise.*

Navigate to the next lesson. Say, *Look back at the handout, Concentration of Gases in the Atmosphere Over Time, from the last lesson and look at the last two gases in the handout, carbon dioxide and methane. These are two greenhouse gases we learned about. What did we learn about how the amounts of these gases were changing in the atmosphere?* Students should recall that they indicated that the amounts of these gases were increasing.

Ask students to consider if this increase is normal or not by asking students what new questions the increase in gases they have identified raises for them. Example prompts and responses are below.

Suggested prompt	Sample student response
We just learned that the gases were increasing. What new questions does this raise for you?	Is this increase normal? Has this increase happened before?
What data would we need to look at to determine if this is normal or not, or if it has happened before?	We need to look back at long-term data like we did with the droughts and floods. We used long-term data to help us figure out that the trend was not normal for our case sites.

Say, *OK, it sounds like we will have to look at that longer term data that you requested to determine if this is normal, or has happened before. Maybe we can determine if this is normal or not in the next class.*

Additional Lesson 8 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA

CCSS.ELA-Literacy.RST.6-8.2 Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

CCSS.ELA-Literacy.RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

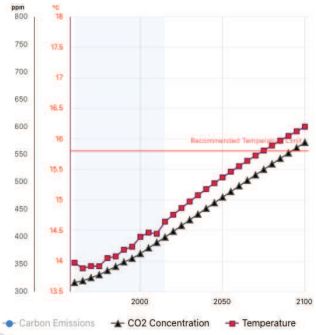
CCSS.ELA-Literacy.RST.6-8.10 By the end of grade 8, read and comprehend science/technical texts in the grades 6-8 text complexity band independently and proficiently.

Students gather information from written text and synthesize that information with what they learned through working with molecular models and an interactive. Students must determine the central ideas they can summarize from the reading and across multiple sources to add to the class' Model Ideas list and their own Progress Tracker.

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN MATH

CCSS.Math.Content.7.RP.A.2: Recognize and represent proportional relationships between quantities.

In this lesson,students will engage in developing a conceptual understanding of proportional relationships between greenhouse gases (GHGs) and atmospheric air temperature. This will serve as foundational knowledge for students to work with in subsequent lessons, particularly as they make predictions about future projections of GHGs concentrations and air temperature in Lesson 12 (shown to the right). While students do not graph the relationship in this lesson, they will be coming to consensus on the foundational ideas that GHGs are proportionally related to temperature and that the relationship is causal. This will support students in making sense of solutions that involve cutting carbon dioxide emissions and how cuts to emissions impact the concentration of CO_2 in the atmosphere and, in turn, air temperature.



Working toward this graphing activity in Lesson 12 UCAR Center for Science Education

LESSON 9: Are the changes in the amount of CO2 in the atmosphere part of normal cycles that Earth goes through?

PREVIOUS LESSON

We used molecular models, an interactive, and a reading to figure out that GHG molecules absorb energy, vibrate, and release that energy, which results in warming the atmosphere. We conclude that, since GHGs are increasing in the atmosphere, this is what is causing temperatures to get warmer. We wonder if this increase in GHGs is normal and just a natural cycle.

THIS LESSON

INVESTIGATION

1 day

Nico Grütter

We carry out an investigation to determine if gas can be trapped in ice. When we figure out that it can, we find out more about how scientists use ice core samples from locations on Earth that have very old ice to determine the amounts of carbon dioxide in the air over time. We focus on carbon dioxide because it has the highest concentration of all GHGs. We examine carbon dioxide data from ice cores dating back 800,000 years and notice that carbon dioxide naturally fluctuates up and down, but the current levels are outside of the normal high range for carbon dioxide. This makes us wonder what is different today compared to the past.

NEXT LESSON

We will zoom into the last 200 years of Earth's history to understand what might have led to the rapid increase in atmospheric CO2. We will watch a visualization and read about key innovations in human history that transformed the types of energy used to power our communities. We will figure out that, as population grows and energy consumption rises, human activity contributes to the release of CO2. We will wonder how using fossil fuels to power homes and cars is related to rising CO2 levels. We will burn a sample, and as the fuel loses mass, CO2 and water vapor will be produced. We will examine fossil fuel molecules and identify that they are made mostly from carbon, hydrogen, and oxygen, which will explain how burning fossil fuels causes increased CO2 in the atmosphere.

BUILDING TOWARD NGSS

MS-ESS3-1, MS-ESS3-3, MS-ESS3-4, MS-ESS3-5, MS-ETS1-2

WHAT STUDENTS WILL DO

9.A Analyze and interpret data on graphs of carbon dioxide levels collected from ice cores to collect evidence of whether the changes in these levels are cyclical in nature and a normal occurrence or are changing at an non-normal rate.

WHAT STUDENTS WILL FIGURE OUT

- CO_2 levels over the last 100 years have been rising consistently.
- CO_2 levels are higher than at any time in the past normal cycles and seem to be increasing really fast.
- When we analyze ice core data from hundreds of thousands of years, we find that there are normal cycles, but the last 100 years are not following the normal cycle.

Lesson 9 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	3 min		**NAVIGATION** Recall that one cause of rising temperatures is an increase in carbon dioxide and predict normalcy of this rise.	A	
2	5 min		**PREDICT PAST CO2 LEVELS** Brainstorm what carbon dioxide levels might have been in the long ago past.	B-C	
3	5 min		**ANALYZE ICE SAMPLES** Examine ice cubes made from non-carbonated water and carbonated water.	D	ice cube, paper plate or small cup, magnifying glass (optional)
4	16 min		**ANALYZING GASES TRAPPED IN ICE** We use a CO_2 detector to test ice made with tap water and ice made with carbonated water to determine if gas is trapped in ice and which has more carbon dioxide.	E-G	Pouring Carbonated Water video (optional), computer and projector, 2 1-gallon plastic baggies, 2 small condiment containers with lids, clear bottle of carbonated water (optional), cup to pour the carbonated water into (optional), ice cubes made from carbonated water, ice cubes made from tap water, clear plastic cups or other small plastic container
5	16 min		**EXAMINE ICE CORE DATA** We review a StoryMap about scientists who collect ice core data and examine the data they have produced through their experiments.	H	https://arcg.is/OD0PH, computer and projector

End of day 1

Lesson 9 • Materials List

	per student	per group	per class
Lesson materials	• science notebook • ice cube • paper plate or small cup • magnifying glass (optional)		• Pouring Carbonated Water video (optional) • computer and projector • 2 1-gallon plastic baggies • 2 small condiment containers with lids • clear bottle of carbonated water (optional) • cup to pour the carbonated water into (optional) • ice cubes made from carbonated water • ice cubes made from tap water • clear plastic cups or other small plastic container • https://arcg.is/OD0PH

Materials preparation (45 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

1. If possible, secure ice cubes made with regular water to use in the first part of the lesson. Ideally you would have one ice cube per student, but at the least, it would work to have one ice cube per table group. Students are going to make observations of the ice and what they can see. You will also want to have a small clear container, like a small plastic cup or condiment cup, to place the ice cube in for students to use as they make observations of the ice cubes. This will help to prevent the ice cube from melting too fast.
2. Prior to this lesson you will want to use two ice cube trays to freeze carbonated water in one ice cube tray and non-carbonated water in the second ice cube tray. These ice cubes will be used during the second part of this lesson in a Scientists Circle setting. You will want at least 2 trays per class, but if you can make more than 2 trays per class, it will allow students to make close-up observations of the ice cubes.
3. Be prepared to play *Pouring Carbonated Water* from https://youtu.be/rNPIGQK0C4g.
4. If you have access to computers for students in groups of 2-3, practice opening *Using Ice Cores to Study Carbon Dioxide* from https://arcg.is/OD0PH and review it so that you know how to help students.
    a. If you do not have access to computers, consider the following options or a combination of them:
        i. Have students use personal phones to view the StoryMap.
        ii. Project the StoryMap for the class to view together.
        iii. Use hardcopies of *Carbon Dioxide Levels Over Time* so that students can look at the graphs presented in the StoryMap.
        iv. Use following videos:
            1. Science in Antarctica!: https://youtu.be/216ocSEUOhY
            2. Drilling Ice Cores: https://youtu.be/L_n27lBV2Bg
            3. Using Ice Cores: https://youtu.be/KfDgMfH7jWY
5. Consider the optional extension activity using the Tuva platform for students to create and analyze their own CO_2 graphs. Use *Extension Opportunity with Tuva* for more guidance and swap out the StoryMap link by using https://arcg.is/18SHfO2 instead. The Tuva interactive data is embedded within this StoryMap.

The night before or morning of class, set up the investigation as described on *Lab Instructions for Comparing Frozen Carbonated with Non-Carbonated Water*. You will want this available to show the class during the Scientists Circle after they design a way to capture gas bubbles that have been trapped in frozen water.

Lesson 9 • Where We Are Going and NOT Going

Where We Are Going

In the previous lesson, we were left wondering if greenhouse gases, like carbon dioxide, naturally go up and down, causing Earth to have colder and warmer periods as part of a natural cycle. We will reason out how scientists could use ice layers to measure gas composition in the atmosphere in the past (DCI). After analyzing some ice cubes made from carbonated and non-carbonated water and noticing that there are some gas bubbles in the ice cube, as well as crystals and different shades of white, students will use a carbon dioxide detector to test the gas that is released when the ice is melted in a baggie. We find that the ice cubes with carbonated water do release carbon dioxide. We view a StoryMap with video clips and text describing what scientists in the field do to test the gases that are trapped in ice that has been on Earth for many years. We analyze the data these scientists have collected (SEP: Analyzing and Interpreting Data) to determine the composition of the air at different times in history, finding that the level of carbon dioxide has been increasing at a rate that is not normal compared to the last 800,000 years (CCC: Stability and Change).

Where We Are NOT Going

Though students will be figuring some things out about processes and procedures scientists use to collect data about the past using ice core data, we will not get into the mechanism behind carbon-14 dating and how scientists know the age of the ice layers.

LEARNING PLAN for LESSON 9

1 · NAVIGATION

3 min

MATERIALS: science notebook

Revisit what we figured out about the gases that make up Earth's atmosphere and how they are related to the temperature. Display **slide A** and direct students to review their Progress Tracker as needed. Say, *In our efforts to figure out what could be causing temperatures to be rising on Earth, we figured out some things about the gases in the atmosphere and how they affect the temperature on Earth.*

Suggested prompts	Sample student responses
What did we figure out about the gases in the atmosphere?	There are different gases that make up the atmosphere, like oxygen, nitrogen, carbon dioxide and water vapor. Some of these gases are called greenhouse gases because they help to keep the temperature on Earth controlled so that it doesn't get too hot or too cold.
How do greenhouse gases affect the temperature on Earth?	The greenhouse gases absorb energy, and when this happens, the energy of the gas molecule increases. Then it gives off energy, and when this energy is directed back at Earth, it causes the temperature of the atmosphere to increase. They are proportional—when gases increase, so does temperature. When the gases decrease, so does the temperature.
And which gas(es) did we find are increasing?	Carbon dioxide and methane.
Which of these gases did we figure out affects temperature on Earth most?	Carbon dioxide.

Say, *Right, we saw in the last couple of lessons that carbon dioxide amounts in the atmosphere are increasing and now we have figured out some ideas about how carbon dioxide is related to the temperature on Earth.*

2 · PREDICT PAST CO2 LEVELS

5 min

MATERIALS: None

Facilitate a discussion on predictions about whether the increase in carbon dioxide is a normal trend. Say, *So, if carbon dioxide helps to regulate the temperature on Earth and we see that it has been increasing over the last 100 years, do you think this is part of a normal process on Earth?*

Suggested prompts	Sample student responses
If we could look at data about carbon dioxide levels in the atmosphere far back in time, what do you think we would see? Has it just continued to increase and if we look far back in time the levels would be really low?	Not sure... I don't think the levels could be too low if it helps to keep the temperature on Earth regulated or consistent like we figured out in the last lesson.
OK, are there other times you can think of in history that could be a result of changes in greenhouse gases, specifically carbon dioxide?	Maybe ice ages because I think the temperature was colder then. Yeah...or maybe during the dinosaur times it might be different than now because I think it might have been warmer then.

Say, *In earlier units, like the Everest Unit, we learned how scientists can figure out a lot about how some things have changed on Earth through analyzing rock layers. Rocks aren't the only type of layers they can use to find out what Earth was like long ago. Wherever there is ice or snow year-round, scientists have found that they can look at layers in the snowfall or ice crystals that have fallen in these places to get more clues about what Earth was like at different periods of time.*

Consider where layers of snow and ice are located. Display **slide B**. Brainstorm with a partner: *Where could you go on Earth today to find snow or ice that lasts from one year to the next?* Ask a few students to share their ideas. Some possible student responses could include the North or South Pole, Antarctica, Alaska, or mountains like the Himalayas.

Say, *The poles are one place that has ice and/or snow year-round, and we did hear about ice in Alaska, too. Some high elevation places, like Everest, are other places where there is snow or ice year-round.*

Consider types of data from snow or ice. Display **slide C**. Say, *Take a moment to think about this question: if you could sample layers of ice or snow from one or more of these areas on Earth, what do you think you might find in these layers that could provide data about what Earth was like long ago?*

3 · ANALYZE ICE SAMPLES

5 min

MATERIALS: ice cube, paper plate or small cup, magnifying glass (optional)

Make observations of ice cubes. Display **slide D**. Say, *In order to begin thinking about whether we could figure anything out from looking at ice samples, I have some ice cubes for you to observe. This is one single ice cube made from tap water. What are some things you notice?*

Pass out an ice cube in a small cup or on a paper plate, per student, or per table if you do not have enough per student. Provide magnifying glasses if available. Let students share what they notice. Some possible observations they may share:

- There are different shades of color in the ice cube. Some parts are clear and some are more whitish.
- There are some bubbles in the ice cube.
- There are some crystal-looking parts or pieces.
- It is melting in the cup (or on the plate).
- The shape changes when it melts, and there are less bubbles.

Say, *This is a key thing that scientists discovered—that it looks like there is more than just water in the ice.*

Share the following ideas for what scientists have noticed and tested with the ice cores:

- They noticed that it appears water traps gas when it freezes, and we can see that as these bubbles in the ice cube.
- Over time old snow that doesn't melt gets compressed into ice under new snow. This process traps gas, too.
- This led these scientists to melt the ice so that the gas in the bubbles could be released and captured.
- They then tested the gas to see what type(s) and amounts were in the air at the time that this ice or snow was formed.
- These tests provide scientists with the composition of gases in the atmosphere at the time the snow fell or ice formed.

Ask, *Since we are concerned mostly about carbon dioxide right now, what are some ways we know of to test for carbon dioxide gas?*

Possible student responses:

- We could test the flammability because from *Bath Bombs Unit*, we know that carbon dioxide is not flammable.
- We could use the carbon dioxide probe we used in *Maple Syrup Unit* on any gas we could collect.
- We could use BTB like we used in *Inside Our Bodies Unit* to test for carbon dioxide presence.

Say, *Wow! We have a lot of tools we could use to test a gas for carbon dioxide.*

ADDITIONAL GUIDANCE

This next section is written assuming students have done previous 7th grade OpenSciEd units during which they figured out different ways to identify substances. In *OpenSciEd Unit 7.1: How can we make something new that was not there before? (Bath Bombs Unit)*, they figured out that gases have properties of flammability and that carbon dioxide is non-flammable. In *OpenSciEd Unit 7.3: How do things inside our bodies work together to make us feel the way we do? (Inside Our Bodies Unit)*, they used a Bromothymol Blue (BTB) as an indicator for carbon dioxide, and in *OpenSciEd Unit 7.4: Where does food come from, and where does it go next? (Maple Syrup Unit)*, they used both a carbon dioxide detector and BTB to find evidence of carbon dioxide when investigating how plants make food. If your students have not participated in these units, or at least in one of the units that uses the CO_2 detector, you may need to share with them that this is an indicator used to detect evidence of carbon dioxide.

4 · ANALYZING GASES TRAPPED IN ICE

16 min

MATERIALS: Pouring Carbonated Water video (optional), computer and projector, 2 1-gallon plastic baggies, 2 small condiment containers with lids, clear bottle of carbonated water (optional), cup to pour the carbonated water into (optional), ice cubes made from carbonated water, ice cubes made from tap water, clear plastic cups or other small plastic container

Display slide E. Say, *Besides the ice cubes I shared with you that were made from tap, or non-carbonated water, I have ice cubes made from carbonated water. What do we know about carbonated water, like this sparkling water?* You could show the *Pouring Carbonated Water* video from https://youtu.be/rNPlGQK0C4g. Or if you have some, it could be helpful to pass around a bottle of carbonated water for students to make observations. In addition, pouring out carbonated water into a cup will allow students to see the bubbles rising to the top. Say, *What do you notice? How is carbonated water different from tap water?*

Sample student responses:

- *It has a gas added to it that causes the bubbles.*
- *I think it is carbon dioxide that is added to it.*
- *It is called carbonated water, which seems like that means there is carbon-related something added to it.*
- *It has a lot of bubbles!*
- *Yeah...it is like soda pop that has carbonation too and has bubbles.*

✱ ATTENDING TO EQUITY

By giving students an opportunity to address how to investigate bubbles in the ice, you are not only providing them with an opportunity to connect to prior knowledge and experiences, but are also legitimizing their ideas as relevant sources for facilitating classroom inquiry.

ADDITIONAL GUIDANCE

See the Teacher Prep section for what needs to be prepared before this lesson. See *Lab Instructions for Comparing Frozen Carbonated with Non-Carbonated Water* for directions on how to set up the investigation with ice cubes and the carbon dioxide detector. Watch *Testing Ice for Gases* video as an example of how to run this investigation: https://youtu.be/PQ3GNMTi_-4.

In addition, if you do not have a carbon dioxide detector, but do have BTB (Bromothymol blue),you can run the investigation using the ice cubes with BTB. Follow instructions on the second half of *Lab Instructions for Comparing Frozen Carbonated with Non-Carbonated Water*. Watch *Using BTB to Test Ice* video as an example of how to run this investigation: https://youtu.be/fogyXRAsdDE.

Gather in a Scientists Circle. Make sure all students can see the demonstration in the center of the circle. Plug in and turn on the heating pad so that it can warm up while you facilitate this next section. Be sure the heating pad is in a place that students can gather around; ideally, it would be in the center of this circle. Display **slide F**. Say, *So, I hear you saying that carbonated water has carbon dioxide bubbles added.* Pass around a couple of the ice cubes in clear plastic cups that you have made using carbonated water. Ask students to turn and talk with a partner. Ask, *What are some things you notice? How is this ice cube different from the other one made from non-carbonated water? How does it compare to what you saw with the carbonated water?* Students should say that this one looks whiter, or milky-er and has a lot of bubbles.

Say, *Let's think through how scientists might design an investigation to determine what gas is in the bubbles they find in ice samples.* ✱

Suggested prompts	Sample student responses
I hear you all saying that carbonated water has carbon dioxide added to it. So, if we wanted to be able to determine that the gas in the bubbles in these ice cubes is carbon dioxide, how might we capture the gas bubbles?	We would have to melt the ice cube so that the gas could be released. Yeah and we probably need to do this in a closed container so that we could capture the gas.
I have a carbon dioxide detector that we could use with these ice cubes to figure out if we can find evidence of carbon dioxide gas. Does anyone remember how we used this detector in the past to help us do that?	Yeah, in the Maple Syrup Unit we used this detector when we were trying to figure out what plants do at night and during the day. The detector shows the readings of carbon dioxide and humidity.
Right, so how could we use this detector if we wanted to test the gas that is in the bubbles in these ice cubes?	We could put the ice cube in a baggie with the carbon dioxide detector. Then we can watch what happens to the readings on the detector as the ice cube melts.

Say, *Let's set this up. I have the CO_2 detector here, 2 baggies, and ice cubes.*

Make predictions about what will happen in each of the baggies. Display **slide G**. Say, *Share with an elbow partner your predictions about what you think we will see happen to the readings of CO_2 on the detector in each of these baggie setups.* Have a few students share what predictions they and their partner discussed.

ADDITIONAL GUIDANCE

If your students want to use a different container than a baggie to make the closed system around the ice cube and detector and you have that container, feel free to cater this investigation to fit what your students plan. The purpose of this short class demonstration investigation is for students to see that one way we might be able to find data about the composition of carbon dioxide on Earth long ago is to use ice sample data from ice that has been around for many, many years.

Say, *It might take a while for the ice cubes to melt, so we can use a heating pad from Lesson 3 to speed up the melting process. Let's begin by putting one of the baggies with the ice cubes in it on the heating pad and place the detector inside so that we can watch what happens to the readings as the ice cubes melt.*

Use *Lab Instructions for Comparing Frozen Carbonated with Non-Carbonated Water* for guidance on the steps for this investigation. You will want to do one type of ice cube at a time so that the class can watch for any changes in the readings on the carbon dioxide detector. This will take a few minutes, so as the class watches, ask a few students to share what they notice happening. Once there is evident melting and reading fluctuations, the class can switch to collecting data for the other baggie. You do not need to wait until the ice cubes have fully melted.

ADDITIONAL GUIDANCE

Be sure to use *Lab Instructions for Comparing Frozen Carbonated with Non-Carbonated Water* for instructions on how to set up this investigation prior to this lesson so that you will be prepared with the materials and the suggested set of steps for the investigation. If your students suggest a different set of steps that would still result in them collecting data about whether gases can be trapped in ice, you are encouraged to follow their suggestions.

Present the results from the investigation that you set up ahead of time. Ask, *What are some things you notice?* Students should say:

- The readings on the detector in the baggie with the carbonated water ice cube changed a lot more than when the detector was in the baggie of the non-carbonated water ice cube.
- There is some condensation on both of the baggies.
- The readings of humidity in both baggies went up as the ice cubes melted.

Making sense of these results. Ask, *What do these results tell us? Does this support the idea that ice can trap bubbles of gas?*

Students should say yes because readings on the detector for the ice cube that was made from the carbonated water were much higher than the readings from the melted ice cubes made from non-carbonated water, which means carbon dioxide gas was trapped in there and was released when it melted.

5 · EXAMINE ICE CORE DATA

16 min

MATERIALS: https://arcg.is/OD0PH, computer and projector

ALTERNATE ACTIVITY

The main activity described for examining ice core data is based on using version 1 of the StoryMap located at https://arcg.is/OD0PH. In this StoryMap, students will only analyze the trends and patterns on provided graphs. An alternate extension has also been created.

Extension Opportunity: Rather than viewing the CO_2 graphs included in version 1 of the StoryMap, students can practice developing and interpreting these graphs using the Tuva platform embedded into version 2 of the StoryMap. This extension activity can provide students with the opportunity to develop deeper aspects of the practices of 4. Analyzing and Interpreting Data and 5. Mathematics and Computational Thinking. Specifically:

- 4.2: Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships.
- 5.1: Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends.

Use *Extension Opportunity with Tuva* for extra guidance on using Tuva. The StoryMap and interactive Tuva data set can be accessed at https://arcg.is/18SHfO2.

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING STABILITY AND CHANGE

Encourage students to use the crosscutting concept of Stability and Change as a lens for examining the Ice Core data. Circulate around to students, pressing them to notice that relatively small changes took place across approximately 800,000 years and anytime carbon dioxide levels increased, it was typically followed by a similar decrease. This represents a relatively stable system. This is in comparison to now where there is a very big increase taking place in a relatively short period of time and the change is far outside the normal range seen in earlier data.

Introduce StoryMap to students. Display **slide H**. Remind students that the question we are trying to answer is, *Are the changes in the amount of carbon dioxide in the atmosphere part of normal cycles Earth goes through?* Tell students they are going to review a StoryMap with text and videos that describe how scientists collect and use ice cores today. They will then analyze data produced by the scientists to help us answer the lesson question. Tell students to jot down their noticings from the text, videos, and graphs in their notebook, and to be prepared to share with the class. You may choose to review with students the different parts of the StoryMap that they will see. Divide students into groups of 2-3 to review the StoryMap.

ALTERNATE ACTIVITY

If you do not have access to computers or devices for students to work in groups, there are alternate ways to facilitate this activity. You could choose one option, or a combination of options.

- Have students use their personal phones or other internet-connected devices to view the StoryMap.
- Project the StoryMap for the class to view together.
- Use hardcopies of *Carbon Dioxide Levels Over Time* so that students can look at the graphs presented in the StoryMap.
- Use following videos:
    - Science in Antarctica!: https://youtu.be/216ocSEUOhY
    - Drilling Ice Cores: https://youtu.be/L_n27lBV2Bg
    - Using Ice Cores: https://youtu.be/KfDgMfH7jWY

View StoryMap in groups. Give groups 15 minutes to view the StoryMap. As students read the text and view the videos at the beginning of the StoryMap, walk around and have students share their observations and discuss any similarities and differences they noticed about what they see scientists doing and what we did in class with the ice cubes and CO_2 detector.✱

Suggested prompts	Sample student responses
What were some things you noticed from the videos that scientists do to collect data about the gases in the air in the past?	They have big long drills that dig up long ice samples. They take samples of ice, like really long ice cubes. They melt the ice samples in a vacuum to collect the gases that are trapped inside.
Was there anything from the video clips that was similar to what we did when we tested for carbon dioxide?	Yes! In one of the videos it showed different samples in different containers being tested for different gases!

ASSESSMENT OPPORTUNITY

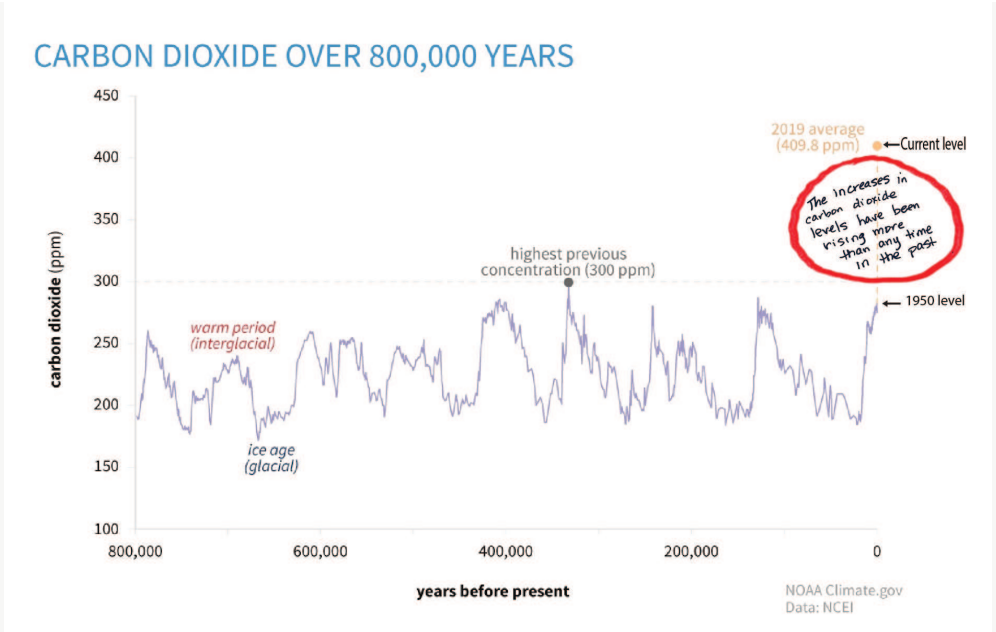
Building towards: 9.A Analyze and interpret carbon dioxide levels collected from ice core data (graphs) to collect evidence of whether the changes in these levels are cyclical in nature and a normal occurrence or are changing at an non-normal rate.

What to look/listen for:
When students are working in their groups to analyze the data, listen for them to notice that there have been normal, or cyclical, increases and decreases in the amount of carbon dioxide in the atmosphere over time, but the increase that is happening right now is not normal. Students should also notice that the first graph does show an increase in carbon dioxide since the 1950s, but the amount of increase that is represented since then in the second graph is much steeper when it is compared to 800,000 years ago. They should argue that this is another piece of data that shows this increase is not normal.

What to do: If students are struggling with comparing the two graphs, ask them questions about what is being represented on the graph by referring them back to the *x*- and *y*- axes. Then ask them questions about how the changes in the slope of the lines compare. Are they both increasing? Support them in finding where 1950 is represented on the second graph to help them figure out if the increase is something that seems like a normal occurrence.

Once students have reached the end of the StoryMap and had a few minutes to look at the graphs, say, *We looked at some data that was collected from scientists using ice core samples to find the amounts of different greenhouse gases in the atmosphere in the past. Because we said we were most concerned about figuring out changes in carbon dioxide, the graphs we looked at only included changes in carbon dioxide over time. What did you see in the data?* ✱ *Is the amount of increase in carbon dioxide that we are seeing today part of a normal cycle? Has this been happening over time?* Students should say:

- No! This is not normal!
- There have been increases and decreases in the amounts of CO_2 in the air, but never in the past have the levels been as high as today.
- CO_2 in the atmosphere increased a lot over time.



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Say, *The ice core data tells us that CO_2 levels in the atmosphere are increasing at a faster rate than normal cycles. What do you think is different now than in the past that is causing more CO_2 to be in the atmosphere?*

Listen for students to suggest:

- *more people,*
- *more pollution,*
- *burning fossil fuels,*
- *fewer trees or trees being cut down, and*
- *cities and more people "stuff."*

Tell students that in the next lesson, they will explore this question and figure out what is causing more CO_2 to be in the atmosphere.

Additional Lesson 9 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA

CCSS.ELA-LITERACY.RST.6-8.7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

Students integrate information from the ice cube observations with the information provided in text, media, and graphs in the StoryMaps to make sense of how scientists track CO_2 levels over long periods of time.

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN MATH

CCSS.MATH.CONTENT.6.SP.B.4 Display numerical data in plots on a number line, including dot plots, histograms, and box plots.

CCSS.MATH.CONTENT.6.SP.B.5 Summarize numerical data sets in relation to their context, such as by:

- **CCSS.MATH.CONTENT.6.SP.B.5.B Describing the nature of the attribute under investigation, including how it was measured and its units of measurement.**
- **CCSS.MATH.CONTENT.6.SP.B.5.C Giving quantitative measures of center (median and/or mean) and variability (interquartile range and/or mean absolute deviation), as well as describing any overall pattern and any striking deviations from the overall pattern with reference to the context in which the data were gathered.**

This lesson provides an opportunity for students to revisit mathematics standards developed in 6th grade as they analyze the CO_2 data over time. Students study the graphs closely to understand what is being measured and describe the general pattern and variability over time.

LESSON 10: What is happening in the world to cause the sharp rise in CO2?

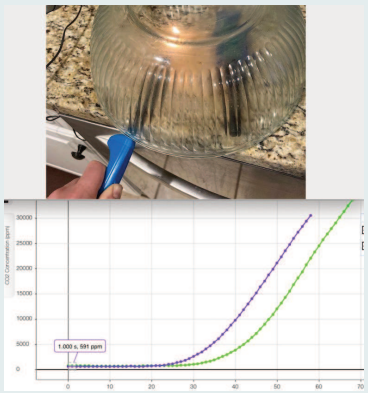
PREVIOUS LESSON

We carried out an investigation and figured out that gas can be trapped in ice. We found out about how scientists use ice core samples from locations on Earth that have very old ice to determine the amounts of carbon dioxide in the air over time. We focused on carbon dioxide and examined carbon dioxide data from ice cores dating back 800,000 years. We noticed that carbon dioxide naturally fluctuates up and down, but the current levels are outside of the normal high range for carbon dioxide.

THIS LESSON

INVESTIGATION

2 days



In this lesson, we zoom into the last 200 years of Earth's history to understand what led to a rapid increase in atmospheric CO2 outside the normal pattern for CO2 historically. We watch a visualization and read about key innovations in human history that have transformed the types of energy used to power our communities. We figure out that, as population grows and energy consumption rises, human activity contributes to the release of CO2. We wonder how using fossil fuels to power homes and cars is related to rising CO2 levels. We burn a sample, and as the fuel loses mass, CO2 and water vapor are produced. We examine fossil fuel molecules and identify that they are made mostly from carbon, hydrogen, and oxygen, which explain how burning fossil fuels causes increased CO2 in the atmosphere.

NEXT LESSON

We will modify a model of Earth's Carbon System to represent locations and movement of carbon. We will do a kinesthetic activity to simulate these processes before and after human activity. We will figure out that photosynthesis cannot take up CO2 at the same rate that burning fuels puts CO2 in the atmosphere, which creates a buildup of CO2 in the atmosphere.

BUILDING TOWARD NGSS

MS-ESS3-1, MS-ESS3-3, MS-ESS3-4, MS-ESS3-5, MS-ETS1-2

WHAT STUDENTS WILL DO

10.A Integrate qualitative and quantitative scientific information in written text with digital tools to analyze trends of atmospheric CO_2 levels, energy consumption, and human population over time to determine a correlation between human activities and CO_2 emissions.

10.B Ask questions that require sufficient and appropriate evidence as to whether CO_2 comes from combustion of fossil fuels for energy, and is causing the rising CO_2 levels in the atmosphere .

WHAT STUDENTS WILL FIGURE OUT

- Large deposits of mineral resources (such as "fossil fuels") are used to power our communities and transportation networks.
- Population growth and increasing per capita consumption of fossil fuels are correlated with rising CO_2 levels.
- Carbon dioxide and water vapor (both greenhouse gases) are products of the combustion of fossil fuels.
- The increased combustion of fossil fuels by a growing population causes an increase in CO_2 emissions as a by-product of the reaction.

Lesson 10 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	5 min		**IDENTIFY WHEN THE PROBLEM STARTED** Identify and zoom in on the approximate dates during which CO_2 rapidly increased.	A-B	Model Ideas list, markers
2	5 min		**INITIAL IDEAS ABOUT WHAT IS CAUSING THE RISE** Notice and wonder about what was happening in the world at the time when CO_2 started to increase rapidly.	C	Global CO2 Emissions video
3	18 min		**EXAMINING DATA AND INFORMATION ABOUT NEW ENERGY SOURCES** Read about and analyze data on major changes in energy sources in recent centuries.	D-E	*Powering our World*, *Examining Data Over Time*, Fuel Consumption Tuva Data Set
4	12 min		**CONNECTING ENERGY USE, POPULATION, AND PER-CAPITA CONSUMPTION** Students integrate ideas about how human population growth alongside increases in per-capita consumption led to a rapid increase of CO_2 in the atmosphere.	F-G	*Population, CO2 Levels, and Fuel Consumption*
5	3 min		**NAVIGATION** Problematize the connection between fossil fuels and CO_2 emissions.	H	
					End of day 1
6	5 min		**NAVIGATION** Elicit from students prior knowledge about molecules that provide energy.	I-K	white board or chart paper, markers
7	20 min		**BURNING FUEL DEMONSTRATION LAB** Demonstrate burning two fossil fuels and record CO_2 and water produced.	L-Q	document projector (optional), Investigating Burning Fuel
8	10 min		**EXAMINE FUEL AND FOOD MOLECULES** Examine molecular models of fuel and sugar that are printed on cards to look for similarities, differences, and the atoms that make up each molecule.	R-S	*Fuel Molecule Cards*
9	10 min		**FACILITATE A BUILDING UNDERSTANDINGS DISCUSSION** Discuss with the class the model ideas from this class. Record ideas on the Model Ideas list and update Progress Trackers.	T	Model Ideas list
					End of day 2

Lesson 10 • Materials List

	per student	per group	per class
Investigating Burning Fuel materials	• safety goggles		• Burning Fuels Set Up video • butane lighter • large clear Pyrex bowl or small aquarium • CO2 sensor • methane-based fuel gel
Lesson materials	• science notebook • *Powering our World* • *Examining Data Over Time* • *Population, CO2 Levels, and Fuel Consumption*	• *Fuel Molecule Cards*	• Model Ideas list • markers • Global CO2 Emissions video • Fuel Consumption Tuva Data Set • white board or chart paper • document projector (optional)

Materials preparation (30 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Ensure you can play the Global Emissions video at https://www.youtube.com/watch?v=6lJ2uZSRfHI.

Based on instructional time available and how much experience students have with graphing data, choose one of two options to interface with the data: 1) premade graphs focused on basic analysis and annotation only, or 2) blank graphing interface that gives students an opportunity to make the graphs themselves (but will take more time). Watch Tuva Setup Instructions at https://youtu.be/oX_ecON0F-k for more information about using Tuva in this lesson.

Test Tuva data interfaces prior to class:
- Fuel Consumption over Time
  - Pre-made graph https://www.openscied.org/global-energy-graph/
  - Blank graph at https://www.openscied.org/global-energy/
- Population, Fuel Consumption, and CO_2 over time
  - Pre-made graph at https://www.openscied.org/population-growth-graph/
  - Blank graph at https://www.openscied.org/population-growth/

This lesson also includes three possible ways to interact with the data. Based on how much instructional time is available and your classroom's access to computers, choose one option below:
- Option 1: Gather computer devices to have at least one device for 2-3 students. Students can annotate graphs within Tuva and save digital copies.
- Option 2: Project Tuva onto a whiteboard and have the whole class annotate the graphs with dry erase markers.
- Option 3: If instructional time or resources are limited, all graphs can be used in paper form and are provided as handouts if necessary.

Use the decision table on the next page to choose your own configuration, materials, and graphing level.

	Option 1: 2-3 students per device	Option 2: Teacher projecting graphs	Option 3: Using paper graphs
Pre-made graph	Students can adjust axises, annotate graphics, and analyze trends.	Students annotate graphs with dry erase markers.	Students annotate graphs with pencils.
Blank graph	Along with the above, students also make the graphs with the added challenge of choosing which variables to put on each axis.	Students, as a class, decide where to move each variable and then annotate, as a whole class, with a dry erase marker.	

Extension opportunity. There is an extension opportunity offered in this lesson to more fully address ESS3.A Natural Resources with respect to mineral resources. See *Extension Opportunity: Uneven Distribution of Fossil Fuel Resources* and **slides U-AB** for more information. Should you choose to complete this extension, navigation into the extension will use the Driving Question Board for students to add new questions to motivate further investigations. Print double-sided copies of *Fossil Fuel Formation Illustrations* for each student and enough double-sided copies of the 3 readings found in *Fossil Fuels Long Ago and Today* for student choice of what they want to read more about.

Day 2: Burning Fuel Demonstration Lab
Setup: Lay out and test the lab materials (butane lighter, CO_2 sensor, glass bowl, and methane-based fuel gel) as suggested in the *Burning Fuels Set Up* video at https://youtu.be/pBZfrkwqX2w and as outlined in *Burning Fuels Instructions*. Make sure to test the CO_2 sensor. It should turn on automatically and show readings for each condition.

- If you are not using a CO_2 sensor, you will need to use bromothymol blue (BTB), white paper, and 2 petri dishes.

Safety: Make sure you have an area in which you can safely conduct the burn tests. If you do these burn tests in the lab, make sure they are on non-flammable lab tables. The amount of smoke and ash that will go into the air is minimal, but let your front office know that you are burning things in the lab today and make sure that you have temperature-based, rather than smoke-based, fire detectors in the lab. If you are concerned about any of these, you can relocate this lab to be done along a concrete surface outside. Be sure to have a fire extinguisher available.
Disposal: Remaining fuel can be kept for future demonstrations. See instructions on the container for disposal of empty containers. Most containers can be placed into a non-flammable container (e.g., a coffee canister) and placed in the garbage.
Storage: Remaining fuels should be stored in a designated flammable cabinet that is locked.

Lesson 10 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students will first focus on obtaining information and using digital tools with data about human population growth and fuel consumption that is correlated to the rise of CO_2 emissions in the atmosphere. The lesson supports students in identifying a correlation between major energy innovations in the 1700, 1800, and 1900s; this correlation will become causation as students collect evidence that burning fossil fuels increases atmospheric CO_2 levels. Alongside these innovations is the rapid growth of human populations. As food became more readily available and in steady supply and medical innovation improved the quality and lengths of lives, the human population began to grow rapidly. The basic conceptual formula to explain the rapid growth of CO_2 on the graphs is that, as the human population grew and there was an increase in consumption per person, the total fuel needs increased, as well as the CO_2 that resulted from the use of the fuel.

Students have worked closely with correlation and causation in the *Everest Unit* and *Tsunami Unit*. This unit will continue to build on these ideas by looking across multiple data sets to establish correlation; they will then plan and carry out an investigation to gather evidence for causation.

In the OpenSciEd Scope and Sequence, students will have experienced the *Bath Bombs Unit*, *Homemade Heater Unit*, *Inside Our Bodies Unit*, and *Maple Syrup Unit* before this unit. In those prior units, students learned a great deal about chemical reactions and applied those ideas to processes in living systems. In the *Bath Bombs Unit* students learned that the atoms that make up the molecules of the substances can break apart and rearrange to form new molecules made of the same atoms, only in different arrangements. In the *Homemade Heater Unit* they added to their understanding that these reactions can release or absorb energy from the surroundings. Students applied these ideas to metabolic reactions in animals in the *Inside Our Bodies Unit* and likened cellular respiration to combustion in that unit.

Where We Are NOT Going

The population growth on the graph is exponential growth, which is something students learn in 8th grade math. If your students understand exponential growth, you can consider including this concept in this lesson.

Students have already established conservation of mass during combustion when they observed burning fat in a closed system during the *Inside Our Bodies Unit* in Lessons 11-12. Since conservation of mass and conservation of carbon atoms has been established in prior units, this lesson will not ask students to balance a combustion equation to confirm that the same number of atoms in the reactants equals the number of atoms in the products. The class will discuss conservation but not balance the equation. If your students need to do more with figuring out conservation of atoms and mass through a chemical reaction, use this opportunity for students to apply those concepts by massing a completely closed system and to practice balancing a combustion equation using methane as the fuel.

LEARNING PLAN for LESSON 10

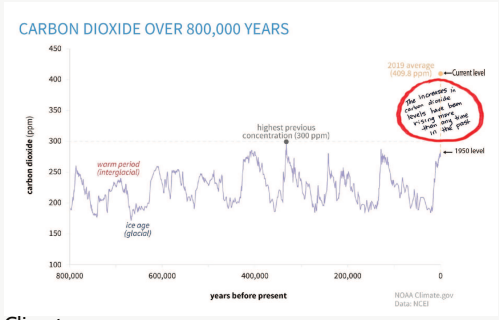
1 · IDENTIFY WHEN THE PROBLEM STARTED

5 min

MATERIALS: science notebook, Model Ideas list, markers

Reconsider the CO_2 graph and update Progress Trackers. Display **slide A**. Say, *Let's think back to what we figured out last time. What did we see last class when we looked at CO_2 over a long time and what were we curious about? Take a moment to update your Progress Tracker with what we figured out about CO_2 in the atmosphere over time.*

Give students about 3-4 minutes to update their Progress Trackers. Ask a few students to share their ideas. Students should respond with something along the lines of: *CO_2 was really much higher now than in the past, and it was going up super fast.* Add at least one big idea to the Model Ideas list.



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Zoom into the dates where CO_2 concentration increased rapidly. Display **slide B**. This is a graph of CO_2 emissions since 1751. Have a quick conversation with students about what is specifically happening in the graph on or around those dates. Ask:

- When did the rise start? (It started in the mid-1800s.)
- What does the data show after that point? (It gets steeper and steeper, and really shoots up around 1950.)
- What do we know about this time period? What was happening in the world? (Students may mention machines, cars, more people, Industrial Revolution.)

2 · INITIAL IDEAS ABOUT WHAT IS CAUSING THE RISE

5 min

MATERIALS: science notebook, Global CO2 Emissions video

Draw out initial ideas about what is causing the rise in CO_2 in recent centuries. Display **slide C**. Say, *Using past atmospheric data, scientists have created a visualization of where CO_2 was produced between the 1700s and today. We will watch this twice. Pay close attention to where the CO_2 is coming from and how this changes over time.*✱

Play the *Global CO_2 Emissions* video at https://www.youtube.com/watch?v=6lJ2uZSRfHI. Play through it twice for students to notice new spatial patterns emerging. It is not important for students to know the country names, but you can help them identify continents and specific countries (e.g., England, United States, etc.) if they are struggling with this.

Ask students what patterns they noticed in the video. These might include:

- CO_2 really increased in England in the late 1700s.
- Then it spread to Europe and the northeastern US in the early to mid-1800s.
- In the late 1800s, CO_2 emissions spread across the US and other places, like Japan and China.

Ask students, *What do we know about what was happening in places like England and the US between the 1700s and today that might be connected to the rise in CO_2?* Students might share initial ideas about:

- major events (e.g., the American Revolution, U.S. settlements in the West),
- inventions, such as steam engines, engines, and cars/trains/airplanes, and
- building factories and making more goods.

✱ ATTENDING TO EQUITY

Universal Design for Learning: Students engage with data and information in this lesson using multiple forms of media. Students begin with a simple line graph then use a time-lapse animated video to begin to identify when changes in CO_2 were happening. This is followed by a reading with text and images to understand what was happening in the world when CO_2 was rising. Finally, they use other graphs to connect energy use and population growth. Providing multiple forms of media to *represent* the information provides more access for the diverse learning needs in your classroom.

ADDITIONAL GUIDANCE

Students might have varying levels of prior ideas depending on whether they have learned about the first and second Industrial Revolutions. It is possible that students may not have experienced an in-depth American history course yet but will have ideas from various American history and world history units from elementary grades. Connect with the social studies teachers in your schools to find out if or when this content area is taught in your school district. However, even if students haven't learned about the Industrial Revolution, they will know general time periods in history, such as the time period for the American Revolution, the American Civil War, and several students may know generally when certain inventions came about, such as the inventions of the lightbulb, trains, cars, planes, and electronics.

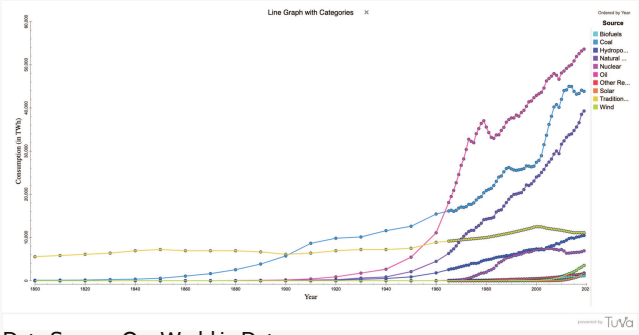
3 · EXAMINING DATA AND INFORMATION ABOUT NEW ENERGY SOURCES

18 min

MATERIALS: *Powering our World*, *Examining Data Over Time*, Fuel Consumption Tuva Data Set

Introduce students to major inventions that changed energy use in the world. Say, *OK, so we know CO_2 was rising in the last couple of centuries and really started to spike around 1950. Let's get some information about what was happening in the world when this was going on.*

Students individually read for 5-8 minutes. Pass out 1 copy of *Powering our World* to each student. There is also a full-color version of the reading in the student edition. Ask students to either read quietly or in partners. They should highlight or mark up the text in places where they think something is connected to the rise in CO_2. Give students a few minutes to read through the text. Return to the graph on **slide B** if students find this useful as they read.



Data Source: Our World in Data

Display and annotate the graph of consumption of energy sources. When students finish reading and marking up the text, display **slide D** and navigate to https://www.openscied.org/global-energy-graph/. This is a graph of energy sources used by the world since the 1800s. Pass out 1 copy of *Examining Data Over Time* to each student, which provides a copy of the graph and space for students to capture their notes and analysis of the data on the graph.

ALTERNATE ACTIVITY

Extension Opportunity: The graph provided in this lesson has all fuel sources already graphed. For students who may need a challenge or have high interest, this is an opportunity for them to make the graph themselves before interpreting the patterns.

- Use https://www.openscied.org/global-energy/ for this extension.
- Use *Tips for Using Tuva* in the student edition to give students support while working in Tuva.
- Do not use *Examining Data Over Time* or wait until after students graph the data before passing it out.

ADDITIONAL GUIDANCE

If time is short or devices are unavailable or unable to load Tuva, you can project the graph on a whiteboard and have students annotate the graph as a class (in lieu of working with the data in Tuva). Use **slide D (alternate)** instead. A copy of this graph is also included in the student edition, *World Energy Consumption, 1800 to Today*.

✱ SUPPORTING STUDENTS IN ENGAGING IN OBTAINING, EVALUATING, AND COMMUNICATING INFORMATION

Use this moment to help students integrate words, graphs, and pictures from the text onto the graph of energy consumption. This work helps support students in the following element: Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world(s).

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING CAUSE AND EFFECT

The focus in this discussion is to begin to build a correlation between fossil fuel use, human population, and rising CO_2. A causal relationship will be established during the combustion lab. At this point students are matching major shifts in fuel use to different levels of consumption of those fuels.

Say, *This graph shows what energy sources people used during this time. Let's use the information from the text to figure out what human activities were happening during this time that CO_2 was rising. We figured out that the rise started in the 1800s but really shot up in the 1950s. Let's combine information about changes in energy sources from the text and plot those events onto the graph.*

Do an example together, such as the rise of coal use in the 1700 and 1800s. Then, ask students to work in pairs or groups of three to plot major events that might be related to the energy sources shown on the graph.✱ Give students a few minutes to work on this. They can add whatever notes and annotations they feel are helpful to explain the changes in the energy sources over time.

Facilitate a Building Understandings Discussion. Ask students to share what they discovered between the Tuva data for fuel consumption by type and the reading.✱

Suggested prompt	Sample student response
What happened in the 1700s that might be connected to the rise in CO_2?	People started to use steam engines.
What about in the 1800s—what was happening at that time?	Coal was being used a lot! We discovered oil and started using it for lighting and fuel.
What about the 1900s?	We started using oil to make fuel for our cars.

KEY IDEAS

Purpose: To provide students an opportunity to make connections with human activities related to energy resources and the rise of CO_2 in the atmosphere.

Look for/listen for:

- Changing energy sources is connected with increased consumption on the graph.
- Coal increased first in the 1800s, followed by oil and gas in the 1900s.
- Coal, oil, and natural gas are called fossil fuels because they have carbon in them that turns into CO_2 when "burned" for fuel.

Consider adding "fossil fuels" to the Word Wall along with any additional words encountered in the reading.

Problematize the idea that we have been using fossil fuels for a long time. Display **slide E**. Once the graph with the timeline and/or annotations is complete, problematize it by saying, *Didn't the reading say people used coal a long time ago? How long have we been using it? If we've been using this kind of fossil fuel for a long time, then why has the consumption graph gone up so fast since the 1800s and especially since 1950?* Listen for ideas like:

- We are using more of it now.
- We now have cars and planes, so we need more of it.

4 · CONNECTING ENERGY USE, POPULATION, AND PER-CAPITA CONSUMPTION

12 min

MATERIALS: *Population, CO2 Levels, and Fuel Consumption*

Investigate population growth and consumption. Build on students' ideas by saying something like, *OK, so we think people might have something to do with this growth. Let's look across the data and see if there is a pattern between the CO_2 emissions and population.*

Load the Population, Fuel Consumption, and CO_2 Tuva graph at https://www.openscied.org/population-growth-graph/. This is a pre-made graph that will allow students to compare trends and patterns across three types of data: population growth, fuel consumption, and atmospheric CO_2 levels. Handout *Population, CO2 Levels, and Fuel Consumption* if you have time for students to annotate the graphs. Display **slide F**.

ALTERNATE ACTIVITY

Similar to the previous Fuel Consumption graphs, there are two scaffolding opportunities here:

- Students who need a challenge can use the blank version of the Tuva data set and build the graph from scratch, using this link: https://www.openscied.org/population-growth/.
- Alternately, if time is short or access to computer devices is limited, either project the premade graph for the whole class to work on together using a whiteboard and dry erase markers. Or, students may use the pre-printed graphs of the data included in the student edition as *Population and CO2 Emissions Graphs*.

Give students a few minutes to look across the three graphs and jot down some noticings onto each one.✱ Then have students share their noticings with a partner before sharing as a whole class. Add new understandings about how human activity, fuel consumption, and CO_2 levels might be correlated. Ask students to share their noticings as a class.

Suggested prompts	Sample student responses
What pattern do you notice across the graphs?	As population goes up, CO_2 emissions go up and/or energy consumption goes up.
Why do you think CO_2 is going up?	Because we are using more energy to power our homes and cars and stuff.
Do we think these patterns in the data are connected to one another? Or just a coincidence?	I think maybe the energy we are using is making the CO_2 levels go up.
How could we find out if that is true? What evidence would we need?	Maybe see if CO_2 is in the energy source.

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING CAUSE AND EFFECT

This is an opportunity for students to focus on the patterns in three data sets that show a *correlation* between the rise of CO_2 in the atmosphere with a rise in human population and energy consumption from fossil fuels. Students might be wondering if one thing is causing another thing, but this will be explored on day 2.

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING SCALE, PROPORTION, AND QUANTITY

This is an additional opportunity to develop another crosscutting concept by developing a conceptual equation for population growth and per capita consumption resulting in a greater magnitude of CO_2 emissions. This relationship thinking supports the development of Scale, Proportion, and Quantity, and in particular, using the element of: Proportional relationships among different types of quantities provides information about the magnitude of properties and processes. In this example, the proportional relationship between the number of people and the average energy needs per person can help to explain the magnitude of CO_2 rise on the graph.

ASSESSMENT OPPORTUNITY

Building towards: 10.A Integrate qualitative and quantitative scientific information in written text with visual displays of atmospheric CO_2 levels, energy consumption, and human population levels to determine a correlation between human activities and CO_2 emissions.

What to look for/listen for:

- Student ideas about the pattern *in each individual graph*. This pattern shows slightly increasing levels in population, energy consumption, and CO_2 emissions in the 1700s and 1800s, with a steep rise starting in the mid-1900s.
- Student ideas about a correlation in the patterns *across the three graphs*. The graphs follow a similar trend.
- Student ideas about how a growing population that consumes large amounts of mineral resources is correlated with the rapid increases in CO_2 in Earth's atmosphere.

What to do: If students struggle to compare the three graphs, consider chunking the graphs into time periods and focusing on specific time periods, asking incremental questions like:

- How would you describe the change in population from 1800 to 1900?
- What about 1900 to 2000?
- Would that same description fit the energy consumption graph (or CO_2 graph)?
- Why do you think they might follow a similar pattern? How could they be connected to one another?

Construct a simple equation to pull together ideas about population growth with energy consumption.✱ Display **slide G**. Ask students, *If we could write an equation to explain how more people and more energy per person would be related to CO_2 in the atmosphere, what would it look like?*

Students should suggest ideas about multiplying the number of people by how much energy they need leading to greater use of fossil fuels and CO_2 emissions. Sample equations might be:

- More people × more energy use per person = greater use of fossil fuels = high CO_2 into the atmosphere.
- Number of people × energy use per person = total energy used in the world. Total energy × CO_2 emitted per type = total CO_2 emissions.

Introduce students to "per-capita consumption." Say, *We have a word that we use to describe how much stuff people use every day. We call it per-capita consumption. The "per-capita" means per person. It is all the stuff (energy, food, goods) that a person consumes every day or year. Can someone describe examples of what that might look like in your daily life?*

Listen for students to suggest:

- *How much electricity we use each day, like our electricity bills.*
- *How much we buy each day, like food or other stuff.*
- *How much water we use each day.*

Give students an opportunity to describe what it might mean for them. It could be how much food they consume or electricity or gasoline. Add "per-capita consumption" to the Word Wall.

5 · NAVIGATION

3 min

MATERIALS: None

Wonder about the correlation between fossil fuels and CO_2. Display **slide H**. Say, *So, we figured out that, as populations grow, their consumption of energy increases. And this increase is correlated to the rise of CO_2. But how is it that this dead plant and animal matter from so long ago can become an energy source for us? What is in the fossil fuels that we use for energy? And exactly what is the connection between fossil fuels and CO_2 in the atmosphere?* Have students do a Turn and Talk with a partner for a minute and then share some ideas with the whole class.

- Accept all student ideas.
- Some students may bring forward an idea from the reading that there is carbon in coal (and other fossil fuels) and that when it is burned, it puts off CO_2.

End of day 1

6 · NAVIGATION

5 min

MATERIALS: science notebook, white board or chart paper, markers

Recall the correlation from day 1. Display **slide I**, and say, *From the last class, we were talking out how we think population growth, fuel consumption, and CO_2 levels are related. What are some ideas we had?*

- Students should recall that, as our population grows and we use more fossil fuels, the amount of CO_2 is increasing in our atmosphere.

Continue prompting students with, *So what do we know or want to know about our fuel consumption and how it is related to CO_2? What do we know about these fuels, particularly fossil fuels?*

- Students might say that we use fossil fuels to get energy for homes, cars, electricity, etc.
- They may also share that fossil fuels are deep underground and were formed millions of years ago from decaying plants and animals.
- Students may be wondering what is in fossil fuels that is related to CO_2.

Ask, *We have many different fossil fuels—how do we get energy from them?* Students should reply that we must burn them to get the energy we need. Connect to previous units by saying, *So, do you remember burning fat in the Inside Our Bodies Unit? What did you figure out was reacting with the fat to burn?* Students should remember that the fat reacted with oxygen to burn. Ask, *Is this true for everything that burns?* Students should recall that combustion reactions always have oxygen as one of the reactants.

Set up a general chemical equation. Say, *We know a way to write chemical reactions from the Bath Bombs Unit. We will just make a general equation for fossil fuels. If we start with a fossil fuel, what do we need to add to our chemical equation?* Write the equation on the board and review terms like "reactants" and "products" with students and note on which side of the arrow they go. You may even want to label those on the board. Keep it up throughout the lesson. Use the example below to help.

(reactants) (products)

Fossil fuel + oxygen (O_2) →

Consider the products of burning fossil fuels. Display **slide J**. Continue the navigation by saying, *I wonder what we get from burning fossil fuels besides the energy?* Lead a short discussion using the dialogue examples below.

✱ SUPPORTING STUDENTS IN ENGAGING IN ASKING QUESTIONS AND DEFINING PROBLEMS

By middle school, students should be asking questions to clarify or identify evidence. In this case, students need evidence that burning fossil fuels produces CO_2 and is what is causing the amount of CO_2 in the air to increase. There will be several opportunities in this lesson for students to use this practice to clarify or identify evidence related to the combustion of fossil fuels.

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING ENERGY AND MATTER

If students mention that they need to know the atoms in the fossil fuels to know what the products are, then they are using this crosscutting concept. They know that the atoms in the products come from the molecules and atoms in the reactants. If students do not use the CCC here, they will have additional opportunities to use it in later activities.

Suggested prompts	Sample student responses
Did we figure out any products from burning fat?	Yes—CO_2. We figured that out when we burned the fat.
Do you think we get the same products when burning fossil fuels?	Yes. I'm not sure—we should check!

Ask questions to identify or clarify evidence. Say, *We figured out earlier that we are using a lot of fossil fuels for energy and we also know that CO_2 levels in our atmosphere are increasing. These two things are correlated. But we don't know for sure that burning fossil fuels is what is causing the CO_2 levels to go up. We think so, and we may have heard that before—but we do not have evidence to support the claim that burning fossil fuels causes CO_2 levels to rise. What questions can we ask and answer that will help us figure that out?* Give students a minute to think of questions they may want to ask and answer.

Ask a few students to share their questions and record them on the board. Questions may include: What are the products of burning fossil fuels? Do all fossil fuels produce the same things? When you burn fossil fuels, do you get CO_2?✱

ASSESSMENT OPPORTUNITY

Building towards: 10.B Ask questions to clarify whether the CO_2 in the atmosphere can come from burning fossil fuels for energy.

What to look/listen for:

- students asking for evidence for the products of the combustion of fossil fuels and
- students recognizing and asking questions about energy as a product of the combustion reactions, as well as matter that comes from the reactants.

What to do: Listen as students share their questions that they can answer to help them figure out if burning fossil fuels and rising CO_2 levels are related. Their questions should ask for evidence to support or refute this claim. Questions they may ask are: *What are the products of the combustion reaction of fossil fuels? Do you get the same products from all fossil fuels? Is CO_2 one of the products of burning fossil fuels?*

Predict product(s) of burning fossil fuels. Display **slide K** and say, *What do we predict will happen when we react (burn) this fuel with oxygen? What would happen to the atoms? What product or products would we get? Jot down your predictions in your notebook. Title your response, "Predictions of reacting fossil fuel with oxygen."* Student predictions about the products may include CO_2, possibly carbon monoxide, smoke, and ash. Students may also list energy as a product. Students may say that the atoms or molecules in the fossil fuels turn into the atoms of the products.✱

ADDITIONAL GUIDANCE

The next two activities may be done in either order depending on which makes the most sense based on the questions and ideas that your students share in the navigation. If your students want to know what the atoms are in the molecules that make up fossil fuels when they are asked about the products of burning them, this is great! It indicates that students truly understand the law of conservation and know that the atoms in the products must come from atoms that are reacting. If your class wants to see the molecules first, do the **EXAMINE FUEL AND FOOD MOLECULES** activity first and do the **BURNING FUEL DEMONSTRATION LAB** after students have had a chance to look at the molecules. On the other hand, if students want to burn the fuels and use a detector or indicator to find out the products of burning fossil fuels, then continue in the order it is written here.

Ask for volunteers to share ideas. Allow a few students to share their predictions. Predictions will include the production of CO_2. Ask, *How have we tested for this in the past?* Students should recall using BTB and/or CO_2 sensors to test for the presence of CO_2 and want to use them again.

7 · BURNING FUEL DEMONSTRATION LAB

20 min

MATERIALS: Investigating Burning Fuel, science notebook, document projector (optional)

Collaborate to plan the demonstration. Say, *Let's see if our predictions are true. You said we can measure CO_2 using a sensor or using BTB. We did that in Inside Our Bodies Unit. Let's use a similar setup to test for the products from burning fossil fuels. What question are we trying to answer? Keeping that in mind will help us decide how to set up the investigation.* Students should respond that we are trying to answer the question, "What are the products of the reaction of fossil fuel and oxygen?"

Suggested prompts	Sample student responses
What question are we trying to answer?	We want to know what is produced when we burn it. What are the products of burning fossil fuels?
What things do we need to consider?	We think it produces a gas, so we need to trap the gas.
How did we do that in earlier units?	We used a big clear bowl to trap the gas. We also tried to make it air tight.
That is hard to do sometimes—we will do the best we can. But we have to let oxygen in or use a really big bowl!	
What else should we consider or do?	Last time we made mass measurements—we measured the fat to see if the mass was changing.
Are mass measurements something we should do this time?	Not really. But we need to see if the fuel mass is changing.
OK, how are we going to know if CO_2 is produced?	We can use a CO_2 sensor—put it under the bowl. Or we could put a container of BTB and watch for a color change.
It sounds like we need to make observations of any changes we notice. Our CO_2 sensor also measures humidity. What is humidity?	Humidity tells you about water vapor in the air.
I wonder if that changes? We can measure that, too, since we have it in our sensor.	

Set up science notebooks for the demonstration. Display **slide L**. Have students make a two-column chart on a new page in their notebooks. They should label the two columns, "Before" and "After." Tell students to record measurements before you burn the fuel and after. They should also make any additional observations that they think are important to figuring out what the products of the reaction are.

✱ SUPPORTING STUDENTS IN ENGAGING IN PLANNING AND CARRYING OUT INVESTIGATIONS

This is a good opportunity for students to practice different aspects of identifying data they will collect, how they will collect it, and how to organize the data to make sense of the investigation.

✱ SUPPORTING STUDENTS IN ENGAGING IN ASKING QUESTIONS AND DEFINING PROBLEMS

Asking questions to identify and/or clarify evidence is one of the practices to focus on during this activity. Students who are skeptical about results are demonstrating that they are beginning to act and think like scientists. This is a good place to encourage that skepticism and to encourage students to ask questions of you and of their peers to clarify evidence for the products of these reactions.

To answer the questions for this investigation, it is not necessary to measure the mass of the fuel before and after. However, if students want to make these measurements, allow them to do so. This is not a closed system, but students can measure the lighter before and after the demonstration. Use these measurements to reinforce where the matter is going when the fuel burns.

Bring students together and introduce the investigation system. Ask students to gather around the demonstration table but remain at least 4 feet from the table. This distance is required for safety and will ensure that everyone can see. You may allow the first row to sit in chairs and have the students behind them stand.

ADDITIONAL GUIDANCE

See the Teacher Prep section for what needs to be prepared before this demonstration. See *Burning Fuels Instructions* for directions on how to set up the demonstrations and for additional support.

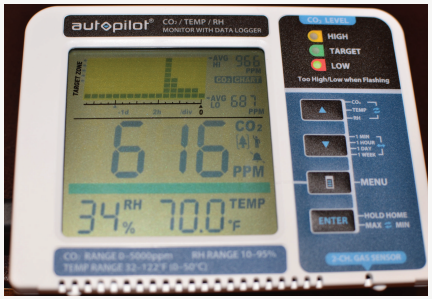
Remind students of the investigation system you used in the *Inside Our Bodies Unit* and display **slide M**. This setup shows one similar to the one used in the *Inside Our Bodies Unit*, but if you are using something different, you may replace the picture with one of your setup. Identify each part of the investigation system and call attention to the fuel that you are using. Have students record the name of their fuel in the first column of their chart. You will use a butane lighter initially. Pass one around the class and have students notice the liquid fuel (butane) in the lighter.

Say, *Let's see if our predictions are true. What measurements and observations do we need to make?* Students may respond with some of the following ideas:

- measure CO_2 concentration
- observations of any visible changes to the bowl or items inside the bowl
- observations of any "smoke"
- mass of the fuel to see if its changing (if recommended by students)

Set up the investigation system. Follow the instructions on *Burning Fuels Instructions* to set up the system. Use the teacher reference for more details of the setup and running the demonstration.

Take the initial measurements of the air in the system. If your school has a no-flame policy, play the *Burning Fuels Demonstration* video at https://youtu.be/gub7jM9B604. Once values on the sensor have stabilized, have students record initial readings from the sensor or the color of BTB under the bowl. The butane lighter should not be lit.



Run the investigation. Display **slide N**. Ask for a student volunteer to read the readings off of the detector for the amount of CO_2 and water vapor (relative humidity). Have them show the other students where they are getting the information on the detector. (The image shows a CO_2 reading of 616 parts per million (ppm) and a relative humidity reading of 34 percent.) Allow the demonstration to proceed until the CO_2 sensor has reached its maximum level.✱

SAFETY PRECAUTIONS

Ensure student safety.

- Have students put their safety goggles on.
- Students should still be in a circle around the demonstration table at least four feet away from it (for safety and so that everyone can see).

Share what the class has figured out. Allow students to remain around the demonstration table. Ask a few students to share what they have figured out are the products of burning butane. Display **slide O**. Refer to the general equation you started earlier. Write "butane" underneath "Fossil Fuel" in the chemical reaction.

(reactants) (products)

Fossil fuel + oxygen (O_2) →
Butane

As students share, encourage other students to ask questions that will help them clarify evidence. Encouraging this is an important part of the discussion. An example dialogue is shown below.✱

Suggested prompts	Sample student responses	Follow-up questions
Can someone share one thing they figured out with this demo?	I figured out that CO_2 was produced.	*Does someone have a follow-up question for _____ that will help you understand more about what he/she figured out?*
	I figured out that water was also produced.	*Does someone have a follow-up question for _____ that will help you understand more about what he/she figured out?*

ADDITIONAL GUIDANCE

Students learned in the *Storms Unit* what relative humidity measures, but they may need to be reminded. One hundred percent humidity does not mean that the air is filled with only water vapor molecules. Here is a short summary used in *Storms Unit* with students to explain what it is measuring. Say: *Relative humidity isn't a measure of the percentage of water in the air, but rather how close the amount of water in the air is to the maximum that can be in the air before it reaches the maximum that can be held in the air. For example, 100 percent relative humidity means that the air can't hold any more water vapor without it clumping together and coming out in little droplets. On some days, 100 percent relative humidity could mean that the air has reached that 4 percent value we saw in the range of possible amounts of water vapor found in the air from day-to-day and place-to-place.*

Students will also notice condensation on the inside of the bowl as the flame is burning. This is additional evidence that water vapor is a product of burning fossil fuels.

Students should reply that CO_2 and water vapor (or just water) are products of burning butane. Students may have asked if this is true for all fossil fuels, and, if so, that is great. Build on their question. But if they have not brought this idea up, ask, *Do you think this is true for all fossil fuels that burn?* Students should be skeptical about this generalized idea after only testing one fossil fuel. Ask students what we can do to find out if the products of other reactions of burning fossil fuels yield the same products.

Suggest an additional test. Display **slide P** and say, *I have another fuel that we can try. It is made from fossil fuels as well. Methanol is an alcohol that is made from petroleum products—fossil fuels. Has anyone seen one of these cans of fuel that are fuel gel? A familiar brand of fuel gel is Sterno. Some of these are made from fossil fuels, like this one*. Hold up the can or pass it around for students to see.

Repeat the same procedure using the can of methanol based fuel gel in place of the butane lighter. You should get similar results.

ASSESSMENT OPPORTUNITY

Building towards: 10.B.2 Ask questions to clarify whether the CO_2 in the atmosphere can come from burning fossil fuels for energy.

What to look/listen for:

- students asking each other for evidence for the products of the combustion of fossil fuels such as:
  - What evidence do you have that H_2O is produced?
  - How do you know the H_2O wasn't in the air to start with?
  - Do you have evidence beyond the humidity sensor values?
  - What evidence do you have that CO_2 is produced?
  - How do you know the CO_2 wasn't in the air to start with?
- students being skeptical because there is not sufficient evidence to convince them that fossil fuels in general produce CO_2 and water when they burn;
- students requesting or asking questions to get more evidence to support their findings—evidence that is sufficient to make a claim that CO_2 and water are products of the combustion of a variety of fossil fuels; and
- students recognizing that energy is a product of the combustion reactions, as well as matter that comes from the reactants.

What to do: Encourage students to ask each other questions, especially if the student responding is vague or gives an incomplete answer. Students should be asking questions *of each other* to clarify any claims or the evidence they have collected. Some students may need sentence starters to help them frame their questions. If your students need this support, write a few sentence starters on the whiteboard. Some examples of starters include: What do you mean by_____? What evidence do you have that_____ is true? How do you know _____?

Return to general chemical reaction. Display **slide Q**. Say, *We have burned two different fossil fuels and have gotten similar results. Are you comfortable with saying that CO_2 and water are two products of the reaction?* Students may all be convinced but you may have some who are not. The teacher reference, *Burning Fuels Instructions*, gives suggestions for other tests with additional fossil fuels.

Say, *Can we add products to this reaction that we started with?* If some students are not convinced that this reaction can be generalized, write "butane" and "methanol" underneath "Fossil Fuel" so that you honor their skepticism but can move ahead.

(reactants)	(products)
Fossil fuel + oxygen (O_2) →	CO2 + water

ADDITIONAL GUIDANCE

Students may ask about other products of the combustion of fossil fuels, such as smoke or carbon monoxide. While the major component of a fossil fuel, such as gasoline, is octane, there are other additives and compounds included in the gasoline mixture. If pure octane is provided with sufficient oxygen during combustion, the products will be CO_2 and water. However, complete combustion rarely takes place. If there is insufficient oxygen available, some carbon monoxide will also be produced. Carbon monoxide (CO) is the result of incomplete combustion—it happens when there is not enough oxygen available during combustion. Smoke may also be produced. This happens when there are additives, incomplete combustion, or other factors. Smoke may contain liquids and solids that contain very fine particles of elemental carbon. You can see soot often when there is a lot of smoke in a fire.

ALTERNATE ACTIVITY

As planned here, the activity does not specifically focus on the conservation of matter as part of this equation. However, this is a good opportunity to balance the equation and give students an opportunity to practice the ideas of conservation of matter. For example, you could use methane, C_4 to balance the equation as such: $CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_20$

8 · EXAMINE FUEL AND FOOD MOLECULES

10 min

MATERIALS: science notebook, *Fuel Molecule Cards*

ADDITIONAL GUIDANCE

Your class may have done the Examine Fuel and Food Molecules activity before the Burning Fuel Demonstration Lab. If so, adjust the directions for this activity to account for the different order of activities from what is printed here.

Link the products of the reaction to the reactants. Display **slide R**. Students may have wondered about the atoms in the reactants when predicting the products of the reaction of fossil fuels with oxygen.✱ If you have students who are still skeptical about reactions of fossil fuels always producing CO_2 and water, this activity may provide the additional evidence they need to be convinced.

Say, *What did we learn about the atoms that make up products in a chemical reaction from Bath Bombs Unit? How can we use what we know about atoms in a chemical reaction and what we figured out to be products of the reaction to help us predict what fossil fuels are made of?*
Have students jot down in their notebooks atoms that they think make up fossil fuels. Remind them that we know fossil fuels react with oxygen in the air when they burn.

Examine common fuel molecules and sugar molecules. Distribute the cards cut from *Fuel Molecule Cards* so that each group of students has one set of cards.

Display **slide S** and say, *As you work with your group, think about how the molecules are similar and how they are different. Group them into two groups—sugars and fuels. How are these two groups similar and how are they different? Be ready to share what you have figured out.*

Suggested prompts	Sample student responses	Follow-up questions
What did you find that was similar for all of these molecules?	They all have carbon and hydrogen in their molecules. Some have oxygen.	*What does that tell you about the products when we burn one of these?*
Did you find any differences?	Some molecules were very complex and some were pretty simple.	*Can you give an example of a simple molecule and one that you think is complex?*
	Some of the molecules had oxygen and some did not.	*If the products of burning the ones without oxygen are still CO_2 and H_2O, where does the oxygen in these products come from?*
I have been calling these "fuel molecule cards." Are all of these fuels?	No, some are sugars. But we learned that sugar is a fuel for our bodies, so I guess sugars are a type of fuel, just not for our homes or cars.	

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING ENERGY AND MATTER

The Examine Fuel and Food Molecules activity reinforces the big idea and crosscutting concept that matter is conserved because atoms are conserved in chemical processes. As students wonder about the atoms in the reactants and want to use that information to help them either predict or confirm the atoms in the products of the reaction, they are demonstrating that they have internalized and are truly using this crosscutting concept to figure out new science ideas. Knowing that the reactants in the reaction (hydrocarbons and oxygen) contain hydrogen, carbon, and oxygen and then reasoning that those atoms and only those atoms must make up the products of the reaction, is a fundamental step in using the crosscutting concept of conservation as an intellectual tool that will help them understand core science ideas.

Take advantage of opportunities in this activity to encourage students to apply this crosscutting concept to respond to questions and to share ideas. Examples of ways to accomplish this are included here but feel free to add additional support for your students if needed.

9 · FACILITATE A BUILDING UNDERSTANDINGS DISCUSSION

10 min

MATERIALS: science notebook, Model Ideas list

Facilitate a Building Understandings Discussion. Project **slide T**. Use this opportunity to establish agreement to answer the questions generated prior to the demonstration. Ask, *Did we answer your questions that I wrote on the board when we first started this lesson?*

Look at the questions students generated at the end of the navigation. Students should have answered most if not all of their questions.

Say, *Wait! It seems we figured out something big. Let's think about this carbon that is now in CO_2 in the air. And we know that is a problem. Can someone remind me why a lot of CO_2 in the atmosphere is a problem?*

Suggested prompts	Sample student responses	Follow-up questions
Why is extra CO_2 (from burning fossil fuels) in the atmosphere a problem?	It is what is causing us to get warmer—we figured that out in another lesson. (Lesson 7)	*Isn't this just a natural cycle?*
Where did the carbon in the CO_2 come from?	It came from burning fossil fuels.	*Are you saying the atoms from the CO_2 were in the fossil fuel?*
Where did the fossil fuel come from?	It was buried in the ground—down deep!	*Can you describe how carbon is moving through our Earth system?*
So, we have carbon that was once underground as part of the molecules that make up fossil fuels. And where is it ending up?	In the atmosphere!	*And what is wrong with that? Is that a problem?* *So, it sounds like we have some ideas to add to our Progress Tracker. What ideas or idea should we add that we have figured out today?*

KEY IDEAS

Purpose of this discussion: See what we can agree upon regarding the combustion of fossil fuels.

Listen for these ideas:

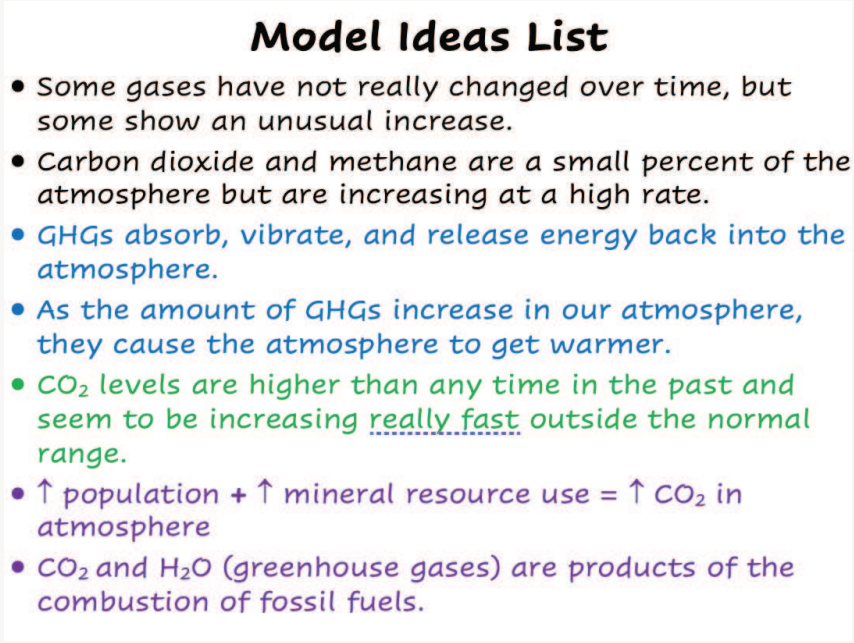
- Water appeared on the walls of the container.
- Carbon dioxide increased on the sensor.
- Carbon dioxide and water are produced from burning fossil fuels.
- Carbon from fossil fuels that were buried underground is now part of the atmosphere.

Add new ideas to the class Model Ideas poster, and students add the idea to their Progress Tracker. Say, *What is the one big idea we figured out today that would be important to include on our Model Ideas poster?* Students should respond that they figured out that burning fossil fuels produces CO_2 and water. Encourage students to add this idea to their Progress Trackers as you write the idea on the Model Ideas poster (shown in red in the image). Students may want to include the general chemical equation that we completed.

Fossil fuel + oxygen (O_2) → CO_2 + water

Say, *Remind me why we are not really worried about too much water vapor even though it is produced, too, and is a greenhouse gas.* Students should recall that, when humidity gets too high, the water will precipitate out of the atmosphere—the water cycle takes care of it!

Another big idea to add to the Model Ideas list is described in the previous dialogue—carbon stored underground moves to the atmosphere because of the combustion of fossil fuels. Add this idea to the list, too, and encourage students to add it to their Progress Trackers.



Navigate. Say, *So, we are putting carbon (as CO_2) into the atmosphere by burning fossil fuels. What things burn fossil fuels?* Students should reply with: vehicles, most electricity is generated using fossil fuels, homes are heated with electricity, oil, natural gas, or propane—all fossil fuels or made by fossil fuels.

Continue by saying, *We must be putting a lot of carbon into the atmosphere. And, we know this is becoming a problem with rising temperatures. I wonder if there are any natural processes that take CO_2 out of the atmosphere? Do you have any ideas?* Allow a few students to respond without discussion. We will pick up with this question in the next class.

ADDITIONAL GUIDANCE	**Natural resources guidance and extension opportunities:** If you are proceeding with the extension opportunity for ESS3.A Natural Resources, adjust the navigation at the end of this lesson to set students up for adding new questions to the DQB about fossil fuel resources at the start of the next class period. The extension is designed to (1) allow students to connect to prior knowledge and experiences about fossil fuels, (2) ask new questions which are added to the DQB, (3) investigate using illustrations and readings to make sense of how fossil fuels form and where they are found, and (4) broaden to related phenomena of uneven distribution of other resources. See *Extension Opportunity: Uneven Distribution of Fossil Fuel Resources* and **slides U-AB** for more guidance.

Additional Lesson 10 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN MATH	Constructing an equation for how population and per-capita consumption result in greater magnitude of CO_2 emissions provides an opportunity to build in deeper mathematics understanding around this standard: CCSS.MATH.CONTENT.7.EE.B.4: Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities. This step in the lesson can be quantified for students by integrating simple numbers to represent the equation. For example, start with the classroom and say: *If our classroom is made of only 5 students (population) and we consume* x *amount of energy each year with* y *amount of CO_2 emissions released, then our total CO_2 emissions would be* z. The equation could be 5 times × times $y = z$ Then ask, how might this equation change if our population doubled? Tripled? Importantly, the 5 would change, but also the total z (CO_2 emissions).

LESSON 11: Why could burning fossil fuels create a problem for CO2 in the atmosphere?

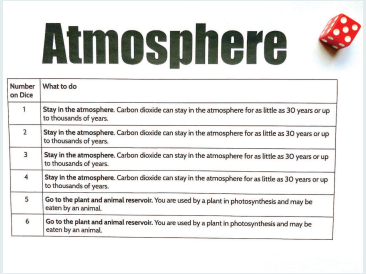
PREVIOUS LESSON

We zoomed into the last 200 years of Earth's history to understand what led to a rapid increase in atmospheric CO2. We watched a visualization and read about key innovations in human history that transformed the types of energy used to power our communities. We figured out that, as population grows and energy consumption rises, human activity contributes to the release of CO2. We wondered how using fossil fuels to power homes and cars is related to rising CO2 levels. We burned a sample, and as the fuel loses mass, CO2 and water vapor were produced. We examined fossil fuel molecules and identified that they are made mostly from carbon, hydrogen, and oxygen, which explained how burning fossil fuels causes increased CO2 in the atmosphere.

THIS LESSON

INVESTIGATION

1 day



We wonder why the CO2 from fossil fuels is causing such a problem. We modify a model of Earth's Carbon System to represent the locations of carbon and the processes that move it around. We simulate these processes using a kinesthetic activity of the system before and after human activity. We figure out that photosynthesis cannot take up CO2 at the same rate that burning fuels puts CO2 in the atmosphere and that this is creating a buildup of CO2 in the atmosphere. We think we can explain the problem now.

NEXT LESSON

We will develop and support a causal model between fossil fuel use and changing water resources and will review and clarify a tweet regarding climate change and its impacts. We will take an assessment refuting inaccurate claims made in another tweet regarding human activities and climate change.

BUILDING TOWARD NGSS

MS-ESS3-1, MS-ESS3-3, MS-ESS3-4, MS-ESS3-5, MS-ETS1-2

WHAT STUDENTS WILL DO

11.A Apply mathematical concepts to compare the rate of combustion and cellular respiration putting CO_2 into the atmosphere to the rate for photosynthesis taking CO_2 out of the atmosphere leading to an imbalance in the system.

WHAT STUDENTS WILL FIGURE OUT

- Photosynthesis is a way to get CO_2 out of the atmosphere, but the rate of photosynthesis is not enough to take up CO_2 from combustion of fossil fuels and cellular respiration combined.
- Combustion of fossil fuels is creating a carbon imbalance in the atmosphere.

Lesson 11 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	3 min		**NAVIGATION** Elicit prior knowledge from students to prime them for thinking about carbon cycling.	A	
2	12 min		**MODIFY A CARBON SYSTEM MODEL** Modify a carbon system model to include human activities that have altered the natural flow of carbon. Use this model to predict what is happening to cause CO_2 to increase in the atmosphere.	B-D	*Earth's Carbon System Model*, colored pencils, class Earth's Carbon System Model, colored markers
3	18 min		**TRACK CARBON ATOMS USING THE CARBON DICE GAME** Simulate changes to the carbon system by having students act like carbon atoms moving around the system before and after humans significantly altered the system.	E	dice, Quick Reference Card (optional), digital Carbon Dice Game (optional alternative), *Carbon Dice Game Instructions and Station Cards*, station cards
4	10 min		**FACILITATE A BUILDING UNDERSTANDINGS DISCUSSION AND COMPARE RATES** Facilitate a discussion to have students share what they noticed from the simulated activity and to compare rates of the arrows.	F-I	class Earth's Carbon System Model, Model Ideas list
5	2 min		**NAVIGATION** Have students complete an exit ticket to share their individual understanding of rates of CO_2 entering and leaving the atmosphere resulting in a buildup of CO_2.	J	

End of day 1

Lesson 11 • Materials List

	per student	per group	per class
Lesson materials	• *Earth's Carbon System Model* • colored pencils • dice • Quick Reference Card (optional) • digital Carbon Dice Game (optional alternative)		• class Earth's Carbon System Model • colored markers • *Carbon Dice Game Instructions and Station Cards* • station cards • Model Ideas list

Materials preparation (45 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

There are two main activities for this lesson: (1) Developing or using the Earth's Carbon System Model, and (2) the Carbon Dice Game. Each requires some advance preparation.

Earth's Carbon System Model handout: The goal in this lesson is for students to *use* the carbon system model to make sense of CO_2 increasing in the atmosphere. However, depending on how much you have been following the OpenSciEd 7th grade scope and sequence, your students may be better positioned to develop the model from scratch or use a model template that is already populated with parts of the system. You will need to determine where you want to start with students. See *Guidance on Carbon System Model Templates* for more guidance on which template to use.

Print the carbon system model handout option that is right for your students. We recommend Option 1 for time efficiency and Option 2 or 3 for a more complete modeling activity. All three options are located in *Earth's Carbon System Model* handout with a grayscale option for Option 1. Print one for each student.

Class Size Earth's Carbon System Model: Make a class size version of the carbon system model you choose on chart paper. This model will be used again in later lessons.

Carbon Dice Game: There are many variations of the game online. We have chosen a version focused on carbon cycling through terrestrial systems only. However, you can add oceans, too. Read carefully *Carbon Dice Game Instructions and Station Cards* which includes detailed instructions to set up the game. Decide where to locate your 'station cards', and depending on class size, how to start out your students in each station. Be prepared to sanitize dice between class periods, too.

There is a Digital Dice Game alternative for an online option too.

Lesson 11 • Where We Are Going and NOT Going

Where We Are Going

In prior units from the 7th grade OpenSciEd Scope and Sequence, students will have learned a great deal about chemical reactions, tracing carbon atoms through reactions, and applying those ideas to explain processes in living systems (e.g., the *Bath Bombs Unit*, *Inside Our Bodies Unit*, and *Maple Syrup Unit*). In the *Bath Bombs Unit* students learned that the atoms that make up the molecules of the substances can break apart and rearrange to form new molecules made from the same atoms, only in different arrangements. In the *Homemade Heater Unit* they added to their understanding that these reactions can release or absorb energy from the surroundings. Students applied these ideas to metabolic reactions in animals in the *Inside Our Bodies Unit* and likened cellular respiration to combustion in that unit. They also developed a deeper understanding of cellular respiration and photosynthesis, and how these processes move carbon atoms through food webs at an ecosystem level during the *Maple Syrup Unit*. In the previous lesson in this unit, students also developed an atomic-molecular scale understanding of combustion to identify a cause and effect relationship between burning fossil fuels and CO_2 in the atmosphere. All of this previously developed understanding will be activated in this 1 day lesson. Therefore you can connect to the following DCIs, which are not focal in this unit, but activated in this new context:

- PS1.B: Chemical Reactions: Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.
- LS1.C Organization for Matter and Energy Flow in Organisms: Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen.
- PS3.D Energy in Chemical Processes and Everyday Life: The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from the sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen. Cellular respiration in plants and animals involves chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials.

This lesson will extend student understanding by asking students to (1) compare these processes in the context of a large-scale system, and (2) compare rates of photosynthesis, cellular respiration, and combustion in terms of putting carbon dioxide into the atmosphere or taking it out. This is a stepping stone toward a more sophisticated global carbon cycling and quantitative pool and flux carbon model that students will develop in high school (see HS-LS2-5, HS-ESS2-6). We acknowledge that a large-scale model for photosynthesis, cellular respiration, and combustion is more complex than might be expected for students to explore in the middle school grade band, but we felt strongly that students needed a concrete amount of carbon dioxide from human activities that is out of balance with natural processes. With this new understanding, students can then have a way to evaluate how impactful different kinds of solutions are toward rebalancing carbon. We provided extra scaffolding to support students in reflecting on the carbon-transforming processes they have already learned about at organismal and ecosystem scale, now in the context of a large-scale representation of them.

This lesson is designed so that you can support students in modifying a carbon cycle model. It is important that students learn how to work with and make sense of content representations and models that tend to be static depictions of a system. In this lesson, they will start with a model, make sense of it with their own prior understanding, and modify it based on what is changing in the system. There is an option to develop the model with your class first. This option would require more instructional time.

Scale will be a useful lens for students to apply in this lesson. Your students will be working on scaling processes from the macroscale (e.g., single plant photosynthesis) to global photosynthetic activity. They will make sense of the amount of carbon that enters or leaves the atmosphere from these three carbon cycling processes. Essentially recognizing that the photosynthesis, cellular respiration, and combustion arrows in the model are not the same amount.

Where We Are NOT Going

This lesson does not include a full carbon system model that includes oceans. Likewise it is very limited in scope in terms of fluxes between carbon reservoirs, or pools. The “pools” in this model are represented with macroscale icons that are familiar to students. The lesson only focuses on three processes students have prior knowledge about, leaving out a lot of carbon cycling processes that students will learn about later in their schooling. Students will develop a more complete global carbon cycle model and pool and flux model in high school. The focus on three processes now helps students to calculate a target for carbon imbalance that they need going forward. Avoid complicating this model further as students will develop a more complete, complex, and quantitative model in high school.

LEARNING PLAN for LESSON 11

1 · NAVIGATION

3 min

MATERIALS: None

Use the combustion demonstration to brainstorm other sources of CO_2. Say, *We figured out burning fuels gives off CO_2 into the air. But we know of other things that take in or put off CO_2 as well. It seems like a pretty common molecule that's moved around a lot.*

Have students turn and talk about things they know that give off or take in CO_2. Display **slide A**. Give students 1 minute to brainstorm ideas with partners.✱ Then elicit ideas from the whole class. Listen for students to suggest the following:

- Plants take in CO_2 and give it off, too.
- People breathe out CO_2.
- Animals breathe out CO_2.
- Decomposers give off CO_2.
- Anything that does cellular respiration gives off CO_2.
- Anything that does photosynthesis takes in CO_2.

Say, *Wow, there are a lot of ways we can move CO_2 into and out of the air. And there are a lot of organisms on Earth, including us, that are giving off CO_2 into the air all the time, too. Seems like burning of fossil fuels is just one small piece of the bigger picture.*

✱ ATTENDING TO EQUITY

Universal Design for Learning: Elicit students' prior knowledge and experiences at the start of the lesson. This will prime their thinking for examining and modifying the carbon system model next, where they will apply their understanding of these processes at a larger scale.

2 · MODIFY A CARBON SYSTEM MODEL

12 min

MATERIALS: *Earth's Carbon System Model*, colored pencils, class Earth's Carbon System Model, colored markers

ADDITIONAL GUIDANCE

The goal in this lesson is for students to *modify and use* a carbon system model to make sense of why burning fossil fuels is a problem for increasing CO_2 in the atmosphere. The instruction steps below will guide you and your students through modifying the model. Use Option 1 from *Earth's Carbon System Model*. If you want students to develop the model first, there are two other options available. Option 3 is a simple model scaffold to get started. Option 2 provides more scaffolding than Option 3. Follow the same steps you did in Lesson 2 to develop Earth's Water System model. These two options will require more instructional time than what is allotted here and students will need their understanding from the *Bath Bombs Unit*, *Inside Our Bodies Unit*, and *Maple Syrup Unit* units to make this activity productive.

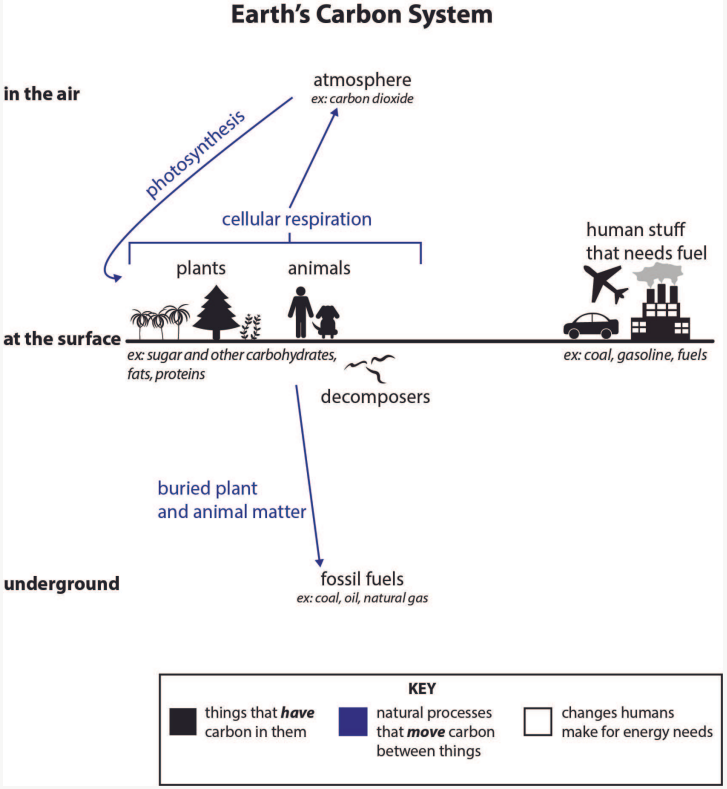
The carbon system model focuses on terrestrial carbon cycling. If you plan to add the ocean to the Carbon Dice Game, take time to add the ocean and sea-to-air gas exchange processes to the model now. This will make the modeling activity and dice game more closely matched. We recommend keeping the model as simple as possible.

Introduce the purpose of using a system model for our goal. Display **slide B**. Say, *When we were trying to figure out what was going on with water, we set up a system model to explain droughts and floods. System models are useful for showing important parts of the system, how they interact, and figure out what could be changing. Today, we're going to use a system model and modify it to show what is changing in the carbon system.*

Examine and review the carbon system model.✱ Pass out 1 copy of *Earth's Carbon System Model*, Option 1, to each student that depicts locations of carbon and natural processes that move carbon between locations. Give students 1 to 2 minutes to examine the model and use the prompts on the slide to guide their review.

✱ ATTENDING TO EQUITY

We acknowledge that a large-scale model for photosynthesis, cellular respiration, and combustion is more complex than might be expected for students to explore in the middle school grade band, but we felt strongly that students needed a concrete amount of carbon dioxide from human activities that is out of balance with natural processes. With this new understanding, students can then have a way to evaluate how impactful different kinds of solutions are toward rebalancing carbon. Because this carbon cycle model is moving toward high school level understanding (e.g., HS-LS2-5, HS-ESS2-6), we've provided extra scaffolding to support students in reflecting on the carbon-transforming processes they have already learned about at organismal and ecosystem scale, now in the context of a large-scale representation of them.



✱ SUPPORTING STUDENTS IN DEVELOPING AND USING SCALE, PROPORTION, AND QUANTITY

Scale will be a useful lens for students to use as they examine the new carbon system model. Below are prompts to support students' thinking about scale.

- Is the model presented at a (smaller/larger/the same) scale than the phenomenon we've explored before?
- How does the scale of (photosynthesis/cellular respiration) on this model compare to how we represented it before?

Suggested prompts	Sample student responses
What parts of this model seem familiar to us?	Plants take in CO_2. People breathe out CO_2. Fossil fuels come from buried, ancient plants (or some students may say buried ancient dinosaurs).
Where do you notice different molecules that have carbon in them?	CO_2 in the air. Sugars, carbohydrates, proteins, fats in plants, animals, and decomposers. Gasoline, coal, and other fuels in fossil fuels.
How do you see carbon moving between the surface where we live and the atmosphere?	Photosynthesis takes it out of the atmosphere. Cellular respiration puts it into the atmosphere.

Suggested prompts	Sample student responses
How do you see carbon moving between the surface where we live and underground?	Plants and animals from long ago got buried and turned into fossil fuels.
What parts of this model are new or different from what we've talked about?	Combining plants, animals, and decomposers together for cellular respiration may be different. Before we talked about individual organisms and now we're showing all organisms on Earth.✱

Say, *This is really helpful because it captures a lot more things happening with carbon than we've been talking about the past few class periods. But it's also not representing anything that humans are doing to change the system.*

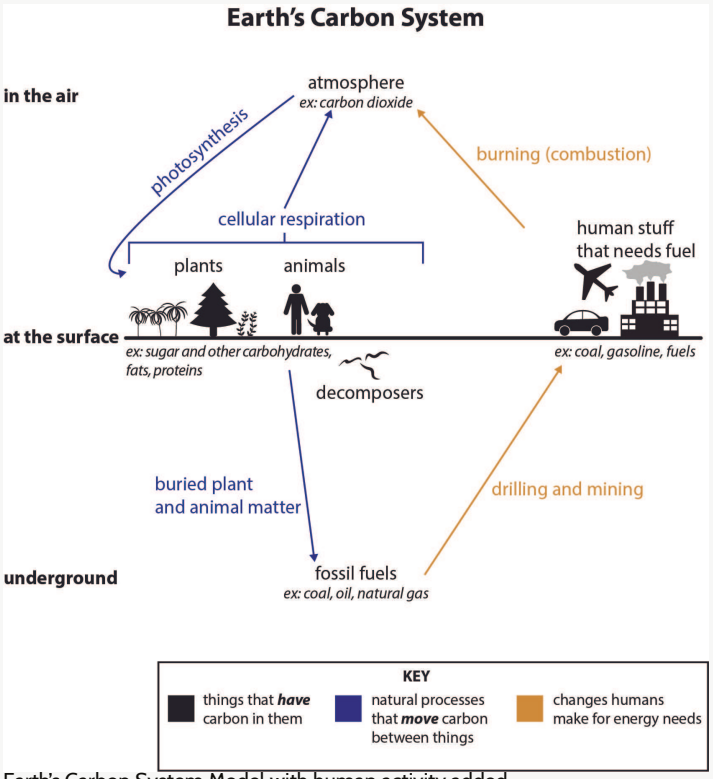
Modify the model with a partner to include human processes that move carbon. Display **slide C.** Have students work with a partner to modify the model. Have them pick a new color to represent how humans change the system. They can add more parts, or locations, to the model. Circulate among partners to see if they are focusing on "combustion" as the main process moving CO_2 into the atmosphere, and drilling and mining as processes that move carbon to the surface. Note: students can use the term 'carbon' to refer to any carbon-containing molecule; they do not need to know specific molecules, other than CO_2.

Briefly, update a class carbon system model with suggested changes. Elicit from students how they modified the model. Make sure to capture students' ideas onto the class model, using a new colored marker. You should have "combustion" and "mining/drilling" represented on the model now as shown in the example.

Display **slide D**. Say, *We have a more complete system model now. Now let's use our model to predict what could be going on in the system to cause CO_2 to increase in the atmosphere. What are some of our ideas?*

Listen for students to suggest:

- *Burning more fossil fuels today that are getting stuck in the atmosphere.*
- *There are two arrows going into the atmosphere and only one coming out, so maybe there is more going in than can come out.*
- *We're cutting down trees, so the photosynthesis arrow is getting smaller.*
- *We're getting more and more people, so the cellular respiration arrow could be getting larger.*



Earth's Carbon System Model with human activity added

Say, *It sounds like you all think the amount of carbon moving between places, which we represented with arrows, could be changing, which results in more CO_2 going into or staying in the atmosphere. I have a game we can play where we can test how this might work.*

3 · TRACK CARBON ATOMS USING THE CARBON DICE GAME

18 min

MATERIALS: dice, Quick Reference Card (optional), digital Carbon Dice Game (optional alternative), *Carbon Dice Game Instructions and Station Cards*, station cards

ALTERNATE ACTIVITY

There are two alternative activities to replace the Carbon Dice Game depending on if you (1) want to add oceans or (2) are teaching in a remote setting. Please visit *Carbon Dice Game Instructions and Station Cards* for more guidance on these alternative versions of the activity. Visit the Key Ideas callout below to help you modify this activity as needed, but stay aligned to the learning goals.

Provide instructions to the Carbon Dice Game. Display **slide E**. Explain that:

- stations around the room represent locations of carbon,
- students are carbon atoms inside different carbon molecules moving through the system,
- students will roll the dice and move to different locations based on the number they rolled,
- when they move they represent a carbon atom moving along one of the arrows from their model,
- round 1 of the game will represent the carbon system when fossil fuels were locked underground, and
- round 2 of the game will represent the carbon system when people started using fossil fuels for energy.

Pass out 1 dice to each student. Pass out the 1 copy of the Quick Reference Card as an optional reference sheet to guide students in moving to the correct location.

Play round 1 of the game. Follow these steps:

- Arrange students in their starting location. Have students in the fossil fuel reservoir remain in their seats.
- Have the students begin round 1 by rolling their dice. Roughly ⅔ of the class will be actively moving through the system, while the other third will be "locked" in the fossil fuel reservoir.
- Pause every couple of rolls and elicit from the fossil fuel students what they are noticing about where different classmates are moving and why.
- Have students complete roughly 10-15 rolls or up to 4 minutes. Students can roll the dice at their own pace and move as quickly as they can. You can pause their movement as needed.

Play round 2 of the game. Follow these steps:

- Introduce the change to the system with the addition of drilling and mining (which unlocks the fossil fuel students) and combustion of fossil fuels. Fossil fuel atoms can start rolling their way into the system.
- Allow students 5-6 minutes to roll their dice and move through the system.
- Pause as needed when you start to notice a buildup in any of the locations or a depletion in locations, such as fossil fuels. If you need to adjust the game, "reset" the students to the starting locations and make adjustments. If you do this, take a minute to share how this simulation of the system is based on "chance" with the roll of the dice. In the real world, the system is much more predictable.
- Once complete, have students return their dice to you and return to their seats.

SAFETY PRECAUTIONS

Make sure to sanitize the dice between classes. You can do this by having students drop the dice in a bowl of warm bleach water at the end of the game and taking the dice out to dry on a paper towel before the next class. One tablespoon of bleach to a gallon of water should be sufficient. Follow guidance from here: https://www.cdc.gov/hygiene/about/when-and-how-to-clean-and-disinfect-your-home.html

4 · FACILITATE A BUILDING UNDERSTANDINGS DISCUSSION AND COMPARE RATES

10 min

MATERIALS: class Earth's Carbon System Model, Model Ideas list

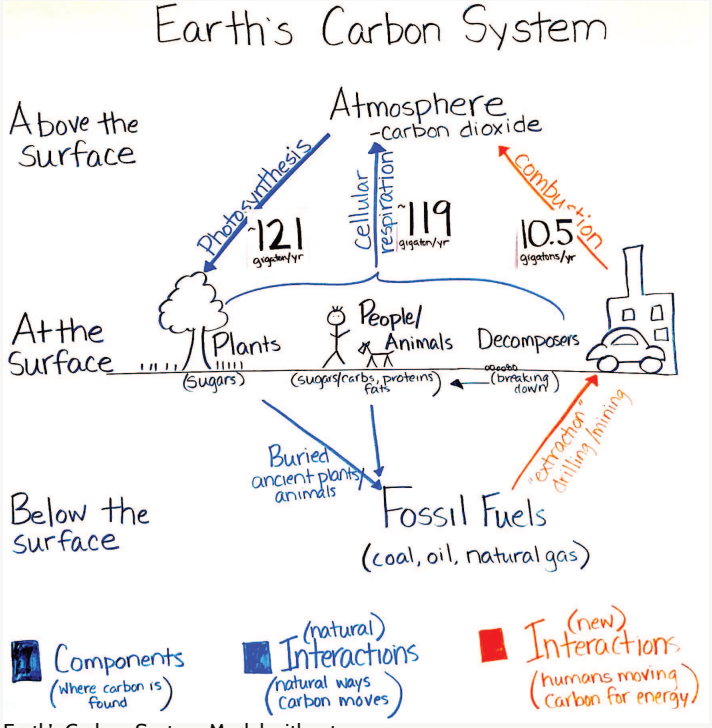
Ask students to share what they noticed during the game. Display **slide F**. Elicit from students what they noticed happened to carbon after combustion was added.

Suggested prompt	Sample student response
How did carbon move through the system before combustion of fossil fuels?	Everyone just moved from place to place. No one got stuck.
What changed in the system when we added combustion?	The only place for the fossil fuel atoms to go was the atmosphere. A lot of us got stuck in the atmosphere together.
Why do we think this change happened?	In the first round there were a lot of us 'locked' in our seats, but in the second round there were a lot more of us moving around.

Give students the actual numbers to the amounts of carbon moving in and out of the atmosphere. Display **slide G**. Using sticky notes, post the numbers, in gigatons of carbon per year (GtC/yr), to the arrows on the class model. Have students add the numbers to their individual system models, too, and calculate the imbalance.

- Photosynthesis takes in 121 GtC/year.
- Cellular respiration adds approximately 119 GtC/year.
- Combustion adds 10.5 GtC/year.
- Imbalance of about 8.5 GtC/year (entering the atmosphere)

Facilitate a Building Understandings Discussion. Display **slide H**. Prompt students to discuss the new information about rates and the imbalance of 8.5 GtC/yr, combined with what they noticed from the Carbon Dice Game.



Earth's Carbon System Model with rates

KEY IDEAS

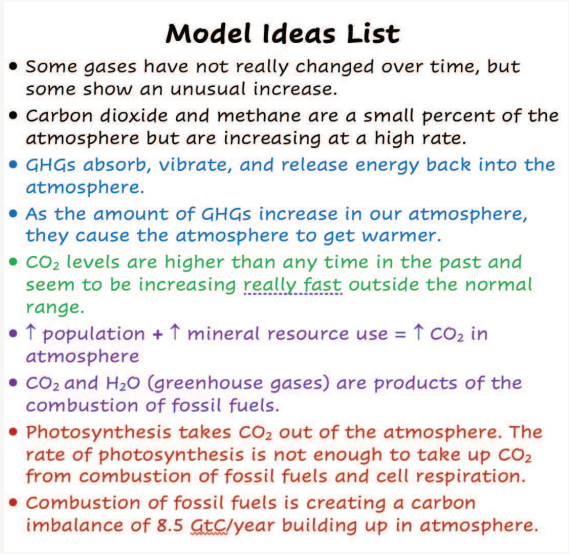
Purpose of the discussion: to engage in mathematical thinking about rates to conclude that combustion is leading to more CO_2 going into the atmosphere than can be taken up by photosynthesis.

What to look/listen for: students to conclude on the following science ideas:

- Photosynthesis and cellular respiration seem to give off and take up CO_2 from the atmosphere at a similar rate.
- Combustion is putting CO_2 into the atmosphere without any process to take it out except photosynthesis.
- Photosynthesis takes CO_2 out of the atmosphere, but the rate of photosynthesis is not enough to take up CO_2 from combustion of fossil fuels and cellular respiration combined.
- Combustion of fossil fuels is creating a carbon imbalance in the atmosphere of about 8.5 Gt/C per year which is why so much CO_2 builds up in the atmosphere.
- The carbon once stored underground is going into the atmosphere when we burn fossil fuels.

Additional guidance: If students wonder about water vapor given off from combustion and its role as a greenhouse gas, explain to students that water vapor stays in the atmosphere for days to weeks, but carbon dioxide stays in the atmosphere for dozens of years to much, much longer. While water vapor is a greenhouse gas, its short life in the atmosphere makes it less problematic.

Add Model Idea(s) to the class list. Display **slide I**. As you facilitate the discussion, ask students what ideas they can synthesize from the evidence they have collected. Ask students to offer suggestions and decide to add 1-2 ideas to the class list. Examples are shown in the image to the right and could be any combination of the Key Ideas listed above. Note there is also an individual assessment moment with the Exit Ticket.



5 · NAVIGATION

2 min

MATERIALS: None

Share thinking on an exit ticket. Display **slide J**. Give students time to complete the exit ticket. Encourage them to use rates to help them compare processes and to explain why CO_2 is building up in the atmosphere.

ASSESSMENT OPPORTUNITY

Building towards: 11.A Apply mathematical concepts to compare the rate of combustion and cellular respiration putting CO_2 into the atmosphere to the rate for photosynthesis taking CO_2 out of the atmosphere leading to an imbalance in the system.

What to look/listen for:

- see the Key Ideas section above,
- students to apply the rates to make sense of the imbalance that occurs when comparing the rate of CO_2 entering the atmosphere from combustion versus the rate of CO_2 taken out of the atmosphere from photosynthesis,
- students use the rates to explain that a net of 8.5 GtC/yr is going into the atmosphere without an offsetting process to take it out.
- students may explain that the processes are not balanced.
- students may explain that when humans started to burn fossil fuels we created a change to the system.

What to do:

- *During the discussion:* If students need additional support, have them return to the graphs from Lesson 10 depicting population growth and energy use and discuss (1) what would we predict will happen to the combustion number given our population growth and needs for energy? and (2) What do we predict could happen to the photosynthesis number given land use choices we learned about in the *Palm Oil Unit*? Have students complete a third round of the dice game but with increased fossil fuel use so that, when they roll the dice, there is more opportunity to leave the fossil fuel reservoir. Have them complete a round with reduced fossil fuel use where there is only one opportunity (rolling a 6) to leave the fossil fuel location. The additional rounds may help students see that the rate of use of fossil fuels can greatly affect buildup of carbon atoms in the atmosphere.
- *In response to the exit ticket:* Review the exit tickets before the assessment in Lesson 12. Depending on what you notice, consider allotting time to (1) look for patterns in responses and identify any partially correct or incorrect responses to inform your next steps. What you do will depend on the patterns you notice, (2) arrange students in groups of 3 with their individual exit tickets. Ask them to use ideas from their individual responses to craft a consensus statement to share with the class. They can exchange their consensus statement for evaluation by another group, and then make revisions.

Additional Lesson 11 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN MATH

CCSS.Math.Content.6.RP.A.3: Use ratio and rate reasoning to solve real-world and mathematical problems.

After 6th grade students should be familiar with unit rates. In this lesson, students use the unit rate of gigatons of carbon per year. Have your students compare rates for photosynthesis, cellular respiration, and combustion to make sense of the increase in carbon dioxide in the atmosphere. Have students compare the magnitude of combustion, which seems far less than the natural processes, yet there is no offset for this source of CO_2.

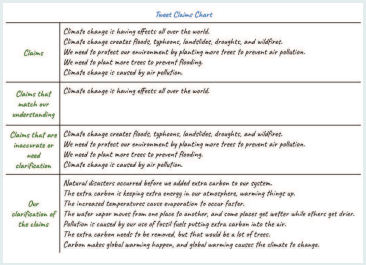
LESSON 12: How are changes to Earth's carbon system impacting Earth's water system?

PREVIOUS LESSON *We modified a model of Earth's Carbon System to represent locations and movement of carbon. We did a kinesthetic activity to simulate these processes before and after human activity. We figured out that photosynthesis cannot take up CO2 at the same rate that burning fuels puts CO2 in the atmosphere, which creates a buildup of CO2 in the atmosphere.*

THIS LESSON

PUTTING PIECES TOGETHER

2 days



Tweet Claims Chart

Claims	Climate change is having effects all over the world. Climate change creates floods, typhoons, landslides, droughts, and wildfires. We need to protect our environment by planting more trees to prevent air pollution. We need to plant more trees to prevent flooding. Climate change is caused by air pollution.
Claims that match our understanding	Climate change is having effects all over the world.
Claims that are inaccurate or need clarification	Climate change creates floods, typhoons, landslides, droughts, and wildfires. We need to protect our environment by planting more trees to prevent air pollution. We need to plant more trees to prevent flooding. Climate change is caused by air pollution.
Our clarification of the claims	Natural disasters occurred before we added extra carbon to our system. The extra carbon is keeping extra energy in our atmosphere, warming things up. The increased temperatures cause evaporation to occur faster. The water vapor moves from one place to another, and some places get wetter while others get drier. Pollution is caused by our use of fossil fuels putting extra carbon into the air. The extra carbon needs to be removed, but that would be a lot of trees. Carbon makes global warming happen, and global warming causes the climate to change.

We develop a model, supported with evidence, of the causal relationship between fossil fuel use and rising air temperatures and changing water resources. We review a tweet regarding climate change and its impacts, and we break the tweet down into claims being made by the author of the tweet. Together, we clarify the information in the tweet. Then, as an individual assessment, we identify claims made in another tweet and refute any inaccurate claims by providing an explanation of the causal relationships between human activities and climate change.

NEXT LESSON *We will define our CO2 problem and use a simulation to determine emissions would have to be reduced by 9 gigatons to maintain current global temperatures.*

BUILDING TOWARD NGSS

MS-ESS3-1, MS-ESS3-3, MS-ESS3-4, MS-ESS3-5, MS-ETS1-2

WHAT STUDENTS WILL DO

12.A Develop a model to describe how fossil fuel use causes changes to the climate, which affects community water resources.

12.B Construct an argument supported by science ideas to refute and clarify claims through an explanation of the causal chain of events between the changing climate and water resources.

WHAT STUDENTS WILL FIGURE OUT

- Changes in the carbon system have an effect on Earth's water system.
- We can use our scientific understanding to clarify claims about the connection between fossil fuel use, the changing carbon system, and Earth's water system.

Lesson 12 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	15 min		**DEVELOP CAUSE-AND-EFFECT DIAGRAMS** Develop diagrams in groups, and then look for similarities across the diagrams and refine them based upon our science ideas.	A-B	*Model Ideas List*, *Cause-and-Effect Diagram*, *Fossil Fuel Use Cause-and-Effect Diagram* (optional), numbered Model Ideas lists from Lessons 1-6 and 7-11, Cause-and-Effect diagram from Lesson 5, Fossil Fuel Use Cause-and-Effect diagram, markers
2	15 min		**DEVELOP A WHOLE GROUP CONSENSUS MODEL**	C	*Model Ideas List*, *Fossil Fuel Use Cause-and-Effect Diagram*, *Cause-and-Effect Diagram* (optional), chart paper with diagram boxes added, markers, Cause-and-Effect diagram from Lesson 5
3	15 min		**CO-CONSTRUCT AN ARGUMENT TO A TWITTER POST** Read a Twitter post and dissect the post for claims. Evaluate the claims as a class and clarify any inaccuracies.	D-E	Tweet Claims chart, markers
					End of day 1
4	10 min		**CLARIFY CLAIMS BASED ON EVIDENCE** Revisit claims that were inaccurate or need clarification, and develop an explanation to revise each claim.	F	Tweet Claims chart, markers
5	5 min		**CONSIDER TWEETS IN THE REAL WORLD** Turn and talk about an encounter with a tweet or other post that was not fully accurate and reflect on the response to that post.	G	
6	25 min		**COMPLETE THE TWEET ASSESSMENT** Go over the assessment and allow work time to complete the assessment.	H	*Version 1: Social Media Post Assessment* or *Version 2: Social Media Post Assessment*
7	5 min		**NAVIGATION** Revisit the model to point out the carbon dioxide imbalance and start to generate ways to help solve the problem.	I-J	Earth's Carbon System Model
					End of day 2

Lesson 12 • Materials List

	per student	per group	per class
Lesson materials	• *Model Ideas List* • *Cause-and-Effect Diagram* • *Fossil Fuel Use Cause-and-Effect Diagram* (optional) • *Fossil Fuel Use Cause-and-Effect Diagram* • *Cause-and-Effect Diagram* (optional) • *Version 1: Social Media Post Assessment* or *Version 2: Social Media Post Assessment*		• numbered Model Ideas lists from Lessons 1-6 and 7-11 • Cause-and-Effect diagram from Lesson 5 • Fossil Fuel Use Cause-and-Effect diagram • markers • chart paper with diagram boxes added • Tweet Claims chart • Earth's Carbon System Model

Materials preparation (25 minutes)

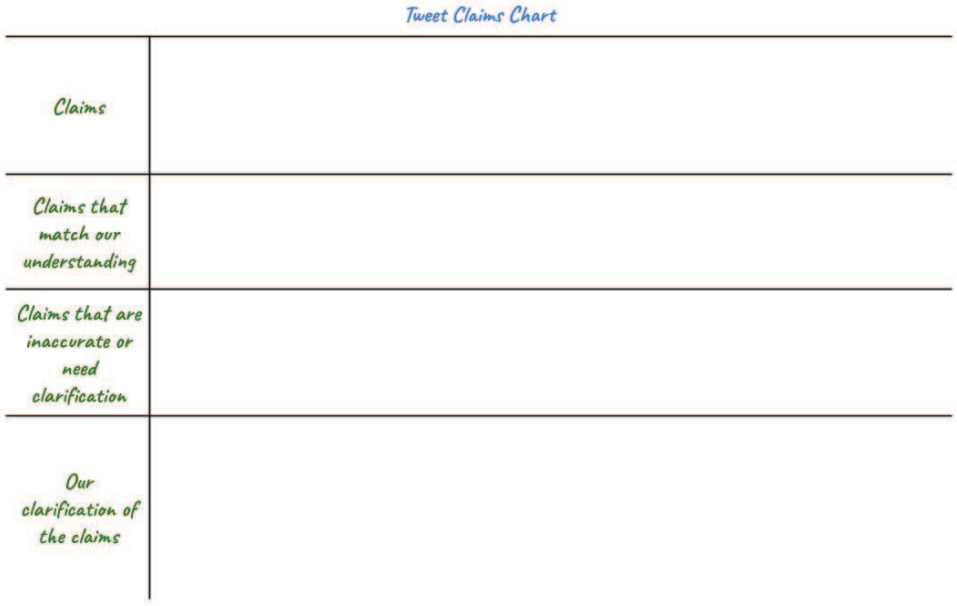
Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Have the Model Ideas lists from Lessons 1-6 and 7-11 available for students to view.

For day 1:

- Construct a chart with two boxes on opposite sides of the chart paper. In the far left box, write "fossil fuel use." In the far right box, write "air temperatures are rising." Title the chart paper "Fossil Fuel Use Cause-and-Effect diagram."
- Number each idea on both of the Model Ideas lists.
- Type the numbered list of model ideas to pass out to students using the handout template *Model Ideas List*. Add or delete rows to the table as necessary. Number the ideas on the class chart to match.
- View *Cause-and-Effect Diagram* to make sure the Cause-and-Effect diagram matches the diagram the class developed in Lesson 5. If the language is slightly different, recreate a version of your class Cause-and-Effect diagram in place of this handout to distribute to students.
- Print off copies of *Fossil Fuel Use Cause-and-Effect Diagram* if desired. This handout can be used in place of students constructing the Fossil Fuels Cause-and-Effect diagram in their notebooks.
- Construct a Tweet Claims chart. Create rows titled "claims," "claims that match our understanding," "claims that are inaccurate or need clarification," and "our clarification of the claims."



For day 2:

- Identify which students will receive *Version 1: Social Media Post Assessment* and which students will receive *Version 2: Social Media Post Assessment* based on their performance on the causal diagram and the progress on the class discussion of the Twitter post on day 1.
  - *Version 1: Social Media Post Assessment* is meant for general class use.
  - *Version 2: Social Media Post Assessment* is meant for students who could benefit from an additional challenge.
- Determine if any students will need additional scaffolds to complete *Version 1: Social Media Post Assessment*. Ideas for scaffolding are located on day 2 of the teacher guide. Prepare any additional scaffolds for students as deemed necessary.

Lesson 12 • Where We Are Going and NOT Going

Where We Are Going

In Lessons 7-11, students will have developed 2 separate lists of model ideas that, when unified, explain how fossil fuel use leads to changes in our water system. During this lesson, students will construct a causal diagram that unifies science ideas to explain how (1) changes in Earth's carbon system from Lessons 7-11 using model ideas assembled from ESS3.A, ESS3.C, and ESS3.D connect to (2) changes that are occurring in the water system using model ideas from ESS3.A, ESS2.D, and ESS2.C assembled in Lessons 1-6 and connects directly to the cause-and-effect diagram developed in Lesson 5. Students will reference and combine ideas from both lesson sets to explain how this causal chain of events explains the anchoring phenomenon of droughts and floods. Students diagram the connections between the two systems in groups and as a class.

Students will use this knowledge of the causal chain of system connections to identify accurate and inaccurate claims made on a social media platform. The social media posts are dissected by the class into claims. Students then determine what is accurate and inaccurate about the claims made and use science ideas and evidence they have collected to modify the claims to be a more accurate reflection of the changes in the carbon and water systems that lead to droughts and floods.

In an assessment, students use the skills of identifying claims and supporting or refuting those claims on another social media post that they work with individually. Students dissect a tweet into individual claims, determine which claims are inaccurate, and select claims to rewrite to reflect current scientific understanding of climate change and its impacts on our water system. Students then work to support these claims using evidence from our model ideas.

Where We Are NOT Going

While it may be apparent for some students at this point that the causal chain of events will continue to increase with the increase in carbon emissions, making future projections about carbon emissions will not be presented and explored until Lesson Set 3, as students delve into the scale of solutions needed to fix the problem. This interrelated portion of ESS3.C and ESS3.D that discusses reducing human vulnerability using science, technology, and engineering ideas will be developed over the course of Lessons 13-18.

LEARNING PLAN for LESSON 12

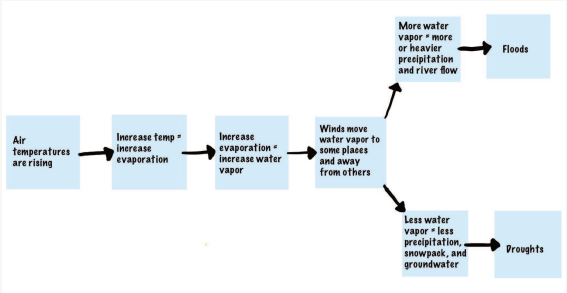
1 · DEVELOP CAUSE-AND-EFFECT DIAGRAMS

15 min

MATERIALS: *Model Ideas List*, *Cause-and-Effect Diagram*, *Fossil Fuel Use Cause-and-Effect Diagram* (optional), numbered Model Ideas lists from Lessons 1-6 and 7-11, Cause-and-Effect diagram from Lesson 5, Fossil Fuel Use Cause-and-Effect diagram, markers

Say, *Last class we determined that we have a carbon imbalance from fossil fuels that seems to be related to our overall global increases in temperatures. We even created a model and updated our model ideas list. Let's see if we can use these ideas to determine how fossil fuels cause our increase in temperatures, which are leading to changing water resources for our communities.*

Revisit the Cause-and-Effect diagram from Lesson 5. Project **slide A.** Remind students that in Lesson 5 we constructed a Cause-and-Effect diagram to show how an increase in temperatures leads to a change in community water resources, such as increased droughts and flooding. Distribute *Cause-and-Effect Diagram* to students. Ask students to turn to a partner and use the diagram to explain how an increase in temperatures leads to increased droughts and floods for some communities. After a brief review in partner pairs, explain that we have done the work to connect these two events, but now we have ideas about what might be causing the increase in temperatures.

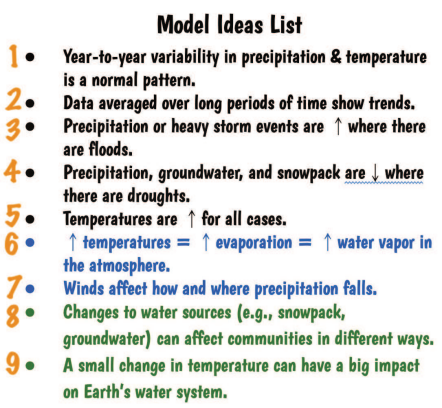


Go over the Fossil Fuel base diagram as a class. Display the Fossil Fuel Use Cause-and-Effect diagram. Explain to students that our last diagram had a starting box that says, "increase in temperatures." Since we have already constructed a model to show how an increase in temperatures has led to the increase in droughts and floods, we will now work to trace fossil fuel use to this cause. Give students time to record this chart horizontally in their science notebooks, leaving plenty of room to fill in approximately 2 more missing boxes in the middle section of their pages. In the box on the far right, have students write "fossil fuel use." In the box on the far left, have students write "increases in temperatures." Alternatively, you can pass out *Fossil Fuel Use Cause-and-Effect Diagram* for students to tape into their notebooks.

Explain to students that in a moment they will work in a small group to determine what boxes need to be added to show how fossil fuel use is resulting in an increase in temperatures, as we did in Lesson 5 from increases in temperatures to increases in droughts and floods.

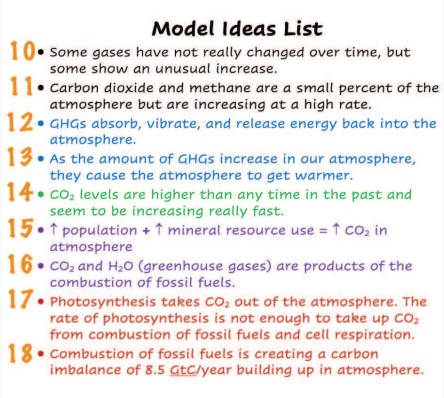
Cue students to connect their diagram to the model ideas. Remind students that as scientists we want to make sure that our thinking is supported by our science ideas, or model ideas. Explain that as scientists, they should make sure that each added box is supported by evidence and the science ideas. Say, *In order to make sure that our ideas are connected to our learning, we will use our Model Ideas lists from our previous lessons. I've numbered the ideas on the lists so that we can easily reference which ones we are using.* Tell students that, as they add boxes, they will use the numbered Model Ideas list to support the ideas and connections in their boxes. Students will do this by adding the corresponding supporting model idea number next to their newly added boxes on their diagrams. Once the connection to rising air temperatures has been made, students will then use their model ideas to support the boxes from the Lesson 5 cause-and-effect diagram.

Pass out the numbered Model Ideas list handout. Distribute a completed copy of *Model Ideas List* to students. Point out how the handout is a copy of the key model ideas compiled in prior lessons by the class. Illustrate to the class how to support the ideas using the numbered Model Ideas lists by doing the first box on the chart paper together.



Model Ideas List

1. Year-to-year variability in precipitation & temperature is a normal pattern.
2. Data averaged over long periods of time show trends.
3. Precipitation or heavy storm events are ↑ where there are floods.
4. Precipitation, groundwater, and snowpack are ↓ where there are droughts.
5. Temperatures are ↑ for all cases.
6. ↑ temperatures = ↑ evaporation = ↑ water vapor in the atmosphere.
7. Winds affect how and where precipitation falls.
8. Changes to water sources (e.g., snowpack, groundwater) can affect communities in different ways.
9. A small change in temperature can have a big impact on Earth's water system.



Model Ideas List

10. Some gases have not really changed over time, but some show an unusual increase.
11. Carbon dioxide and methane are a small percent of the atmosphere but are increasing at a high rate.
12. GHGs absorb, vibrate, and release energy back into the atmosphere.
13. As the amount of GHGs increase in our atmosphere, they cause the atmosphere to get warmer.
14. CO_2 levels are higher than any time in the past and seem to be increasing really fast.
15. ↑ population + ↑ mineral resource use = ↑ CO_2 in atmosphere
16. CO_2 and H_2O (greenhouse gases) are products of the combustion of fossil fuels.
17. Photosynthesis takes CO_2 out of the atmosphere. The rate of photosynthesis is not enough to take up CO_2 from combustion of fossil fuels and cell respiration.
18. Combustion of fossil fuels is creating a carbon imbalance of 8.5 GtC/year building up in atmosphere.

Suggested prompts	Sample student responses
Let's practice using our Model Ideas list to support what we have placed in our first diagram box. Our first diagram box reads, "fossil fuel use." Which model idea supports fossil fuel use as the beginning of our chain of events?	Students should reference the model ideas associated with combustion of fossil fuels and CO_2 emissions.
What number on our Model Ideas list is that idea?	Students should identify the number in front of that model idea. (examples: #16, #18)
OK. Let's write that number underneath our box in our diagram to show that this box is supported by that model idea.	

Take a moment to write the model idea number underneath the first box.

Say, *In your groups we will continue to add boxes until we have shown how fossil fuel use is causing an increase in temperatures. Under each box, add in the model idea number that supports your reasoning behind adding that box. As you go across your diagram, think about how each box causes the next box to occur.*

Generate models in small groups. Project **slide B**. Tell students that after they have had a chance to revise their diagrams, we will get a chance to come together and update them as a class.

Go over **slide B** with students.

- Complete your diagram boxes with your group. Start with the "fossil fuel use" box and work your way over to the "increases in temperatures" box. Explain how each box is connected in your groups.
- Discuss how each box is supported by a model idea(s). Write that model idea(s) number under the box.
- After the boxes from "fossil fuel use" to "increases in temperatures" have been constructed and supported with model ideas, shift to the preconstructed diagram from Lesson 5. Determine which model ideas support the Lesson 5 diagram by adding in the corresponding model ideas numbers under each of the pre-existing boxes.

Direct students to use **slide B** as a guide when working in their groups. Give students roughly 10 minutes in their groups to compile their diagrams, while supporting each box in both the old and new diagrams with their model ideas.

ASSESSMENT OPPORTUNITY

Building towards: 12.A Develop a model to describe how fossil fuel use causes changes to the climate, affecting community water resources.

What to look for/listen for:

- Arrows between each box should show the causal chain between fossil fuel use and changing water resources.
- Fossil fuel use causes increased levels of carbon dioxide in our atmosphere.
- Increased carbon dioxide in the atmosphere leads to an increase in temperatures.
- Look for each box to be supported by the corresponding science ideas from the Model Ideas list.

What to do:

- At this time, this is a formative assessment to gauge student understanding of the connections between the carbon system and water system, and how those are supported by the science ideas built in previous lessons. The class will work together to clarify these ideas in the next step of the lesson, and a summative assessment will be presented in the next class period to assess these ideas.
- Help with the connection between fossil fuel use and increased carbon dioxide: Ask students about what the fossil fuel use does that causes changes in the carbon system and, in turn, the atmosphere.
- Review the relationship established between carbon dioxide and temperatures: Ask students what they observed in Lesson 7 as they were using the interactive and the particle models. Ask students what the particle model of carbon dioxide did with the energy and what that carbon dioxide particle may be doing to the system to eventually lead to changing water resources.
- Help with identifying the model ideas that support increasing temperatures and evaporation rates: Ask students what we noticed increasing temperatures doing to the water in our evaporation columns from Lesson 3. Ask students what our data showed and if this had an effect on our water system, and what model idea explains this.
- Help with identifying the model ideas that support evaporation rates and the movement of water: Ask students, once the water evaporated, what happened to that water? What caused some places to get wetter while others were getting drier? What model ideas help to explain this?
- Help with model idea connections: Point out the specific box that students have not completed or need help with. Ask how the model idea supports the box in question, or what model ideas connect to the science ideas in the box. Ask what model ideas would have an impact on how the box would function in their causal chain of events.

2 · DEVELOP A WHOLE GROUP CONSENSUS MODEL

15 min

MATERIALS: *Model Ideas List*, *Fossil Fuel Use Cause-and-Effect Diagram*, *Cause-and-Effect Diagram* (optional), chart paper with diagram boxes added, markers, Cause-and-Effect diagram from Lesson 5

Organize students in a Scientists Circle to compare diagrams. Ask students to bring their notebooks, *Fossil Fuel Use Cause-and-Effect Diagram* (if used) *Cause-and-Effect Diagram*, a pencil, and *Model Ideas List*. Make sure that the Lesson 5 Cause-and-Effect diagram is posted to the right of the Fossil Fuels Cause-and-Effect diagram and visible to all students in the Scientists Circle.

Say, *We have had some time to work in our groups and determine how fossil fuel use and changing water resources are linked. Our big question we were trying to answer to this point was, How are changes in Earth's system impacting our communities?*

Reflect on our learning to this point. Take a step back with the class and ask students, *Before we start to work on our consensus diagram, how would you say that our thinking about this question has changed since Lesson 1?*

Allow students to respond. Students may generate ideas, such as:

- We used to think that some areas were always having droughts and floods like they are today, but the amount and timing of precipitation is changing in these communities.
- We learned that global warming is having an impact on communities in different ways, and that impact is going to be different depending on where you live and how you normally get your precipitation and water resources.
- We heard that carbon dioxide was causing problems with the atmosphere and global warming but didn't understand how that occurred until now.
- We have learned that, even though there are other gases in our atmosphere, the biggest issue is carbon dioxide, and increasing carbon dioxide is causing temperatures to rise.
- We learned that global warming due to carbon dioxide is changing our climate, which is why we may see more or less precipitation or water than normal.
- Accept all other relevant responses.

Say, *We have come a long way in our thinking about how changes in our carbon system are affecting water for our communities. Let's see if we can work together to model the steps that lead from fossil fuel use to increased temperatures, and how these increased temperatures lead to the water resource changes we are seeing in our communities.*

ADDITIONAL GUIDANCE

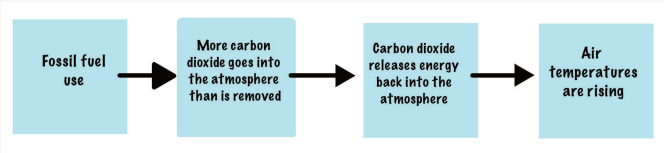
In this lesson, students are actively creating a diagrammatic representation. While a diagram is a type of model meant for use in later grades (*A Framework for K-12 Science Education*, pg. 58), the language used in discussing this diagram with the class shifts from the word diagram to model as students start to use their initial diagrams to explain their thinking and support their thinking with model ideas. Students will be more familiar with the term consensus model rather than consensus diagram. The term model will be used to describe this type of representation.

Develop a consensus model. Project **slide C**. Begin a consensus model discussion by referencing the first box, "fossil fuel use." Remind students that we have placed the number of the corresponding model idea under the box to show that this box is supported by our science ideas. Focus on the first box and ask students about what is happening and what that action causes to happen next in the chain of events. Example prompts and responses are below. It is OK if students want to add extra boxes, such as "the burning of fossil fuels releases carbon dioxide," as you go from step to step in this causal chain.

Suggested prompts	Sample student responses
We started our model with fossil fuel use in the first box. What would we say that our fossil fuel use causes to happen that could cause an increase in temperatures?	Using fossil fuels causes extra carbon dioxide that isn't normally part of the system to go into the atmosphere.
Why is that a problem? Doesn't carbon dioxide naturally exist in our atmosphere?	Carbon dioxide exists, but we are adding way more than there was naturally. We are adding way more than what is in the natural carbon system. More carbon dioxide goes into the atmosphere than there is normally. And photosynthesis, which takes up carbon dioxide, cannot keep up with how much carbon dioxide is going into the atmosphere.

Suggested prompts	Sample student responses
OK. Let's write "more carbon dioxide goes into the atmosphere than is removed" in our second box. *Write the statement in box 2, directly after "fossil fuel use." Connect the two boxes with an arrow pointing to the newly constructed box.*	Allow students to modify their diagrams, if needed.
What evidence have we encountered in our lessons that supports this science idea?	We saw a couple of graphs that showed us that carbon dioxide increases. We saw that the trees and other processes remove carbon dioxide from the air, but we are putting carbon dioxide in the air faster than it can be removed. We burned a fuel, and it gave off carbon dioxide into the air. We learned about ice cores and how much carbon dioxide there has been in the past. With fossil fuel use, we are adding way more than there used to be in our atmosphere.
Great. It sounds like we have a lot of evidence from past lessons that we can use to support this box. What model ideas numbers belong under this box?	Students should reference numbers that correspond to the following model ideas: • Carbon dioxide and water vapor (greenhouse gases) are products of the combustion of fossil fuels. • Photosynthesis is the only way to get carbon dioxide out of the atmosphere. The rate of photosynthesis is not enough to take up carbon dioxide from combustion of fossil fuels. • Combustion of fossil fuels is creating a carbon imbalance in the atmosphere. Students may list others as well.
We've added, "More carbon dioxide goes into the atmosphere than is removed" to our models. What would we say the extra carbon dioxide causes to happen that could cause increases in our temperatures?	The carbon dioxide traps heat. When there is more carbon dioxide, there is more heat trapped.

Guide students in completing the model. Next, generate a box that says, "Carbon dioxide releases energy back to the atmosphere." Continue by asking students to connect this idea to the model ideas and linking this box to the "increase in temperatures" box. Once the "increase in temperatures" box is completed, place the Lesson 5 Cause-and-Effect diagram on the right side of the Fossil Fuels Cause-and-Effect diagram to connect the two processes. Overlap the two boxes that say, "increase in temperatures." Continue across the completed model sections to identify what model ideas support the rest of the now-connected causal chain. Students should be able to answer the following questions about each box that will help guide them from box to box as they work across the causes shown in the models:

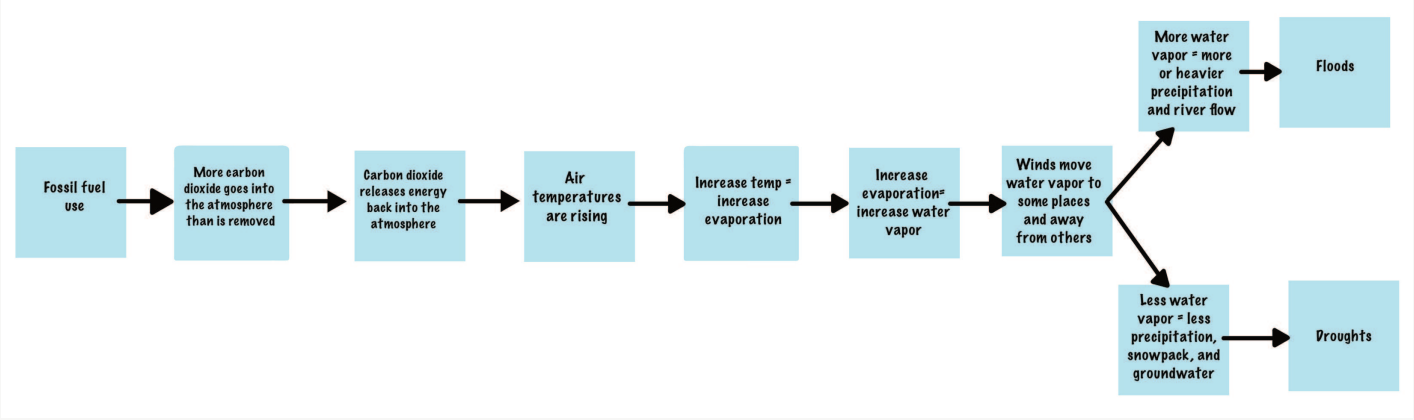


- What evidence have we encountered in our lessons that supports this science idea?
- What model idea numbers support this box?

In addition to listening for the science ideas to support the new Fossil Fuels Cause-and-Effect model, listen for students to identify and explain the following connections in the Lesson 5 Cause-and-Effect diagram:

- Increased temperatures cause increased evaporation rates.
- Increased evaporation rates cause more water to cycle through our water system but in uneven ways.
- Increased water in our water system causes more flooding in some locations, and increased evaporation without replacement by precipitation causes more droughts in other locations.

Students should develop a causal chain that resembles the model below.



Reflect on our learning. After constructing the model, take a moment to reflect as a class on the chain of events that can lead to changes in water resources. Re-read each box and ask students if they agree with the chain of events.

Say, *We have done an excellent job mapping how using fossil fuels adds carbon dioxide to our atmosphere, which affects temperature and water resources. We thought about each part and how that has an effect on the next part of our model. Now that we are able to explain how increased levels of carbon dioxide in our atmosphere can lead to increases in droughts and floods, we can start thinking about using the information to inform others.*

3 · CO-CONSTRUCT AN ARGUMENT TO A TWITTER POST

15 min

MATERIALS: Tweet Claims chart, markers

Say, *We are not the first class or group of people to try and communicate about this problem. Others have been doing so for decades. Some have done a great job of communicating the science behind what is happening, and others have struggled with making the information well understood and accurate.*

Discuss social media claims. Say, *This is especially true when people share their ideas on platforms that have limited characters that may restrict their ability to share the full information. This seems to happen a lot on social*

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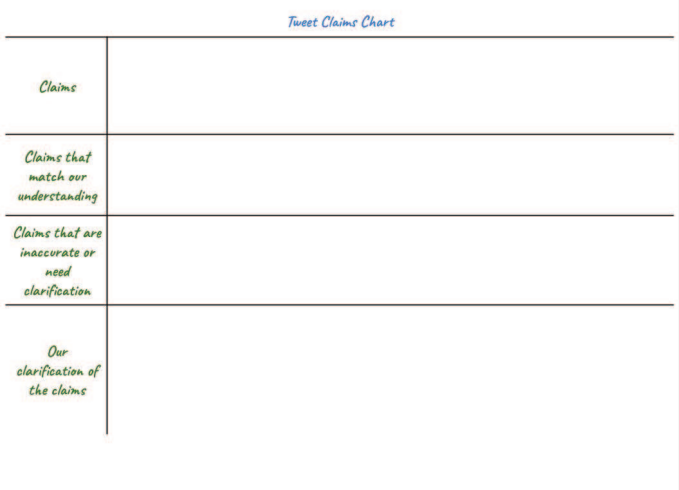
media. I found a tweet that tries to explain the effects of climate change. Let's look at the tweet to figure out if the science is being conveyed accurately, or if the person has missed something due to the character limit.

Display **slide D**. Allow students to read the claim and turn and talk to a partner about the prompt on the slide:

- What does this person claim climate change is doing?
- What other claims are being made in this tweet?

Allow students 1-2 minutes to talk to their partners before bringing the class back together. Have 2-3 students share some of the claims that were made.

Display the Tweet Claims chart. Say, *I heard a lot of different claims you were discussing. Let's dissect the tweet line by line as a class.* Read the tweet out loud and discuss each claim as it is given. Record each claim in the area labeled "claims" on the Tweet Claims chart. Example prompts and responses are below.



Suggested prompts	Sample student responses
Let's read the first sentence together—"This is the effect of #Climatechange in all over the world." What claim is the author of this tweet making in that first sentence? *OK. Let's add that to our claims chart.*	Climate change is having effects all over the world.
The second sentence says, "It create flood, typhoon, landslide, drought, and wild fires." What is the second sentence claiming? *OK. Let's add that claim to our chart.*	Climate change creates floods, typhoons, landslides, droughts, and wildfires.
The third sentence reads, "We must protect our environment and plant more tree to prevent air pollution and flooding in the future." What claim is being made here? *Great. Let's add those claims to our charts.*	We need to protect our environment by planting more trees to prevent air pollution. We need to plant more trees to prevent flooding.
Are there any claims that are developed over several sentences or general statements this person is trying to make?	Climate change is caused by air pollution.

At this point, the following claims should be added to the "claims" section of the chart:

- Climate change is having effects all over the world.
- Climate change creates floods, typhoons, landslides, droughts, and wildfires.
- We need to protect our environment by planting more trees to prevent air pollution.

- We need to plant more trees to prevent flooding.
- Climate change is caused by air pollution.

Say, *Now that we have dissected the tweet into claims, let's take a moment to think about which claims we have evidence to support and which claims need clarification.*

Determine which claims need clarification. Project **slide E**. Give students 2 minutes to turn and talk to a partner about the claims, and what evidence we have that supports each claim.

Bring the class back together and have students share their responses. Students should identify that the following claims are supported by our current understanding:

- Climate change is having effects all over the world.

Ask students what evidence we have to support this understanding. Students should cite the data from multiple case studies from Lessons 1-5 and data showing an increase in carbon dioxide from Lessons 6-9.

Ask students which claims need clarification. Students should identify the rest of the claims for clarification:

- Climate change creates floods, typhoons, landslides, droughts, and wildfires.
- We need to protect our environment by planting more trees to prevent air pollution.
- We need to plant more trees to prevent flooding.
- Climate change is caused by air pollution.

At this point, the chart should reflect the ideas in this example chart.

Tweet Claims Chart

Claims	Climate change is having effects all over the world. Climate change creates floods, typhoons, landslides, droughts, and wildfires. We need to protect our environment by planting more trees to prevent air pollution. We need to plant more trees to prevent flooding. Climate change is caused by air pollution.
Claims that match our understanding	Climate change is having effects all over the world.
Claims that are inaccurate or need clarification	Climate change creates floods, typhoons, landslides, droughts, and wildfires. We need to protect our environment by planting more trees to prevent air pollution. We need to plant more trees to prevent flooding. Climate change is caused by air pollution.
Our clarification of the claims	

Say, *Awesome. We have identified claims that match our understanding and some that need a little work to be more accurate. In the next class we will spend some time thinking about how we can explain these claims more accurately in a way that matches our science understanding.*

End of day 1

4 · CLARIFY CLAIMS BASED ON EVIDENCE

10 min

MATERIALS: Tweet Claims chart, markers

Recall last class period. Students should recall that they looked at a tweet, broke the tweet down into claims, then sorted the claims based upon whether the claims reflected our own understanding of climate change.

Say, *We figured out the claims could be clarified to be more accurate. Let's brainstorm how to do that.*

Turn and talk about claim explanations. Project **slide F**. Give students 2-3 minutes to read over the claims with their partners and determine how they would clarify them using our science ideas.

Bring the class back together and start working through each claim together. Discuss how each could be clarified to be more accurate. Record their new ideas in the section of the chart titled *Our clarification of the claims.* Example prompts and responses are below.

Suggested prompts	Sample student responses
The first claim we identified was "Climate change creates floods, typhoons, landslides, droughts, and wildfires." We added that to the area that said we needed to clarify this claim. What seems inaccurate about it?	Climate change doesn't create those disasters. Those disasters were around before we started to add extra carbon dioxide to the system. The carbon dioxide just makes the natural disasters worse.
OK. Let's clarify this idea to explain what is actually happening. We said that climate change didn't create these disasters, but they've always been around. How can we explain how climate change made them worse?	The extra carbon is causing extra energy to stay trapped in our atmosphere, warming things up. The increased temperatures are causing evaporation to occur faster, and there is more water vapor in the air in some places and not others. That causes an increase in these natural disasters.
OK. Let's add all of these ideas to the chart.	(Students may restate ideas as they are being added to the chart.)
Let's look at the next claim we identified, "We need to protect our environment by planting more trees to prevent air pollution." How is this inaccurate?	Planting trees won't prevent air pollution. Air pollution is created by us using fossil fuels. Planting trees can take up carbon dioxide.
Let's add those ideas to our chart. How could we explain what is actually happening?	We are using fossil fuels and putting extra carbon dioxide into the air. Extra carbon dioxide needs to be taken out somehow and trees are one way to do this.
Let's add those ideas to our chart. Our next claim is "We need to plant more trees to prevent flooding." What is inaccurate about this statement?	Flooding has been around before climate change. Planting trees will not stop floods from happening.

Suggested prompts	Sample student responses
Do we already have something on our chart that helps clarify or explain how this actually works?	Yes, we explained how carbon dioxide increases temperatures. We explained how the temperatures cause more evaporation, and how some places get more flooding.
OK. Let's look at our last claim. Climate change is caused by air pollution. What is inaccurate about this claim?	Air pollution is a lot of stuff. What we're worried about is too many greenhouse gases, like carbon dioxide. And carbon dioxide causes global warming, not climate change. Climate change happens because of global warming. They missed a step.
So, how could we clarify or explain this claim?	We already have the process of how carbon dioxide warms the atmosphere on our chart, so we just need to add that carbon dioxide makes global warming happen and that global warming causes the climate to change.

Here is an example of a completed Tweet Claims chart.

Tweet Claims Chart

Claims	Climate change is having effects all over the world. Climate change creates floods, typhoons, landslides, droughts, and wildfires. We need to protect our environment by planting more trees to prevent air pollution. We need to plant more trees to prevent flooding. Climate change is caused by air pollution.
Claims that match our understanding	Climate change is having effects all over the world.
Claims that are inaccurate or need clarification	Climate change creates floods, typhoons, landslides, droughts, and wildfires. We need to protect our environment by planting more trees to prevent air pollution. We need to plant more trees to prevent flooding. Climate change is caused by air pollution.
Our clarification of the claims	Natural disasters occurred before we added extra carbon to our system. The extra carbon is keeping extra energy in our atmosphere, warming things up. The increased temperatures cause evaporation to occur faster. The water vapor moves from one place to another, and some places get wetter while others get drier. Pollution is caused by our use of fossil fuels putting extra carbon into the air. The extra carbon needs to be removed, but that would be a lot of trees. Carbon makes global warming happen, and global warming causes the climate to change.

Say, *Great. It looks like we have broken down this tweet and clarified each of the inaccurate claims. While we did a great job with this tweet, I know of several other posts that could also use more clarification. I would imagine that we have all encountered some posts that need further explanation like this one.*

ADDITIONAL GUIDANCE

The Nature of Science in the NGSS
This lesson offers a good opportunity for students to reflect on their learning across two lesson sets, particularly as it relates to the evidence they have gathered to support explanations of phenomena.

According to NGSS *Appendix H*, in middle school, students should learn that "theories are explanations for observable phenomena" and that "the term 'theory' as used in science is very different from the common use outside of science" (p. 5). Consider taking a moment to engage students in a conversation about where they have heard the word *theory* before. Students may suggest that a theory is an idea that hasn't been proven or an educated guess. Accept all responses and then tell students, *Scientists are very specific when they talk about a theory. A theory tells us how and why something happens that we can observe. We collect observable evidence of cause-and-effect relationships in order to lend support for a theory.*

You might consider sharing even more with students about the word theory. Sometimes, scientific ideas are said to be "just a theory." This is said about biological evolution, for example, or the link between anthropogenic greenhouse gases and climate change. This use of theory is often deployed in order to make it seem like these ideas are not widely accepted. In everyday talk, the word theory means just a hunch, but in science, a theory is a powerful explanation for a broad set of observed phenomena. A theory must be supported by many different kinds of evidence in order to be accepted by the scientific community, like evolution and anthropogenic climate change have. Even scientists sometimes use the word *theory* when they really mean an explanation, a hypothesis, or a hunch.

In high school, students will learn that a scientific theory can be disproven when the body of evidence weighs against it. According to NGSS Appendix H, "A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that has been repeatedly confirmed through observation and experiment, and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence."

5 · CONSIDER TWEETS IN THE REAL WORLD

5 min

MATERIALS: None

Reflect on past experiences with inaccuracies. Project **slide G**. Have students turn and talk about the questions on the slide.

- Have you encountered another tweet or a different social media post about global warming or climate change that may not be fully accurate?
- Did you correct the inaccuracies, either in your head or on the social media platform? What was the inaccuracy?

Allow students up to 2 minutes to discuss the questions. Then ask 2-3 students to share with the class.

Say, *In a moment, you will get a tweet. Using our scientific understanding of global warming and climate change, you will break down the tweet into claims and clarify any inaccuracies. We will use the same process we used for the last tweet.*

ALTERNATE ACTIVITY

At this point, the breakdown of the previous tweet is still posted for students to see. Use your discretion in determining if the tweet and the explanation will remain up during the assessment. If students would benefit from seeing the tweet broken down into claims, consider covering only the last row of the Tweet Claims chart so that the claims are visible, but the correction of the inaccuracies is covered.

6 · COMPLETE THE TWEET ASSESSMENT

25 min

MATERIALS: *Version 1: Social Media Post Assessment* or *Version 2: Social Media Post Assessment*

Distribute the assessment. Project **slide H**. Allow students to use the *Model Ideas List* handout. Go over each area of the assessment and explain how it is structured in the same manner as the last tweet that was broken down by the class. If desired, allow students to choose which tweet they would like to analyze, and give the choice take the assessment orally.✱ Answer any questions students may have about the assessment. After the assessment has been explained, allow students time to complete the assessment.✱

ASSESSMENT OPPORTUNITY

Building towards: 12.B Construct an argument supported by science ideas to refute and clarify claims through an explanation of the causal chain of events between the changing climate and water resources.

What to look for/listen for: See *Tweet Claims Assessment Key* for guidance.

What to do:
If students need help developing the claims:

- Remind students to start going line by line to look for individual claims.
- Re-read the tweet at the end. Summarize the meaning of the tweet to look for overarching claims.
- Read each sentence out loud and ask what the author is saying about the topic.
- If students need help determining if claims match our science ideas:
    - Point out an individual claim. Ask if the claim is supported by any model ideas from the class list.
- If students need support crafting reasoning to refute the science ideas:
    - Articulate one sentence that is the scientifically accurate version of the claim.
- Direct students to look at the model ideas.
- Ask students which model ideas explain the scientifically accurate version of the claim.

ALTERNATE ACTIVITY

There are two versions of this assessment, *Version 1: Social Media Post Assessment* and *Version 2: Social Media Post Assessment*. *Version 1: Social Media Post Assessment* is considered to be the assessment on level with current student understanding. *Version 2: Social Media Post Assessment* is intended for students who would benefit from an additional challenge. It may be beneficial for some students to take this assessment orally. If this option is used, schedule a time to administer this assessment orally to the students that prefer this method or would benefit from oral administration.

✱ ATTENDING TO EQUITY

Supporting Universal Design for Learning: Providing students the opportunity to choose the level of perceived challenge by selecting a tweet of their choice can support student engagement and help develop self-determination, pride in accomplishment, and increase the degree to which they feel connected to their learning.

✱ ATTENDING TO EQUITY

Universal Design for Learning: Some students may benefit from assistance in *comprehending* the task and materials. If students need additional structuring to complete *Version 1: Social Media Post Assessment*, the assessment can be scaffolded by giving students the claims as part of the assessment, instead of having students dissect the claims from the tweets. A second scaffold could also be to distribute *Model Ideas List* to students needing additional scaffolds and allowing them to use the model ideas to complete the assessment. These scaffolds can be used together or independently from each other, depending on the needs of the individual student.

7 · NAVIGATION

5 min

MATERIALS: Earth's Carbon System Model

Refocus attention on the carbon dioxide imbalance. Collect the assessment from students. If students are not finished, set up an alternative time for students to complete the assessment. Draw attention to the Earth's Carbon System Model. Say, *We have spent a lot of time focusing*

on the processes that are involved with the carbon system and how that affects our water system. Point out that we have identified the imbalance of carbon dioxide as the reason why the water system is changing. Project **slide I**. Ask students to turn and talk to a partner about the questions on the slide:

- Do you think this carbon dioxide imbalance is going to stay the same or get worse?
- In our group tweet we saw that someone mentioned trees as a way to help with the carbon dioxide imbalance. What ideas do you think would work to help with this carbon dioxide imbalance?

Allow 2-3 students to share out if they think it will stay the same or get worse, and what ideas they have heard of to help with the carbon dioxide imbalance. Ask students, *Does this make you wonder anything about our carbon imbalance or about any solutions to the carbon imbalance?*

Allow a couple of students to share out any questions they have. Prompt students to add any questions they have to the Driving Question Board. Display **slide J**. Say, *It sounds like we have heard of other solutions, and we think the problem is only going to get worse unless we do something about it. For the next class period, let's try to make a list of some different solutions we have heard of and see if those will really help our problem.*

HOME LEARNING OPPORTUNITY

Use **slide J**. Ask students to take a piece of paper home and record any ideas they can think of to help with the carbon dioxide imbalance problem. These ideas on how to reduce carbon dioxide in our atmosphere will be the focal point of the next lesson set, as students focus on solutions to the problem.

Additional Lesson 12 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA

CCSS.ELA-LITERACY.W.7.1: Write arguments to support claims with clear reasons and relevant evidence.

Students engage in writing arguments to support or refute claims made in social media posts. They are encouraged to support their arguments with evidence and model ideas they have figured out in the unit.

LESSON 13: Why is solving the climate change problem so challenging?

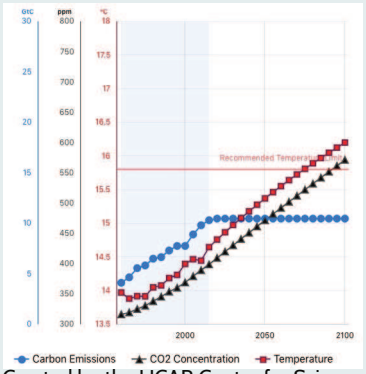
PREVIOUS LESSON

We developed and supported a causal model between fossil fuel use and rising air temperatures causing changing water resources. We reviewed a tweet regarding climate change and its impacts and broke down the tweet into individual claims. We clarified the tweeted information as a class. Then, as an individual assessment, we examined claims made in another tweet and used science ideas and evidence to clarify and refute the claims made.

THIS LESSON

PROBLEMATIZING

1 day



Created by the UCAR Center for Science Education (scied.ucar.edu)

We determine that the problem of increasing temperatures is due to the CO2 imbalance in the atmosphere, which is being caused by combustion of fossil fuels. We use a simulation that projects temperature and atmospheric carbon into the year 2100 and discover that emissions would have to be reduced by 9 gigatons to maintain current global temperatures, with a maximum of 1-2 gigatons of global CO2 emissions a year.

NEXT LESSON

We will calculate our carbon footprint and share our impact on the class Carbon Scoreboard. We will calculate the class average and compare it to the average American footprint. We will revisit our footprint and do a carbon reduction priorities list by selecting 2-4 changes to make that would reduce our footprint and benefit our family in other ways. We will compound the effects of these changes if more people could make similar changes.

BUILDING TOWARD NGSS

MS-ESS3-1, MS-ESS3-3, MS-ESS3-4, MS-ESS3-5, MS-ETS1-2

WHAT STUDENTS WILL DO

13.A Use the carbon dioxide model simulation to generate data and test ideas about different emissions rates scenarios to determine how to reach carbon dioxide equilibrium in the atmosphere.

WHAT STUDENTS WILL FIGURE OUT

- Our carbon imbalance in our atmosphere is mostly due to human combustion of fossil fuels.
- We release an estimated 10.5 gigatons of CO_2 per year from human combustion.
- Simply cutting emissions in half will not halve the temperature increase.
- To reach CO_2 emissions equilibrium, emissions would need to be cut by 9 gigatons per year.
- Any reduction in emissions helps to slow the global temperature increase.

Lesson 13 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	5 min		**REVISIT EARTH'S CARBON SYSTEM MODEL** Look back at Earth's Carbon System Model and initially determine how to solve the carbon imbalance.	A	Earth's Carbon System Model, Defining the Problem chart
2	7 min		**INTRODUCE UCAR SIMPLE CLIMATE MODEL** Introduce the climate model and explain the different features and variables to manipulate.		UCAR Simple Climate Model simulation, computer and projector
3	15 min		**USE SIMULATION TO TEST IDEAS ON CARBON EMISSION SCENARIOS** Use *UCAR Simple Climate Model Observation Tracker* and the *UCAR Simple Climate Model* to test cutting carbon emissions to different amounts and determine the effects of cutting those emissions on temperature and atmospheric CO_2 concentrations.	B-C	*UCAR Simple Climate Model Observation Tracker*, UCAR Simple Climate Model, computer or device
4	10 min		**DISCUSS SIMULATION RESULTS** Use the findings recorded on *UCAR Simple Climate Model Observation Tracker* to determine the changes that need to occur to CO_2 levels in the atmosphere.	D	*UCAR Simple Climate Model Observation Tracker*
5	8 min		**BRAINSTORM HOW WE MIGHT BE CONTRIBUTING AND WHAT WE CAN DO ABOUT IT** Develop initial ideas for what we or others are doing to cut carbon emissions. Assign the *Home Carbon Audit* as home learning.	E-F	*Home Carbon Audit*

End of day 1

Lesson 13 • Materials List

	per student	per group	per class
Lesson materials	• *UCAR Simple Climate Model Observation Tracker* • *Home Carbon Audit*	• UCAR Simple Climate Model • computer or device	• Earth's Carbon System Model • Defining the Problem chart • UCAR Simple Climate Model simulation • computer and projector

Materials preparation (25 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

For day 1:

- Create a chart titled "Defining the Problem;"
    - Label the first row "Problem we are trying to solve."
    - Leave space under this row for two more rows to be added in Lesson 15.
- Test out the *UCAR Simple Climate Model* at https://scied.ucar.edu/interactive/simple-climate-model to make sure that it is compatible with your browser.

Lesson 13 • Where We Are Going and NOT Going

Where We Are Going

Students will revisit the Earth's Carbon System Model to identify that the cause of the CO_2 imbalance is human combustion of fossil fuels (ESS3.D). Students will use the *UCAR Simple Climate Model* to test their theories on the needed rate of CO_2 emissions cuts that need to be made to reduce global temperatures. Students realize that the increase in human activity has reached a point that requires an emissions cut of over half to reach equilibrium. This aligns with the ideas that, as our consumption increases, so do our negative impacts on Earth (ESS3.C.). Students come to realize that our current emissions rate will cause temperatures to rise above the recommended limit and that our human activities will need to be altered or engineered so that the temperature increase does not occur to this level. Ideally this increase is eliminated (ESS3.C.).

Students have previously used simulations to test theories and generate data, most notably in the previous unit, *OpenSciEd Unit 7.5: How does changing an ecosystem affect what lives there? (Palm Oil Unit)*. The design of this lesson assumes that students have developed this aspect of the practice; add or remove scaffold around the simulation to fit your students development of this practice.

Using the lens of Stability and Change in this lesson will help students understand the need to cut carbon emissions significantly to regain temperature equilibrium. This understanding will then motivate their work in Lessons 14-17 as students investigate different solutions aimed at cutting emissions and bringing us closer to equilibrium.

Where We Are NOT Going

During this lesson, students will only begin to brainstorm different solutions to our problem. They will examine their home energy, transportation, and food use for home learning and use the data they collect on the home audit in the next lesson to figure out how these things impact CO_2 levels in the atmosphere. They will examine in-depth and varied solutions in Lesson 15. Further, human behavior and considering the likelihood of adoption by others is going to occur within Lessons 15 and 16 (ESS3.D).

LEARNING PLAN for LESSON 13

1 · REVISIT EARTH'S CARBON SYSTEM MODEL

5 min

MATERIALS: Earth's Carbon System Model, Defining the Problem chart

Define the problem. Say, *Last class we looked at the Earth's Carbon System Model. We made connections between these changes in the carbon system, the increases in global temperatures, and the changes in our water system. We know that we need to help prevent further changes to our water system or our case sites will only experience worse events. As we work to determine how to solve the problem, we first need to identify the big problem that we need to solve. What problem did we discover by looking at this model?*✱

Students should identify that we have more carbon entering the atmosphere than is being taken out. Ask students to explain, in their own words, what problem this extra carbon in the atmosphere is causing. Students will state that the carbon in the atmosphere is causing an increase in global temperatures, which is affecting the water resources that communities depend on. Take a moment to document the problem, too much carbon dioxide is being added to the atmosphere causing an imbalance, on the chart paper titled, "Defining the Problem."

Say, *We have identified that we have too much atmospheric* CO_2 *and that imbalance is causing temperatures to increase. Let's look back at our model and think about what area of carbon production is causing this imbalance.*

Project **slide A**. Allow students to turn and talk about the questions on the slide.

- What area of our model is causing this imbalance?
- What makes the most sense to cut or limit to fix this carbon imbalance?

Discuss the cause of the carbon imbalance. Bring students back together and discuss the questions as a class. As the imbalance is being discussed, point out the area of imbalance on the model. Example prompts and responses are below.

Suggested prompts	Sample student responses
Looking at our model, what area seems to be causing this imbalance?	The unbalanced part seems to be coming from combustion of fossil fuels. The respiration and photosynthesis seem to almost cancel each other out; the part that isn't canceled out is the combustion area. Point out this imbalance on the Earth's Carbon System Model as students are referencing combustion, respiration, and photosynthesis.
Thinking about this imbalance on our model, what makes the most sense to cut or limit to fix our carbon imbalance?	The imbalance is the combustion, so we should either cut or limit that area of the model. We probably need to cut or limit our use of fossil fuels. We have a lot of the carbon taken out by photosynthesis. We need to stop cutting trees or plant more trees.

Identify potential impacts of decreasing carbon emissions. Speculate with students what limits to combustion we might need to happen to solve the imbalance in our carbon system and maintain current temperatures. Example prompts and responses are below.

✱ SUPPORTING STUDENTS IN ENGAGING IN ASKING QUESTIONS AND DEFINING PROBLEMS

Use this opportunity to reinforce with students how to define a (design) problem. Students will have experience with defining problems from the *Palm Oil Unit* but can apply their understanding in this new context. Allow students time to recognize the complexity of the problem and to realize that if it was easy to solve, it wouldn't be much of a problem.

Suggested prompts	Sample student responses
One solution we have identified is the need to cut or limit our combustion of fossil fuels. How much do you think we would have to cut to see a change in our global temperatures and our carbon imbalance?	I think we need to cut it all out. Just stop using it. Maybe we could cut it in half, and that would help the imbalance. If we cut it, any amount will be better than it is now. I'm not sure how much we would have to cut to solve our problem with the imbalance, but maybe a small cut would help temperatures not to increase. Accept all other speculative responses.
Since carbon is what contributes to warming, how might reducing the amount of carbon emissions affect the amount of carbon in our atmosphere?	There would be less carbon in the atmosphere. The amount of carbon could possibly still increase unless something is pulling it out. Accept all other speculative responses.
Do you think temperatures would go down if we reduce carbon emissions generated by combustion?	It makes sense that, the less carbon we use, the less the temperatures would be. It may make the temperatures go down. The temperatures might stay the same. The temperatures might still increase but not as much. It may depend on how much carbon emissions we cut. The carbon stays in the air for a long time, so maybe the temperatures just wouldn't rise as fast. The temperatures might stay warm if the carbon is still in the atmosphere, even if we stop emitting all the extra carbon. I think we have to cut it to 0 to see the temperatures decreasing.

Say, *We seem to have different ideas about what would help our carbon imbalance and what might help reduce global temperatures, but we need more information. We have a simulation that might help us see what happens to the temperatures and the amount of CO_2 in the air if we cut our carbon emissions. We can use this to test out some of our ideas.*

ADDITIONAL GUIDANCE

The simulation presented to students shows that a simple decrease in carbon emissions will not be enough to counter the effects of climate change. The simulation also shows that even cutting emissions in half still leads to increasing temperatures.

- The CarbonTIME project at Michigan State University has found that students may struggle with this idea conceptually and that it may be counter to what students believe. To support conceptual understanding, focus on the math of the different ways carbon is added or removed in the Earth's Carbon System Model, which, if added up, would indicate that emissions of CO_2 from combustion need to be less than 2 GtC/yr for natural processes to keep up. (Note: This is a very simple carbon system model without the inclusion of oceans and other components/processes. The limitations of the simple model can be an opportunity for rich discussion with your students.)
- Through this figuring out process, students will determine that the carbon emissions problem is larger than they may have once thought or believed. The simulation will complicate the problem for students and cause students to realize that emissions will need to be cut drastically. The purpose of this lesson is to "problematize" the carbon imbalance problem for students without disheartening them. If students seem shocked or concerned, explain to students that we can use the findings from the simulation to help figure out what to do about the problem and how we can be part of the solution. Emphasize that the problem is solvable, and our goal is to figure out what will work best for us and our community.

2 · INTRODUCE UCAR SIMPLE CLIMATE MODEL

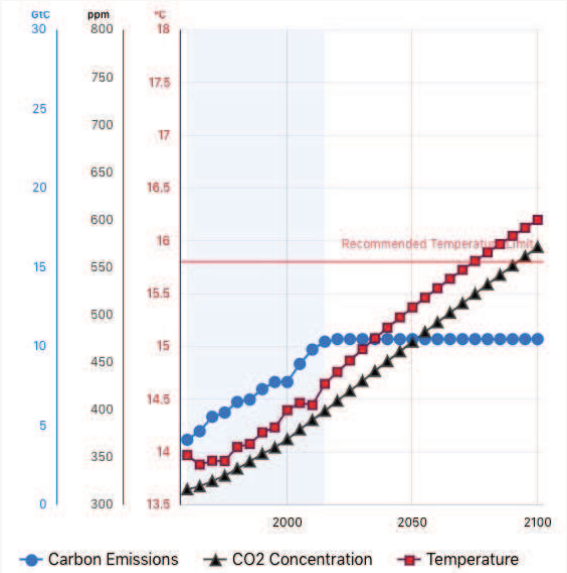
7 min

MATERIALS: UCAR Simple Climate Model simulation, computer and projector

Project the *UCAR Simple Climate Model* simulation (found at https://scied.ucar.edu/interactive/simple-climate-model) for students to view. Explain to students that this simulation shows data for carbon emissions, CO_2 concentration in the atmosphere, and the temperature over the past 55 years. The graph starts in 1960, and the data is accurate up until 2015, where the model simulation begins to estimate the impacts of changing carbon emissions through the year 2100. When play is pressed on the model, the simulation will fill in the data using their mathematical model to show what is projected to happen up until the year 2100.✱

Establish what each line on the graph means. Ask students about what each line represents. Students should identify that the blue line represents carbon emissions, the black line represents the amount of CO_2 in the air, and the red line represents temperature. Ask students what, if any, trends they notice. Students should identify that, as the amount of carbon emissions increases, so do the temperatures along with the CO_2 concentrations.

Explain the recommended temperature limit. Point out the red line at the top of the graph. Explain that this red line represents the recommended temperature limit. This recommended temperature limit is the limit to which we believe the planet can warm without facing potentially dangerous impacts of climate change.



Data after the baseline test is completed Created by the UCAR Center for Science Education (scied.ucar.edu)

✱ ATTENDING TO EQUITY

Universal Design for Learning: If you have students who may struggle with making sense of all three graphed variables at once, turn off one of the variables, such as temperature. Focus students on the relationship between two variables that they know about (e.g., emissions and CO_2 concentration in atmosphere). Then click off emissions and turn on two other variables (e.g., CO_2 concentration and temperature). Discuss this known relationship and how it appears when graphed. When students are ready, turn on all three variables. Scaffolding their experience with data will support students' *perception* and *comprehension* with different *representations.*

✱ SUPPORTING STUDENTS IN ENGAGING IN USING MATHEMATICS AND COMPUTATIONAL THINKING

Say, *Our current emissions are set at 10.5 gigatons per year on this simulation. What would we expect to see happen to all 3 lines if we pressed play?* ✱

Allow students to speculate over what might occur if the emission rates were to hold constant at 10.5 GtC/yr for the next 2100 years. Accept all ideas from students. Potential responses could include the following:✱

- *The temperatures will continue to increase.*
- *The temperatures will stay the same.*
- *The carbon emissions line will stay the same.*
- *The CO_2 concentration line will stay the same.*
- *The CO_2 concentration line will go up.*

Establish a baseline for the comparison of changing emission data. Run the simulation for students. Point out after the simulation has run that the blue area reflects the graph area we started with before the simulation began, and the white area of the graph reflects the data generated by the simulation. After the simulation has run, discuss the results.

Suggested prompts	Sample student responses
What do we notice about carbon emissions as we run the simulation?	The carbon emissions line stayed the same.
Why do you think that it stayed the same?	Because we didn't change it. We kept it the same.
Does that seem in-line with what we think will happen in the future?	Possibly. Maybe we can keep emissions to the same point in the future. We learned that, when population goes up, emissions keep going up, and the graphs all show everything is mainly increasing over time. The emissions will just keep increasing as other countries start to use more fossil fuels. The emissions should keep going up. Maybe we can cut emissions so that the line starts to go down.
What effects did the current emission rate have on the other two lines?	The concentration kept going up, even though we have kept our emissions the same. The temperature line and the emission line went up together. The temperature continued to increase. The temperatures passed the recommended limit around 2075. The temperature went up more than the CO_2 concentration rate in the beginning. It's like a little CO_2 has a big effect on the temps, like we saw in Lessons 6 and 7.

Say, *Interesting. We had taken some guesses on what could possibly help with the CO_2 imbalance problem. We said we might cut it to 0 or cut it a bit, and that might help to reduce the imbalance and maybe have an effect on the temperature. Let's use our ideas to test some scenarios about cutting emissions.*

As students work with the *UCAR Simple Climate Model*, use this opportunity to reinforce their understanding of proportional relationships between CO_2 in the atmosphere and temperature change. It is only when CO_2 concentration in the atmosphere starts to decline that students will observe a mirroring decline in temperature, which is another indicator of a causal relationship that students should have established in Lesson Set 2.

✱ SUPPORTING STUDENTS IN ENGAGING IN PLANNING AND CARRYING OUT INVESTIGATIONS

In this activity, there is an opportunity to reinforce with students that they can use computer models to "run experiments" and generate data. Your students have developed this practice previously in the *Palm Oil Unit*. If your students need additional reinforcement with this practice, focus them on what represents the independent variable in the computer model (i.e., carbon emissions because you can "Select an emissions rate"), and what represents their dependent variables (i.e., CO_2 concentration and temperature).

3 · USE SIMULATION TO TEST IDEAS ON CARBON EMISSION SCENARIOS

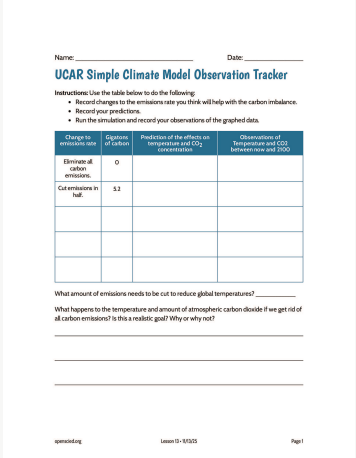
15 min

MATERIALS: *UCAR Simple Climate Model Observation Tracker*, UCAR Simple Climate Model, computer or device

Explain partner work with the simulation. Project **slide B**. Distribute 1 copy of *UCAR Simple Climate Model Observation Tracker* to each student. Explain that in a moment they will get to test out the impact of cutting their emissions by using the simulation in partner pairs. Students will record their ideas about how much CO_2 should be cut in the first two columns and what they think the outcome will be in the third column under "predictions." The fourth column will include their observations about what happened after they have run the simulation. Tell students that two very common potential solutions that are given by people have already been added to the chart for them to test, but they will get to come up with other potential changes to emissions on their own.

Project the baseline for student observations. Project **slide C**. Explain to students that, as they work, a screenshot of the simulation will be displayed, showing the effects on temperature and CO_2 concentrations if the current emissions rate stays the same. Tell students that this can serve as a comparison for their predictions and observations of other carbon emission scenarios.

Begin simulation work. Divide the class into partner pairs or groups of three and allow students to conduct the simulation. Alternatively, students can work individually on their own device. Have students work through each scenario and record their predictions and observations. As students work on their simulation, circulate to answer any questions students may have.



Name: _____ Date: _____

UCAR Simple Climate Model Observation Tracker

Instructions: Use the table below to do the following:

- Record changes to the emissions rate you think will help with the carbon imbalance.
- Record your predictions.
- Run the simulation and record your observations of the graphed data.

Change to emissions rate	Gigatons of carbon	Prediction of the effects on temperature and CO_2 concentration	Observations of Temperature and CO_2 between now and 2100
Eliminate all carbon emissions.	0		
Cut emissions in half.	5.2		

What amount of emissions needs to be cut to reduce global temperatures? _____

What happens to the temperature and amount of atmospheric carbon dioxide if we get rid of all carbon emissions? Is this a realistic goal? Why or why not?

_____

_____

_____

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4 · DISCUSS SIMULATION RESULTS

10 min

MATERIALS: *UCAR Simple Climate Model Observation Tracker*

Discuss findings from the simulation. Display **slide D**. Lead a class discussion using the prompts on the slide to identify the changes to emissions needed to reduce, stabilize, or decrease global temperatures by the reduction of emission rates. Example prompts and responses are below.

KEY IDEAS

Purpose of this discussion: Identify that a slight change in cutting emissions will not be enough to decrease temperatures before reaching the recommended temperature limit by 2100.

Listen for these ideas:

- Cutting emissions in half will not cut atmospheric CO_2 levels in half.
- For temperatures to remain constant, emissions need to be at 1.6 gigatons of carbon per year.
- This means we need to cut roughly 9 GtC/yr to keep temperatures from increasing.
- Any carbon emission levels above 1.6 GtC/yr will result in increasing temperatures and worsening water resource changes.
- If emissions are decreased to any rate below our current rate, we see less warming occurring over time.
- Any emissions at 8 GtC/yr or below will help keep temperatures below the recommended temperature limit by 2100 (the end of the simulation), but the temperatures are still increasing.

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING STABILITY AND CHANGE

Introduce the idea of "equilibrium" in the context of keeping CO_2 concentrations in the atmosphere stable by balancing the amount of CO_2 that enters the atmosphere with that amount of CO_2 taken out of the atmosphere.

ADDITIONAL GUIDANCE

The *UCAR Simple Climate Model* simulation uses data from 2015 and estimates that emissions need to be reduced by 8.9 GtC/yr. For the simplicity of figuring percentages for the impact of solutions on the carbon imbalance used in Lesson 13, we are using the figure of 9 GtC/yr. It is important to note that this 10.5 GtC/yr figure for the combustion emissions flux is an estimate of the levels in 2015 and that carbon emissions have likely increased since this time, meaning that the imbalance is most likely greater than the data used in the simulation. From the math in the class's Earth's Carbon System Model, students may have calculated that anything less than 2 GtC/yr would be OK, which is close to the 1.6 estimate in the UCAR simulation.

ASSESSMENT OPPORTUNITY

Building towards: 13.A Use the carbon dioxide model simulation to generate data and test ideas about different emissions rates scenarios to determine how to reach carbon dioxide equilibrium in the atmosphere.

What to look for/listen for: Listen for students to determine that, even by cutting emissions in half, the global temperature will still increase. Students should identify that a cut of 9 GtC/yr will need to be made to emissions to reach CO_2 equilibrium in the atmosphere.

What to do: If students do not recognize that the rate needs to be cut by 9 GtC/yr, ask students if anyone was able to cut emissions to a point where the temperatures remained steady. Students should identify that this rate is at 1.6 GtC/yr. Ask students what the difference is between the starting rate and the cut rate. Students should identify that it is roughly 9 GtC/yr. If students argue that the rate is at 8.9 GtC/yr, remind students that this simulation is using 2015 data, and emissions have since increased. By using the rounded-up 9 GtC/yr estimate, we can have a number that more closely reflects the actual imbalance and amount needed to reach CO_2 equilibrium in the carbon system.

Suggested prompts	Sample student responses	Follow-up questions
We all started off with the same condition, which was eliminating carbon emissions altogether. What did you notice as you ran the simulation with emissions set to 0 GtC/yr?	The temperature started to go down. The atmospheric CO_2 and the temperature both started to go down	*Why do you think the temperature would go down?* *Is that a realistic goal to have to reduce emission rates to 0 gigatons of carbon a year?*
Some people say that we can't reduce our emissions to 0 GtC/yr, that we need some source of energy. That's why some people propose cutting it in half. What observations did you make when cutting emissions in half?	The emissions fell immediately. The global temperature and CO_2 still increased, but by less than before we cut emissions.	*Do you think cutting emissions in half tomorrow would be realistic?* *What do you think would happen with water resources if we chose to cut emissions in half?* *Do you think that we would eventually go over the red line?* *Did cutting emissions help temperature increases, or should we cut more to help decrease the rise of global temperatures?*

Suggested prompts	Sample student responses	Follow-up questions
	Even though we cut emissions in half, the temperatures were not cut in half.	*Why would cutting emissions in half not cut the global temperature rise in half? What does this tell us about how long atmospheric CO_2 hangs around in the atmosphere?*
We all had the chance to try different emission cut ideas. What did you try, and what did you notice?	We tried reducing the emissions to 8 gigatons per year. We kept the temperatures below the red line until 2100.	*How might that increase in temperatures affect our water system? Why?* *Should we cut more or less? Is that a realistic goal?*
If our goal is to lessen the impacts of climate change and, in turn, try to avoid more water resource changes, what does that mean for the global temperature change on our graph?	We need to try to limit temperature changes on the graph. We need to cut emissions so that the temperatures stay below the line.	*If we need to limit temperature changes, what should we cut our emissions to?* *What does that line mean? Is the red line a line that represents all water cycle changes or a tipping point?*
Did anyone get the temperatures to remain stable across the graph? ✱	Yes, when I tried 1.6 gigatons per year, the temperatures and the atmospheric CO_2 didn't increase but stayed the same.	*So, what would that mean for the current water system changes?* *If we have to cut emissions to 1.6 to maintain the current state of our water system and keep temperatures constant, how much CO_2 would we be eliminating from what UCAR says is our current usage of 10.5 gigatons per year?* *Why do you think we can still emit 1.6 gigatons per year? What processes counteract those emissions?* *Why is 1.6 gigatons per year an equilibrium point for temperatures? What makes sense when we look at the numbers on our Earth's Carbon System Model as to why we can still emit CO_2 and not have an increase in temperatures?*
If we can't cut emissions to a rate that stabilizes the temperatures, is it even worth trying?	Yes, even a small cut can help keep global temperatures from increasing as quickly as compared to the current emission rates.	*So, should we just do one small cut, or should we try to reduce emissions as much as possible?*

Suggested prompts	Sample student responses	Follow-up questions
What should be our ultimate goal?	Cutting carbon emissions to stop climate change. Reducing emissions so that the temperatures don't increase anymore. To keep things from getting worse.	*So, what would that emissions cut be that keeps the climate from changing more?* *What emissions cuts would we need to try to achieve to keep our temperatures from increasing?*

Say, *Interesting. It seems like this is a complex problem. It sounds like we want to limit emissions and hopefully get them down to 1.6 gigatons of carbon per year or below by reducing our emissions by about 9 gigatons per year. Any changes below that 9 gigatons per year would result in increasing temperatures and more changes to our water system. But it also sounds like we will have to cut a lot of our current emissions, and that is going to be another complex problem in itself.*

5 · BRAINSTORM HOW WE MIGHT BE CONTRIBUTING AND WHAT WE CAN DO ABOUT IT

8 min

MATERIALS: *Home Carbon Audit*

Discuss potential solutions to the carbon imbalance problem. Project **slide E**. Say, *So one way to get back in balance is to cut the carbon emissions, but how can we do that?* What are some solutions you have heard your family or friends are doing or have tried to do to reduce carbon emissions?

Elicit student ideas. Accept all student responses. Potential responses could include the following:

- *Cut the use of fossil fuels and go to alternative sources of energy.*
- *Use solar panels or other energy sources.*
- *Driving less and using public transportation.*
- *Turning off lights and reducing electricity use.*

Shift to changes in our own actions. Say, *We have some ideas about some possible solutions but maybe we need more info about our own actions. Let's collect some information about some things we do that maybe we want to think about changing. What are some of the things that we might be doing at home that we could make changes to?*

- We could ask our family about how much they recycle at home and what is recyclable in our community.
- We could ask our family about the types of lights we have at home and keep track of how many lights are on and for how long.
- We could keep track of how we get places—like how often we are driving in the car or walking.
- We could look through things at home that are either in plastic or made of plastic that we don't reuse.
- We could figure out more about the food choices our family makes and share about moving to be more plant-based.

Project **slide F.** Say, *These are some great ideas! So for home learning tonight, use Home Carbon Audit as a guide to collect some information about these activities/actions that you and your family do, and bring this information back to our next class. We can then use it to figure out more about which solutions to implement and how.*

HOME LEARNING OPPORTUNITY

Have students gather information about their home energy, transportation, and food use using *Home Carbon Audit*. They will use this information in the next lesson as they calculate the average carbon footprint for the class.

Additional Lesson 13 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN MATH

CCSS.Math.Content.6.RP.A.3: Use ratio and rate reasoning to solve real-world and mathematical problems.

Day 1 of this lesson has students working with carbon emission rates in gigatons of carbon per year. Students will be testing different emissions rates. The concept of gigaton of carbon per year may not have much meaning to students, but students can understand comparisons of different rates—for example, comparing half the rate, or reducing the rate by ⅕—and can think about the magnitude of those rates.

CCSS.Math.Content.7.RP.A.2: Recognize and represent proportional relationships between quantities.

In this lesson students will circle back to their understanding of proportional relationships between concentration of greenhouse gases (GHGs), namely CO_2 in the atmosphere, and temperature. Students first started to develop their understanding of this relationship in Lesson 7 when they recognized that rising GHGs cause rising temperatures and vice versa. The new element added in this lesson is that students start interpreting graphed data that represent this relationship. When introducing the *UCAR Simple Climate Model* to students, give students an opportunity to make sense of this proportional relationship between CO_2 concentrations and temperature.

LESSON 14: What things can people do to reduce carbon dioxide going into the atmosphere?

PREVIOUS LESSON

We defined our problem as having too much CO2 in the atmosphere, which is causing an imbalance. We used a simulation and discovered emissions would have to be reduced by 9 gigatons to reach equilibrium.

THIS LESSON

INVESTIGATION

1 day

Environmental Literacy and Inquiry Working Group at Lehigh University

We calculate our carbon footprint based on daily habits with home energy use, food, transportation, and waste. We share our carbon impact on the class Carbon Scoreboard. We calculate the average carbon footprint for our class and compare it to the footprint of an average American. We revisit our footprint and make a carbon reduction priorities list by selecting 2-4 changes we are willing to make that would reduce our footprint and would benefit our family in other ways. We compound the effects of these changes if everyone in our classroom, school, and community commits to reducing carbon in a way that makes sense for them.

NEXT LESSON

We will look at large-scale solutions for reducing the amount of CO2 in the atmosphere, and will define our criteria and constraints for a successful solution. We will decide that solutions should be practical and help rebalance carbon. We will organize our information using a Design Matrix, and will decide that multiple solutions are necessary to rebalance CO2 released into the atmosphere. We will wonder what is being done to ensure solutions are implemented and who is responsible.

BUILDING TOWARD NGSS

MS-ESS3-1, MS-ESS3-3, MS-ESS3-4, MS-ESS3-5, MS-ETS1-2

WHAT STUDENTS WILL DO

14.A Apply mathematical concepts to calculate an average carbon impact and possible carbon reduction solutions and scale those reductions to see what would happen if more people were to change their behaviors.

WHAT STUDENTS WILL FIGURE OUT

- Changes to daily activities and behaviors can reduce CO_2 entering the atmosphere.
- If more people do these things, we can reduce CO_2 emissions further.
- Changes to behaviors are limited by other constraints, so each person may have different options available to them.

Lesson 14 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	3 min		**NAVIGATION** Recall results from carbon emissions calculator and initial activities and behaviors to reduce carbon.		
2	12 min		**CALCULATE INDIVIDUAL FOOTPRINT AND POST RESULTS** Introduce the carbon footprint calculator and allow students to calculate and post their footprint results.	A	*Home Carbon Audit*, computer or device, Carbon Emission Calculator, sticky note, marker, computer and projector, Carbon Scoreboard (digital or chart paper)
3	8 min		**CALCULATE CLASS AVERAGE AND COMPARE TO AMERICAN AVERAGE** Calculate the class's average footprint and record on a sticky note. Compare to the American average and discuss noticings.	B-C	calculator, Carbon Scoreboard (digital or chart paper), large sticky note, markers, computer and projector, CO2 Emissions (metric tons per capita) United States data site
4	8 min		**COMPLETE A CARBON REDUCTION PRIORITIES LIST AND POST RESULTS** Have students return to their footprint and choose 2-4 behaviors or activities to reduce their footprint. Students should post their new footprint on the Carbon Scoreboard.	D	*Home Carbon Audit*, computer or device, Carbon Emission Calculator, sticky note, marker, Carbon Scoreboard (digital or chart paper), large sticky note, markers
5	12 min		**FACILITATE A DISCUSSION AND COMPOUND CHANGES** Have students make noticings of the new class scores and to share some of the changes they are willing to make. Scale the carbon savings in the class to the grade level, school, and larger community.	E-G	calculator, Carbon Scoreboard (digital or chart paper), large sticky note, markers
6	2 min		**NAVIGATION** Brainstorm larger scale solutions to address the carbon imbalance.	I	

End of day 1

Lesson 14 • Materials List

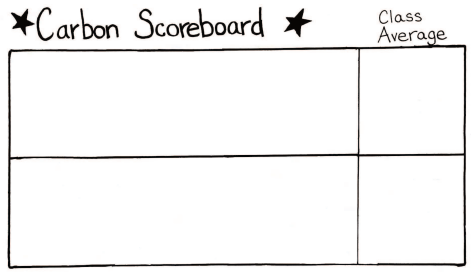
	per student	per group	per class
Lesson materials	• *Home Carbon Audit* • computer or device • Carbon Emission Calculator • sticky note • marker	• calculator	• computer and projector • Carbon Emission Calculator • Carbon Scoreboard (digital or chart paper) • large sticky note • markers • CO2 Emissions (metric tons per capita) United States data site

Materials preparation (25 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Test the *Carbon Emissions Calculator* from https://ei.lehigh.edu/learners/cc/carboncalc.html. Make sure the link is approved and accessible on students' devices. It is preferred that students have their own device to calculate their footprint, so be sure to secure enough devices for 1 per every student.



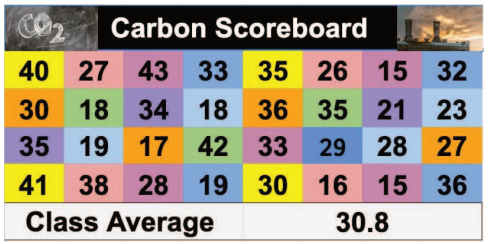
This lesson uses the handout provided in the previous lesson, *Home Carbon Audit*. If students were absent or did not bring this back from home learning, they can still estimate their carbon footprint for this lesson.

The *Carbon Emissions Calculator* is easy for middle schoolers to use, but the estimates are on the high end and may not always be accurate. Therefore, you will add the real data estimate to your discussion as a comparison. Use data from *CO_2 Emissions (metric tons per capita) United States* from https://data.worldbank.org/indicator/EN.GHG.ALL.MT.CE.AR5?locations=US. **Slide C** includes a screenshot of the data, but accessing the data directly allows for more functionality to scroll and see data for each year.

Make your Carbon Scoreboard on a large sheet of chart paper or the whiteboard, as shown in the image. By having students post their scores on sticky notes, you can reuse the Carbon Scoreboard with different classes of students. Retain your class's average for comparison with each other.

Alternatively, make a copy of the Digital Carbon Scoreboard to use in remote learning and/or one-to-one classroom. You can find the link to the spreadsheet file in the OpenSciEd unit Google folder.

Before this lesson, decide which target populations you want students to use to compound their solutions. Examples include class size, grade level, school, school district, neighborhood, zip code, town, and state. Locate the population number for the different comparisons you want to make and have these numbers ready for quick multiplication to compound reductions in CO_2. Note that the current US population is approximately 330 million people, and the current average zip-code population is between 9,000 - 10,000 people.



Lesson 14 • Where We Are Going and NOT Going

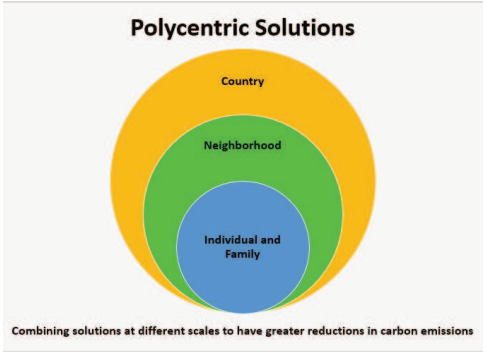
Where We Are Going

In the lesson, we're going to investigate some of our daily activities and behaviors as they relate to the "likely" solutions we brainstormed in the previous lesson. Gathering this information from home will help identify where changes could be easier or more difficult to make, and how much those changes can have an impact if many people engage in them. This will be in anticipation of selecting a solution or a couple of solutions we want to communicate to our community in Lesson 17.

Students will continue to work toward the following science ideas:

- **ESS3.D Global Climate Change.** Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depends on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding human behavior and applying that knowledge wisely in decisions and activities. (MS-ESS3-5)
- **ETS1.B Developing Possible Solutions.** There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (MS-ETS1-2),(MS-ETS1-3)

Throughout this unit students have been working with data set and simulations to first understand Earth's water and carbon system models; in Lesson 13 and now in Lesson 14, students are building on their mathematical and computational thinking by linking human activities and behaviors to the Carbon System Model in service of understanding which behaviors emit the most carbon and which solution (or combination of solutions) might reduce carbon emissions. The home carbon audit provides students with simple quantitative evidence attached to each behavior and activity. At this point, students have worked with percentages, rates, and ratios and should be able to individually and collectively make sense of the carbon audit and the class average, along with the compounding impact scaling solutions up to larger populations.



Example polycentric solution graphic

An important aspect to effectively addressing the carbon imbalance in Earth's atmosphere is that of scaling solutions across individuals, communities, and regions/countries. This lesson builds out an important idea of polycentric solutions -- that is, that solutions work across different scales and having solutions at multiple scales would be necessary to effectively address atmospheric CO_2. We suggest you add a graphic organizer visually on or near the Carbon System Model to help students understand that collective action across scales is essential to addressing the problem. This is an example organizer for this lesson, but consider alternate titles to the circles. As you get to Lesson 15, students will work with large-scale solutions to solving the carbon imbalance, and in Lesson 16, students will work with solutions that are 1) individual & family, 2) community, and 3) government and business scalesThe important idea across these three lessons is that scaling solutions is necessary to correct the carbon imbalance.

Where We Are NOT Going

The carbon footprint calculator selected for this lesson is fairly basic and easy to access for middle schoolers without an intensive home audit. The tradeoff of using a simple interface is that the results are not as accurate as they may be with other calculators, and, with this calculator in particular, results tend to be high. However, the calculator provides relative numbers that students can use for comparison. This lesson will not investigate the math behind those calculations; however, many footprint calculators draw on the same kinds of data that students worked with in Lessons 13 and 14.

Another notable omission from this lesson is a comparison of the average American's footprint to the footprint of people living in other countries. Because of limitations in instructional time, the unit does not explore this topic, but it can be added as an extension opportunity if time is available or students have high interest in this area. When visiting the *CO_2 Emissions (metric tons per capita) United States* from https://data.worldbank.org/indicator/EN.GHG.ALL.MT.CE.AR5?locations=US, there is a possibility of comparing the US average CO_2 emissions to the average emissions of other countries. Unless you have instructional time to investigate these comparisons deeply (~2 class periods), it is recommended not to make comparisons to other countries, or to only make comparisons to other industrialized, high-income nations (For example, in Lesson 10 students saw that the United Kingdom, most of western Europe, and Japan as places that were higher carbon emitters, so these countries could be used as a comparison.). The economic, historical, and other social factors needed to explain the difference between high carbon emitters versus low carbon emitters and the current carbon trends is a rich area for student learning, but one that requires careful and thoughtful instruction.

LEARNING PLAN for LESSON 14

1 · NAVIGATION

3 min

MATERIALS: None

Recall carbon emission results from the previous lesson. Ask, *What did we figure out last class about carbon emissions and what we can do about it?* Ask student students to share ideas such as:

- We used a simulator and figured out that we would have to cut 9.5 gigatons of carbon a year to keep temperatures the same.
- We brainstormed some initial things we could do to cut carbon.

Say, *So now let's review your home learning to see what you and your family are doing (or can do) at home to reduce carbon emissions.*

2 · CALCULATE INDIVIDUAL FOOTPRINT AND POST RESULTS

12 min

MATERIALS: *Home Carbon Audit*, computer or device, Carbon Emission Calculator, sticky note, marker, computer and projector, Carbon Scoreboard (digital or chart paper)

Retrieve home learning handout. Ask students to locate their *Home Carbon Audit* that was assigned for home learning at the end of Lesson 13. If students do not have it, or were absent, they can still participate. Many students will be able to "guess" on the calculator to get a ballpark footprint.✱

Introduce the *Carbon Emissions Calculator*. Project the *Carbon Emissions Calculator* from https://ei.lehigh.edu/learners/cc/carboncalc.html. Say, *This is a carbon footprint calculator that we can use to get an estimate of how much our daily habits contribute to the carbon imbalance. We're going to use this tool to see how well each of us are doing on the solutions we have identified as possibly promising ones to help solve this problem.*

Explain why it's called a carbon footprint (e.g., it's the amount of CO_2 that a person contributes) and how it's calculated (e.g., each activity or behavior uses a certain amount of resources, such as materials to build, fossil fuels to transport, or electricity to heat or cool it). All those resources are combined to estimate the total carbon emissions for each activity.

Preview how to calculate a footprint using your own numbers. You do not need to preview your entire footprint for students, just enough to show students how to navigate the tool.

ADDITIONAL GUIDANCE

It may help to have students round to the nearest tenths decimal place or even a whole number.

- If using the chart paper scoreboard: tell students to organize their scores from least to greatest when they post them. On the far left side should be the lowest scores and on the far right should be the highest scores. You may have a range of scores from less than 10 tons to higher than 30 tons. If using the digital scoreboard: tell students to post their results in the appropriate tab and empty space. The spreadsheet will calculate the average for the class.

, Carbon Scoreboard scores right now] **Give students directions for calculating their footprint.** Display **slide A**. Review the steps to calculate and post results. Show students where the Carbon Scoreboard is located. Use the guidance on the slide:

- Use your *Home Carbon Audit* to help you answer the questions.
- When you get to the final screen, locate your footprint number.
- Record your number in a large, legible font using the marker on the sticky note.
- Post to the class's Carbon Scoreboard.

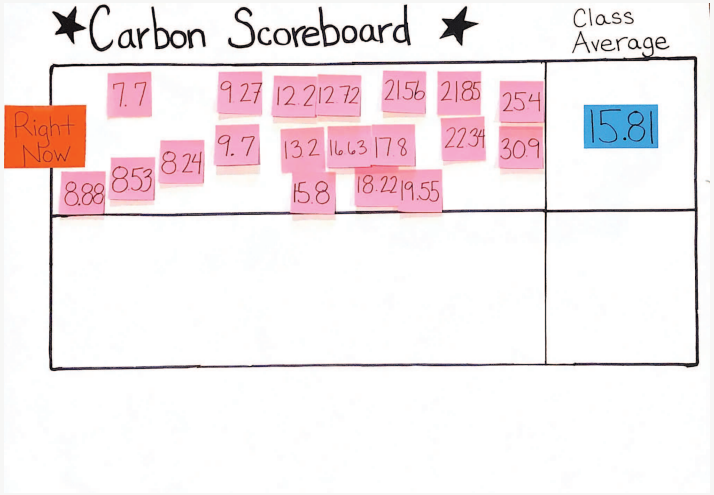
✱ ATTENDING TO EQUITY

Universal Design for Learning: An important thing you can do, particularly in this lesson, is to create a safe space for students. To do this, you need to *minimize threats* in the learning environment. Calculating a personal carbon footprint and sharing results can potentially create a situation in which students feel threatened and, therefore, may disengage. To reduce threat, have students post their carbon footprint numbers anonymously and avoid asking students to make comparisons to each other. Rather, have students make comparisons to themselves in terms of before and after they've made changes to their carbon footprint.

Allows students 10 minutes to calculate their footprint and post their results. Give each student 1 sticky note and marker if using the chart paper scoreboard. Remind students to use their handout to enter the data. Encourage students to start noting areas where they think they have some flexibility to change habits. They may want to note these habits by jotting down a star on their handout as they enter their data.

As students work, add a label to the scoreboard that says, "Right Now," or use the digital tab that says, "Before." Remind students to post their score anonymously, to post the score near similar scores, and to organize scores from lowest to highest. If necessary, have students give their scores to you and post several scores at a time to help ensure anonymity.

Be prepared to calculate the average score if using the chart paper version. Tell students to keep their device open and footprint easily accessible because they will return to it shortly.



3 · CALCULATE CLASS AVERAGE AND COMPARE TO AMERICAN AVERAGE

8 min

MATERIALS: calculator, Carbon Scoreboard (digital or chart paper), large sticky note, markers, computer and projector, CO2 Emissions (metric tons per capita) United States data site

Calculate the class average (skip if using the digital scoreboard)**.** Arrange students in small groups or partners. Provide each group with a calculator. Display **slide B.** Ask groups to discuss what they notice about the footprint numbers across the class. Have them work together to find the class range and to calculate the average. After 3 or so minutes, bring students back together.

Have students share their observations of range and class average.✱ During the discussion, write the class average on a sticky note and post to the Carbon Scoreboard, as shown in the example above. Recording the range could be useful, too, though this is not shown in the example. Post the range near the class average.

Suggested prompts	Sample student responses
What is the range across all the scores in our classroom?	7.7 to 30.9 tons (in example chart above) Accept answers that identify the lowest and highest numbers. Post to the chart.
What do we notice are the lowest footprints? *What do we notice are the highest footprints?*	The lowest are less than 10 tons, but there are only a few of them. The highest are in the twenties and thirties.
Wow, that seems like a large difference. Where did most of the scores tend toward?	Most were in the upper teens and twenties. We only had 1 in the 30s. There were a lot between 12-20 tons. Accept specific observations for each class of students.
And how did you all calculate the average score for our class?	We added up all the scores and divided by the number of people.

✱ SUPPORTING STUDENTS IN ENGAGING IN USING MATHEMATICS AND COMPUTATIONAL THINKING

Use this opportunity to push students to use range and average to get an overall sense of how students are doing on the solutions identified as promising ones to solve the problem. Otherwise, the numbers may not have meaning to students.

Students are also building a mathematical representation that can be later used to describe and support design solutions, and study how taking solutions to larger scales is an important aspect of addressing the carbon imbalance.

✱ ATTENDING TO EQUITY

Climate change can be an upsetting topic for many students. Some students may feel that not enough is being done, and others may feel that it is a hopeless problem. The purpose of looking at the real-time data is to

Suggested prompts	Sample student responses
What did we calculate was our class average?	15.81 tons (in the example chart above) Accept the answer from the class. If students share different answers, have students check their calculations and share where they made an error in their original calculation.
What do these numbers mean for the problem we are trying to solve? How well are we doing right now on the solutions we thought could be helpful and easy to do?	We knew that a plant-rich diet was a helpful solution, but that added a lot to my footprint number. We thought carpooling was helpful but don't really do that right now. I didn't realize how much it adds up based on the size of the car. I was surprised how much using air conditioning could affect my score.
What actions tend to make your scores go up quickly?	Eating everything. Having larger cars. Using the car a lot. Air conditioning more rooms. Taking a lot of showers each day.
What action could you take today to decrease your score? And if we all did it, how might it affect the class average?	Eat more vegetables. Turn off electricity. Carpool to school. Take fewer showers or do fewer loads of laundry.

ADDITIONAL GUIDANCE

If you teach multiple sections of science, keep each class's average score. Build a new Carbon Scoreboard that shows each class's average emissions score and their average score after reductions. Allow students to see how their class compares to other classes in terms of both impact and reductions in carbon.

Compare to real data on the American footprint.✱ Say, *When I was testing this tool, I noticed it was giving slightly high numbers. Because this tool is so simple, it's not factoring in a lot of information to get a more precise estimate. I wanted to see what the most precise estimate is for people in the United States. There is a data website that tracks this information that I want us to check out. Our numbers may be similar to the country average or may be on the high or low side of things. Let's see.*

Display **slide C** or navigate to the *CO_2 Emissions (metric tons per capita) United States* from https://data.worldbank.org/indicator/EN.GHG.ALL.MT.CE.AR5?locations=US if you want to project in real time. This data is current through 2016, but the average US per capita emissions is still around 15.5 tons per capita per year as of 2019.

Have students turn and talk about observations from the graph. Use the prompts on **slide C**. If you are projecting the data in real time, use the same prompts, but give the prompts to students orally.

- What do you notice about the range—highs and lows?
- What do you notice about the overall trends?
- How does the most recent average compare to our class average?

Suggested prompts	Sample student responses

emphasize to students that what the United States has been doing in recent years (shown as 2007-2016 on graph) has resulted in a downward trend in CO_2 emissions. Use this data to encourage your students that we are trending in the right direction, and there are things that everyday citizens can do to support and participate in this trend.

Suggested prompts	Sample student responses
What do you notice about the range—highs and lows?	The lowest is today! At 15.5. The highest was in the early 70s at 22.5.
What do you notice about the overall trends?	There was a quick trend up in the 1960s, then a lot of ups and downs. Since 2007, it's mostly been going down.
How does the most recent average compare to our class average?	Accept any answers, which will vary based on your class average.

Say, *Wow, it's pretty cool that our country is making progress on this problem. I'm wondering if we can do more to help the trend keep going downward. We thought there were some solutions that were promising, but we realized we may not be doing our best on those solutions. We're going to revisit our carbon footprint to see if there are any changes we can make that may improve our footprint.*

4 · COMPLETE A CARBON REDUCTION PRIORITIES LIST AND POST RESULTS

8 min

MATERIALS: *Home Carbon Audit*, computer or device, Carbon Emission Calculator, sticky note, marker, Carbon Scoreboard (digital or chart paper), large sticky note, markers

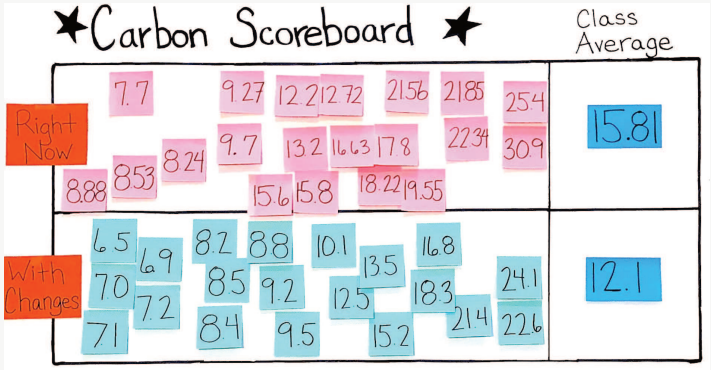
Have students return to their footprint and make changes to lower their score. Display **slide D**. Preview the instructions on the slide and provide each student with another sticky note.

Have students return to their footprint calculator to make 2–4 changes to try to lower their score. Ask students to record their changes by either (1) starring them on their *Home Carbon Audit* handout or (2) recording them in their science notebook.

While students work, post a new heading to the second row of the Carbon Scoreboard titled "With changes."

Have students post their new carbon footprint sticky note to the Carbon Scoreboard following similar strategies as before: anonymous, posted near similar numbers, and organized from least to greatest. If using the digital version, have students post the new numbers to the "after" tab.

Calculate the new range and class average. Ask a few students in class to calculate the new class average and post this to the Carbon Scoreboard using a large sticky note. The number is calculated automatically in the digital version.



Carbon Scoreboard with changes

5 · FACILITATE A DISCUSSION AND COMPOUND CHANGES

12 min

MATERIALS: calculator, Carbon Scoreboard (digital or chart paper), large sticky note, markers

Facilitate a Building Understandings Discussion about everyday changes and compounding effects. This discussion has two parts. First, to develop an understanding that even small everyday actions add up to reduce CO_2 emissions and that actions may be different for people in different situations. Second, to scale the average carbon reduction to larger populations of people.

KEY IDEAS

Purpose of the discussion: to identify that even a few small changes in our daily activities can add up to large impacts on CO_2 emissions, especially when many people do these things.

What to look/listen for:

- Our actions add CO_2 to the atmosphere.
  - Eating less meat or eating more veggies reduces carbon emissions.
  - Using less electricity reduces CO_2 emissions.
  - Recycling keeps you from adding carbon emissions.
  - Driving less or using public transportation or walking reduces CO_2 emissions.
- We can get our average down by making a few changes to our daily activities. We can get our average below the US average.
- If more people do these things, we can get further reduction in CO_2.

Discuss everyday actions and why they vary. Display **slide E**. Use the prompts on the slide to facilitate a discussion of the different actions that students thought they could make, how those actions impact carbon, and other considerations to think about before making a change.

Suggested prompts	Sample student responses	Follow-up questions
What kinds of changes do you want to make?	Turn off the lights and electronics. Recycle. Eat less meat or more vegetables.	*Do they lead to big or small impacts on carbon? Are they realistic for you and your family?*
What actions are not realistic?	Changing the type of home. Changing the number of family members. Changing appliances.	*What are the constraints that would keep people from doing them?*
How could these changes benefit your family in other ways beyond carbon reduction?	Saves our family money. Uses less water. Uses less stuff.	*Are there any potential negative effects of these changes on our families that we need to think about?*
Why are each of your changes different from each other? Is this important?	Each of us has a different living situation. Different houses, family members and eating habits, and such. Some people can change some things that may be harder for others to change. And some people may not be able to do one thing, but they can do something else.	

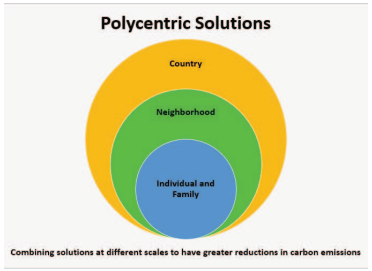
✱ ATTENDING TO EQUITY

If time permits and students can engage in these calculations in partners, use this opportunity to differentiate for math abilities. Allow more advanced math learners to engage in calculations with trickier percentages and/or calculate for different scenarios. With students who need more support, consider going through another calculation together and/or having them take example scenarios with more even numbers (e.g., 50% as opposed to 35%). Allow them to check their numbers with each other and/or you before sharing aloud.

✱ SUPPORTING STUDENTS IN THREE-DIMENSIONAL LEARNING

Students will engage in mathematics and computational thinking in order to scale their carbon reductions to larger populations. The purpose of this work is to understand that individual actions and behaviors nested in larger populations of people engaging in actions has an impact.

Adding a graphic organizer at this point in the lesson can help students visualize the idea of polycentric solutions -- that is, that a combination of solutions occur at different scales and add up to greater reduction in carbon emissions.

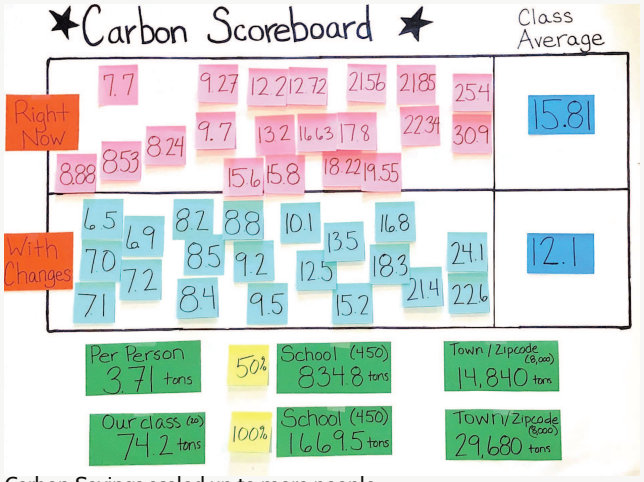


Calculate the carbon savings for the class. Display **slide F**. Have students calculate how much the class saved per person by making the change (simple subtraction).

Scale the per person savings to larger populations. Engage students in calculations and a deeper discussion of scaling the changes to more people. Allow students to choose different populations that they could scale their changes to, such as the school, community, family, church community, everyone in the city, their zip code, their sports team, etc. Be prepared with some of these population numbers on hand or have students estimate the population number. Students should multiply the per person savings by the new larger population.

Record some of these on the Carbon Scoreboard. The example to the right shows the sample Carbon Scoreboard scaled to a school of 450 teachers and students and to a town with a zip-code population of 8,000. There are two calculations—one for 100% participation in changed actions and another for 50% participation.

Have students first do calculations based on 100%. Then, at some moment, problematize to say, *How realistic would it be that everyone would do these things? What is a more realistic percentage?*



Carbon Savings scaled up to more people

Display **slide G** and have students think through realistic percentages of people who may change their habits. To support students in understanding percentages, have all of your students stand up. Ask half to sit down and the other half to stay standing. Then ask a quarter to sit down, while three-quarter remain standing. As students move between sitting and standing, calculate the percent together.

Help students identify a "realistic" percent they'd want to use (e.g., 40%, 50%, 75%).

Recalculate based on the new percentage. Help students multiply their carbon savings that were calculated at 100% by the new percent (e.g., 3.7 x 150 students and teachers = 555 tons; but if only 50% changed their habits, it would be half of that, which is 555/2 = 278 when rounded).

If time permits, arrange students in pairs and allow them to calculate a new carbon savings number for a group size of their choosing and the percent they could convince to engage in an action. Let them share their calculations with the class.✱

Example calculations are shown below for a per person savings of 3.7 tons.

3.7 per person	Class	Grade	School	Neighborhood/ small town	Zip code	Community group (e.g., sports team)	United States
# of people	20	150	450	4,000	8,000	80	331,000,000
Carbon savings 100%	74	555	1,665	14,800	29,600	296	**1,224,700,000 (> 1 Gt)**
Carbon savings 50%	37	278	833	7,400	14,800	148	612,350,000

Post any new carbon savings calculations to the Carbon Scoreboard.

Facilitate a concluding discussion of the scaled numbers. Say, *When we did our own calculations, we were only saving 3.7 tons per person, which didn't seem very big. But look how quickly it grows when more people are willing to make changes. Remember we were trying to save about 9 gigatons of carbon per year (which is 1 billion tons). We don't get very close with a few people, but we do start to get larger numbers when more people are willing to make changes.*✱ Display **slide H**.

Suggested prompts	Sample student responses
What other important things can you summarize from these numbers with respect to the problem we are trying to solve?	Every little bit adds up to lower CO_2 emissions. Even small changes can add up to big impacts on the carbon imbalance. It may feel like the things you are doing don't matter, but if you are doing them with other people, they can make real changes. If you don't make changes, it is hard to expect others to change.
What assumptions did we make about our numbers?	The numbers are based on our average reduction, and we know a lot about the problem. Different people need to be able to make different changes based on their situation, so it may not be easy for everyone to change things in their life.
What is the importance of having larger numbers of people making these changes?	The data showed the more people involved in making small changes, the bigger the impact on the carbon imbalance.
When you look back at the data, at what scale do you think the biggest impact can be made, and why?	The data shows a large impact when entire countries, like the United States, are willing to make changes. Based on the data, it appears that changes made globally would have the biggest impact.

ASSESSMENT OPPORTUNITY

Building towards: 15.A Apply mathematical concepts to calculate the class's average carbon impact and possible carbon reductions and scale those reductions if more people change their behaviors.

What to look/listen for:

- students calculating the carbon savings from their behavior changes,
- students multiplying the savings by different population sizes and understand why they are multiplying,
- students recognizing that their calculations are based on getting 100% of people to make changes and to recalculate a more realistic percentage, and
- students understanding that the numbers reflect an average carbon savings based on different actions people may be willing to take.

What to do: To support students in calculating percentages, particularly for students who struggle with math, talk about the numbers in a concrete example together. Start with class level, talk and show the calculation on the front whiteboard, and what each number and each operation means. It's important for students to recognize that changing the percent is a reflection of how many people can be convinced to change their behaviors. Having students model the percentages using multiple modalities (**slide G**) can support students too.

6 · NAVIGATION

2 min

MATERIALS: None

Provide students with the Exit Ticket. Say, *These ideas about what we can individually do to reduce carbon are great ideas. However, we still haven't found a way to reduce our carbon to the level that we need to maintain or reduce global temperatures. I wonder what other solutions could we consider that are larger scale?* Point to the graphic organizer about polycentric solutions and identify for students that most solutions they have looked at so far are ones that individuals or families can do.

Display **slide I**. Give students a minute to think of ideas that will reduce carbon on a larger scale. After a minute, have each student write down one or more ideas on an Exit Ticket using the prompt on the slide:

- What other solutions could we consider that will reduce carbon on a larger scale?

Say, *In the next class, we'll start thinking about what larger scale solution(s) exist to reduce carbon emissions.*

Additional Lesson 14 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN MATH

CCSS.Math.Content.6.RP.A.3.c: Find a percent of a quantity as a rate per 100 (e.g., 30% of a quantity means 30/100 times the quantity); solve problems involving finding the whole, given a part and the percent.

Students will draw upon 6th grade math to complete this lesson. First, students know how to compute unit rate and will apply this concept to calculate a per person carbon savings number. Students then apply the percent of a quantity (such as the number of people in the school) and the rate per person to solve a problem around carbon reductions based on lifestyle changes. The purpose of engaging in these mathematical calculations is twofold: (1) to understand that individual actions add up and (2) that the percent of the population engaging in those actions matter in terms of the carbon savings that is possible.

LESSON 15: How can large-scale solutions work to reduce carbon in the atmosphere?

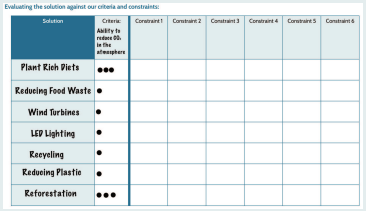
PREVIOUS LESSON

We calculated our carbon footprint and shared our impact on the class Carbon Scoreboard. We calculated the class average and compared it to the average American footprint. We revisited our footprint and did a carbon reduction priorities list by selecting 2-4 changes to make that would reduce our footprint and benefit our family in other ways. We discovered that we could compound the effects of these changes if more people made similar changes.

THIS LESSON

INVESTIGATION

3 days



Evaluating the solution against our criteria and constraints:

Solution	Criteria: Ability to reduce CO_2 in the atmosphere	Constraint 1	Constraint 2	Constraint 3	Constraint 4	Constraint 5	Constraint 6
Plant Rich Diets	●●●						
Reducing Food Waste	●						
Wind Turbines	●						
LED Lighting	●						
Recycling	●						
Reducing Plastic	●						
Reforestation	●●●						

We look at large-scale solutions for reducing the amount of CO2 in the atmosphere. We define our criteria and constraints for a successful solution, and decide that solutions should be practical and help to rebalance carbon. We organize our information using a Design Matrix, and decide that to meet our criteria, multiple solutions are necessary to rebalance the amount of CO2 released into the atmosphere. We wonder what is being done to ensure solutions are implemented and who is responsible.

NEXT LESSON

We will obtain information from community plans to determine how the solutions are being used in the communities and how they rebalance carbon and/or help a community to become more resilient to changes already occurring in the community. We will use these plans as examples to help motivate the need to evaluate and/or develop a plan for their own community.

BUILDING TOWARD NGSS

MS-ESS3-1, MS-ESS3-3, MS-ESS3-4, MS-ESS3-5, MS-ETS1-2

WHAT STUDENTS WILL DO

15.A Evaluate competing solutions using a systematic process and jointly develop agreed upon criteria to determine how small changes in behaviors and technologies can add up to larger impacts on reducing CO_2 in the atmosphere.

WHAT STUDENTS WILL FIGURE OUT

- There are many different solutions that can be implemented to reduce the amount of CO_2 being emitted into the atmosphere.
- There are some solutions that help take CO_2 out of the atmosphere and solutions that reduce carbon emissions.
- Implementing only one solution will not lead to a decrease of CO_2 in the air. Multiple solutions need to be done together in order for any reduction to occur to help rebalance CO_2 in the air.

Lesson 15 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	5 min		**Navigation** Review Lesson 14 ideas and motivate the need to define criteria and constraints for evaluating large-scale solutions to reducing CO_2 in the atmosphere.	A	
2	10 min		**DEFINE CRITERIA FOR ANALYZING SOLUTIONS** Define the problem and the criteria that makes a solution large-scale.	B	Defining the Problem chart, markers
3	30 min		**GATHER INITIAL DATA ON SOLUTIONS** Look through potential solutions in groups and determine which solutions best meet the criteria of the problem.	C-D	*Carbon Solution Cards*
					End of day 1
4	15 min		**INITIAL SOLUTION PROPOSALS** Have students argue for different solutions that meet the criteria in their small groups. Convene the class to share which solutions seem most promising and why.	E-F	*Carbon Solution Cards*, markers, Proposed Solutions chart
5	10 min		**IDENTIFYING THE CONSTRAINTS** Develop a process to narrow down the possible solutions. Use the co-constructed criteria and constraints as part of this process.	G	*Carbon Reduction Solution Matrix*, Proposed Solutions chart, markers, Defining the Problem chart
6	20 min		**REANALYZE SOLUTIONS WITH NEW CONSTRAINTS** Use the new constraints to reanalyze solutions in small groups.	H-I	*Carbon Reduction Solution Matrix*, *Carbon Solution Cards*
					End of day 2
7	30 min		**CONSENSUS DISCUSSION TO CATEGORIZE SOLUTIONS** Facilitate a Consensus Discussion to categorize solutions as likely, not sure, and not good solutions.	J-K	*Carbon Reduction Solution Matrix*, *Carbon Solution Cards*, Rebalancing Carbon chart, sticky notes in multiple colors, markers
8	5 min		**UPDATE PROGRESS TRACKERS** Add new ideas to individual Progress Trackers	L	
9	10 min		**Navigation** Determine where each solution would have the greatest impact on Earth's systems and wonder who might be responsible for implementing those solutions.	M	*Carbon Solution Cards*, *Carbon Reduction Solution Matrix*
					End of day 3

Lesson 15 • Materials List

	per student	per group	per class
Lesson materials	• *Carbon Reduction Solution Matrix* • science notebook	• *Carbon Solution Cards* • markers	• Defining the Problem chart • markers • Proposed Solutions chart • Rebalancing Carbon chart • sticky notes in multiple colors • *Carbon Reduction Solution Matrix*

Materials preparation (20 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

For day 1:

- Modify the "Defining the Problem" chart.
    - Add and label a second row "Criteria."
    - Add and label a third row "Constraints."
- Print *Carbon Solution Cards.* Print enough copies so that each student can read at least 3 cards. A color copy is available in the *How can large-scale solutions work to reduce carbon in the atmosphere?*.
- If you decide that additional carbon solution cards need to be made to match additional student interests or you would like to include solutions that are more locally relevant, *Information for Carbon Solution Cards* can be used to learn how to make new carbon solution cards.

For day 2:

- Create a "Proposed Solutions Chart."
    - Label the first row "Proposed Solutions."
    - On subsequent rows you will list solutions proposed by students during their "Initial Solutions Proposals" discussion.
- Print enough copies of *Carbon Reduction Solution Matrix* for each student.

For day 3:

- Create a "Rebalancing Carbon chart."
    - Draw a chart with the y-axis labeled 0-9 representing the 9 gigatons of carbon. Make sure that each gigaton row is as large as a regular-sized sticky note.
    - Have 4-5 colors of sticky notes ready to represent "likely solutions."

Lesson 15 • Where We Are Going and NOT Going

Where We Are Going

Students will evaluate design solutions for rebalancing CO_2 levels. They will think about the challenges to implement different solutions, which solutions they could implement easily and quickly, and the potential compounding effect of implementing more than one of the solutions. The focus of this lesson is to target the following DCI concepts:

- **ESS3.D Global Climate Change.** Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding human behavior and applying that knowledge wisely in decisions and activities. (MS-ESS3-5)
- **ETS1.B Developing Possible Solutions.** There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (MS-ETS1-2),(MS-ETS1-3).

Students will deepen their understanding of the design tradeoffs when considering different solutions, focusing on both (1) how well the solutions meet the class's criteria to help with the carbon imbalance, as well as (2) a myriad of societal and technological constraints on what is possible. Because there is no single "right" solution, students' engagement with the evaluation process presents an opportunity for them to engage in arguing from evidence about which solutions seem most possible for many people and/or have a true impact on CO_2 emissions.

Where We Are NOT Going

Large-scale infrastructure change (e.g., the way we power our society and transportation), along with local, national, and international policies, are required for a comprehensive, impactful approach to addressing climate change causes and community impacts. Due to the focus of the middle school NGSS, as well as limits in instructional time, the solutions presented in this lesson stay closely connected to human behaviors and technologies.

LEARNING PLAN for LESSON 15

1 · Navigation

5 min

MATERIALS: None

Elicit recommendations for emissions solutions. Display **slide A**. Convene a Scientists Circle. *Say*, *In our last class, we figured out that there are things we can do individually everyday to reduce how much CO_2 we add to the atmosphere. In your exit tickets, you shared some possible solutions to our carbon imbalance problem that could work on a larger-scale.* Ask 4-5 students to share with the class possible large-scale solutions for reducing CO_2 in the atmosphere.

Potential responses could include:

- *Planting a lot of trees to increase the amount of photosynthesis and offset our carbon emissions.*
- *Cut the use of fossil fuels and go to alternative sources of energy.*
- *Create something to pull CO_2 out of the atmosphere.*
- *Do a lot of little solutions to help with the imbalance problem.*

2 · DEFINE CRITERIA FOR ANALYZING SOLUTIONS

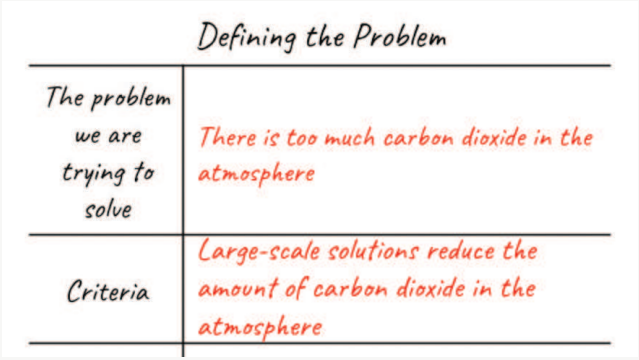
10 min

MATERIALS: Defining the Problem chart, markers

Define the problem and criteria for analyzing solutions. Say, *It sounds like we have a lot of potential larger scale solutions we would like to explore that might help with our carbon imbalance problem.* Remind students that we have documented our problem on our Defining the Problem chart, but we have not yet figured out what our solutions would need to do to be successful. Display **slide B**. Tell students that as they shared information from their exit tickets, you noticed that some solutions to the problem they suggested will reduce emissions, like planting trees, and some might help with rebalancing the amount of CO_2 in the atmosphere. Before we learn more about some possible larger-scale solutions, we first need to decide on criteria for analyzing them. Have students turn and talk with a partner to discuss the questions on the slide.

- If we are considering solutions like planting trees, what does our solution really need to do to be successful?
- What should be the main goal of our carbon imbalance solutions?

Elicit student responses. Students should respond that the solutions, such as planting trees, are taking CO_2 out of the atmosphere instead of just limiting emissions and that all of the successful design solutions would reduce the 9 gtC *(gigatons of carbon)* that is typically added to the atmosphere each year.



Say, *It sounds like we have determined our criteria for a successful design solution. Our main criterion is that large-scale solutions rebalance carbon by reducing the amount of CO_2 released into the atmosphere.*

Add this criteria to the Defining the Problem chart.

Determine what kinds of data are needed. Ask students what kinds of data and information would be needed to help them determine if a design solution would reduce the amount of CO_2 released into the

atmosphere. As they share, reference the criteria field on the Defining the Problem chart. Students should identify that we need to know what the solutions do to reduce the atmospheric CO_2 levels, and how much carbon they reduce. Tell students that you have this information about some solutions they mentioned on their exit tickets, as well as a few more commonly discussed solutions.

ADDITIONAL GUIDANCE

Some students may suggest or be passionate about additional potential carbon solutions not included in the *Carbon Solution Cards*. Your community may also have solutions that are more locally relevant that would be meaningful for students to investigate and utilize. Consider telling students that these additional solutions can be explored also. To do this, add these solutions to the *Carbon Solution Cards* by using the template *Information for Carbon Solution Cards*. These additional solutions can be introduced on day 2 as students consider how well each solution meets the criteria and constraints

3 · GATHER INITIAL DATA ON SOLUTIONS

30 min

MATERIALS: *Carbon Solution Cards*

Introduce students to the different larger scale solutions. Display **slide C**. Explain to students that, in a moment, they will be put into groups and will learn more about some potential solutions to the problem. Read off the solutions list with students, and allow students to help narrow down the list from 16 solutions to 12 solutions that they would like to investigate further.

ADDITIONAL GUIDANCE

The *Carbon Solution Cards* contain a variety of ways to reduce the carbon imbalance. At first glance, some solutions may seem more generally appealing to students than others. Guide students to include solutions that have larger impacts than others, even if they are not as interesting. If you find that students are arguing for eliminating any like plant-based diets, you might ask them to consider why. This will help later in the lesson when students begin to identify constraints because some solutions (like plant-rich diets) will be easier to implement than others (like planting artificial trees or onshore wind turbines).

Explain that each student will work in a group of 3-4 students and will be assigned up to 3 solutions to read about and share with their other group members. This way, each group will be able to examine up to 12 solutions selected by the class. It is possible that students do not want to eliminate any solutions. If that is the case, you may need to adjust the number of student groups and the number of *Carbon Solution Cards* each student is asked to read.

Arrange students in small groups for their initial evaluation pass. ✱ Display **slide D**. Divide students into groups of 3-4, and assign each group member a letter A-D. Present group member A with the first set of solutions from the *Carbon Solution Cards,* group member B with the second set of solutions, group member C with the third set of solutions, and group member D with the fourth set of solutions.

Ask students to pick one card from their card deck. Go over each section with students and explain what information can be found in each area. Point out the scale on the right. Explain that this scale shows the percent change that this solution could make on the 9 gigaton imbalance. The dark red section shows that the carbon imbalance would be reduced to the lower level explained on the card, and the bright red section shows what a larger implementation of that solution would do to the carbon imbalance. Give students about 20 minutes to read their solutions on their own and to share the solutions with their group.

Determine top three solutions. Once students have shared their solutions within groups, task students with determining what their top 3 solutions would be across their whole group. Tell them to be prepared to share with the class tomorrow what solutions they chose and why. At the end of class, either collect the *Carbon Solution Cards*, have students store the cards in a safe place for the next class period, or assign the cards for further home learning.

✱ ATTENDING TO EQUITY

Reading and comprehending information for 3 solutions in 20 minutes could be challenging for many students. The purpose of this activity is for students to do a first pass on solutions. They will do a "deeper dive" into these solutions on day 2. Students should have the opportunity to read at least 1 solution of their choice and up to 3 solutions. Adjust group sizes and the number of solutions assigned to each student based on your judgment about your students' reading levels and the instructional time you have available. For example, some different ways to structure this activity could include the following:

- Students work in groups of 6 with 2 solutions assigned to each member.
- The class narrows to fewer solutions.
- Each student takes 1 solution, meets with a partner with the same solution, and the partners share what they learned with the whole class.

End of day 1

4 · INITIAL SOLUTION PROPOSALS

15 min

MATERIALS: *Carbon Solution Cards*, markers, Proposed Solutions chart

Revisit the carbon problem and criteria for analyzing solutions. Display **slide E**. Say, *Last class we analyzed which solutions would have the biggest impact on reducing the amount of CO_2 in the atmosphere. You became an expert on different potential solutions. Before you share out with the whole class what solutions you propose would help and why, take a few minutes to revisit the discussion you had with your group at the end of class.*

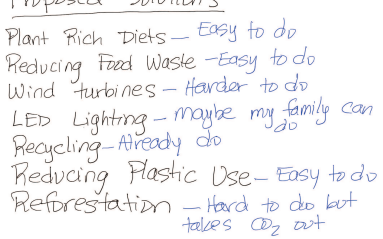
Give groups about 3 minutes to share with each other the ideas about the solutions they analyzed and prepare to share their top suggestions. Have the *Carbon Solution Cards* on hand in case any students would like to reference specific material located on the cards in their groups. As students are sharing, make sure students are ready to explain the reasoning behind their top three solutions.

Convene as a class. Display **slide F**. Come together as a class and ask groups to share their initial consensus on the top solutions. As students share, ask groups to explain why they believe these are the best solutions for our CO_2 problem. Record each group's proposed solutions on the Proposed Solutions chart.

ADDITIONAL GUIDANCE

Recording the proposed solutions where everyone can see them will help students later in the lesson, as students will use this list of solutions to develop constraints. It is possible that all 12 solutions will still end up on the poster if students can argue how the solution will help reduce the imbalance of CO_2 in the atmosphere. This is OK at this point in the lesson because the purpose is for students to become experts on different solutions. We will work to pare these down later in the lesson.

To ensure that each group has a chance to share, it may make sense to start with one group and move around the classroom from group to group. Encourage the other groups to be ready to agree, disagree, or connect their arguments to the one being shared. An example of the Proposed Solution chart is included. You will notice that on the example image, the solution is listed, as well as a brief reasoning in a different color. You may wish to capture some of the reasoning that students share for solutions they propose, as these will help later in the lesson when the class co-constructs constraints.



Push for reasoning. Some students and groups may not initially share their reasoning behind some of their choices. Some possible questions to ask that may be helpful include:

- Why did your group choose that solution over the others?
- How does this solution help us solve the problem we have on our Defining the Problem poster?
- We figured out that changes to the amount of CO_2 in the air needs to change within the next 30 years, so how will the solution you propose help us reach this goal?

5 · IDENTIFYING THE CONSTRAINTS

10 min

MATERIALS: *Carbon Reduction Solution Matrix*, Proposed Solutions chart, markers, Defining the Problem chart

Establish the need to use a systematic process to compare solutions. Display **slide G**. Say, *You all shared some great reasons why the solutions you propose would meet our criteria and help towards decreasing the imbalance of CO_2 in the atmosphere. I noticed that as your groups were sharing the solutions, some of your explanations sounded like we were also using some constraints as well. Let's use a matrix tool similar to what we have used in earlier units, such as the Tsunami Unit, to help us organize the different solutions. We can work together to identify the criteria and constraints for our problem that we can use as we work to narrow down which solution(s) we would want to adopt or follow.* Distribute *Carbon Reduction Solution Matrix* to each student.

ADDITIONAL GUIDANCE

On **slide G** is a representation of the matrix that students have on their handout. Take a few minutes together to set up part of the matrix by filling in the first column together using what is recorded on the Proposed Solutions poster. Though students have likely narrowed down to only 12 solutions included in the *Carbon Solution Cards* from day 1, there are more than 12 rows included on the handout in case your students would like to explore additional solutions. If additional solutions have now been added to the *Carbon Solution Cards*, they can be introduced and added to the matrix as well.

Record the problem to solve. Say, *Let's begin by keeping track of the problem we are trying to solve at the top. We figured out this problem in an earlier lesson. Take a moment and record our problem on the line on your handout. What did you record as our problem?*

Students should say something along the lines of the following:

- *The problem is that there is an imbalance of too much carbon in our atmosphere.*
- *And the imbalance is by 9 GtC/yr (gigatons of carbon per year) of CO_2.*

Using your students' wording or the wording on the Defining the Problem chart, fill in the problem on the line in the matrix that is projected on the board from the slide.

Record the criteria. Say, *OK, we also identified the criteria you used when you analyzed the three Carbon Solution Cards. What did we determine is our criteria for analyzing these solutions?*

Students should say that the solutions should rebalance carbon by reducing the amount of CO_2 in the atmosphere. Say, *Right. We are evaluating these solutions to determine the impact on CO_2 in the atmosphere. Take a moment and fill in this criteria on the matrix in the blue box labeled "criteria."* Do this on the matrix projected on the board as well.

ADDITIONAL GUIDANCE

In past OpenSciEd units, students have had the opportunity to learn about and define criteria and constraints. These words were first utilized in the *Cup Design Unit*, and used again in the *Tsunami Unit*, the *Homemade Heater Unit*, and the *Palm Oil Unit*. If students have already utilized these words in one of their previous units, consider re-adding the word wall card to the Word Wall under "words we earn." If students have not had a chance to define these words, you will have to provide additional context over what these words mean. See the lessons where criteria and constraints are introduced in the *Cup Design Unit* for ideas on how to introduce these words to the class.

Record the solutions to be evaluated further. Say, *If we look at our Proposed Solutions chart, we have many solutions we argue will help. We want to narrow our list down so that we can prioritize what we think we should start with. Let's begin by filling in our matrix with the solutions you and your groups just proposed.* Using the solutions that are recorded on the Proposed Solutions chart, fill in the solutions for which students argued in the matrix projected on the board and tell students to do the same on their handout.

✱ ATTENDING TO EQUITY

If students do not bring it up, you might choose to highlight the social and economic inequities to consider when evaluating solutions. Some people do not have not a choice in whether or not they are able to implement a solution. Fresh and organic produce may not be readily accessible for many, and in some cases may be expensive and unaffordable. Public transportation is something that many people rely upon to get to and from work, school, church, or for getting access to necessities like food and healthcare. It is not necessarily a conscious choice they make to help mitigate climate change. It is also not available in many areas. By seeding these ideas now, students will be more prepared for their consensus discussion on day 3.

Brainstorm constraints in small groups. Say, *Talk with your table groups for a few minutes to think about what some constraints or limitations would be on implementing these different solutions. Be ready to share with the class.* Give students a few minutes to talk with their group.

Record constraints. Bring the class back together and come to agreement on what constraints we should consider. Tell students that, as ideas for constraints are shared, the ones that the class comes to agreement on, we will add to *Carbon Reduction Solution Matrix* at the top in the columns labeled "constraints," but students should not fill these in until the class has agreed.✱

ADDITIONAL GUIDANCE

The suggested prompts below are just that, suggestions. Your class may have identified different criteria and constraints, and all 6 column headers may not be filled. That is OK. There are two constraints you do want to include: something about how easy the solution is to implement and how quickly one could begin implementing the solution. Use your students' words for these ideas, but you will want to get them out.

Suggested prompts	Sample student responses	Follow-up questions
What is a constraint or limitation your group discussed?	How easy the solution is to do or follow.	*Does everyone agree with this? OK, let's fill in "Easy to do or follow" in the column for Constraint 1.*
What is another constraint?	Something that can be done now.	*Does everyone agree with this? OK, let's fill in "Can be done now" in the column for Constraint 2.*
Continue asking for ideas from groups until you have exhausted students' ideas. Your class may argue for less constraints. That is OK, as they will have the opportunity to add to their matrix later in the lesson.	Many people should be able to do or follow the solution so that a bigger impact can happen.	*Does everyone agree with this? OK, let's fill in "Many people can do or follow" in the column for Constraint 3.*
	Something that won't harm animals or living things. Like, if we put in more wind turbines, will more birds be injured?	*Does everyone agree with this? OK, let's fill in "Won't harm living things" in the column for Constraint 4.*
	Cost is important, too. If it costs too much, then not many people will be able to do or follow the solution.	*Does everyone agree with this? OK, let's fill in "Can't be too costly" in the column for Constraint 5.*
	Be beneficial to habitats or living things. Like the trees being planted on land the cows graze—this might make the cows happier to have shade.	*Does everyone agree with this? OK, let's fill in "Benefits habitats or living things" in the column for Constraint 6.*

Now students should have their matrix set up with the problem, the criteria, and the constraints and be ready to reanalyze their solutions using these constraints.

6 · REANALYZE SOLUTIONS WITH NEW CONSTRAINTS

20 min

MATERIALS: *Carbon Reduction Solution Matrix*, *Carbon Solution Cards*

Prepare to reanalyze solutions and review how to represent their conclusions with dots. Display **slide H**. Say, *In other units we have used numbers of dots, or circles, to represent how well a solution meets criteria and constraints, and we'll do the same for the solutions you read in the last lesson. How many dots should we include if we feel the solution fully meets the criteria or constraint?*

Students should say if the solution meets the criteria or constraint really well, then we should put 5 dots or circles in the box.

Say, *Right, so if the solution does not meet the criteria/constraint well at all, then rank it with 1 dot. If a solution is somewhere in between, then use the number of dots or circles to represent that solution*. It might be helpful to do one together for the criteria. An example is included here, but feel free to revise this to use a solution that your class has proposed.

Evaluating the solution against our criteria and constraints:

Solution	Criteria: Ability to reduce CO_2 in the atmosphere	Constraint 1	Constraint 2	Constraint 3	Constraint 4	Constraint 5	Constraint 6
Plant Rich Diets	●●●						
Reducing Food Waste	●						
Wind Turbines	●						
LED Lighting	●						
Recycling	●						
Reducing Plastic	●						
Reforestation	●●●						

Jigsaw groups of students. Display **slide I** and have students retrieve their *Carbon Solution Cards*. Tell students they will be getting into groups with other people who have also evaluated the same three solutions. So, all of the students who evaluated solutions #1-3, or Group A, will get together as a group, all students who evaluated solutions #4-6, or Group B, will get together as a group, etc. There should be at least four groups, A - D.

Say, *You will work with your groups to complete the matrix by reevaluating these solutions for the criteria and constraints. Discuss each of the three with your group and evaluate them for the criteria and the constraints we have determined as a class. If you feel that there is another constraint we should consider as you are digging into your three solutions, add additional constraints to your matrix to share with the class.*✱

As students share what they discussed and decided in their jigsaw groups, circulate among the different groups and listen to their conversations. If you notice that students are just filling in the dots or circles and not supporting these with the evidence or reasoning behind why their jigsaw group evaluated the different solutions the way they did, pause at the group and ask some probing questions:✱

- I noticed you have been filling in the circles to capture how well the different solutions meet the criteria and constraints—why did your group evaluate _____ with a ranking of 3 for criteria?
- Can you tell us more about why your jigsaw group ranked _____ with a ranking of 1 for constraint 1?
- I notice that many of the groups ranked their solutions with a 1 for constraint _____. Were the reasons your groups had similar? Why do you think more than one solution ranks this way for this constraint?

With only a couple minutes left for students to work on their matrix, give them a cue that the class will be ending soon and that in the next class they will work further on categorizing solutions. At the end of class, either collect the *Carbon Solution Cards* or have students store the cards in a safe place for the next class period.

✱ SUPPORTING STUDENTS IN ENGAGING IN ARGUMENT FROM EVIDENCE

During this time students will start to engage in arguments from evidence to decide how to evaluate each solution. Remind students of the Communicating in Scientific Ways sentence starters that could support their discussion. They may want to use sentence starters, such as the following:

- The reason I think that is...
- My evidence supports this rating because...
- I agree/disagree with _____ because...
- I want to add to _____ because...
- I think the rating should be _____ because the evidence shows _____.

✱ SUPPORTING STUDENTS IN ENGAGING IN ARGUMENT FROM EVIDENCE

As students engage in this discussion to evaluate solutions, focus them on how the evidence from their *Carbon Solution Cards* can be useful for evaluating claims and persuading others about the validity of their ideas. When students are engaged in the work of argumentation, they should explicitly build from evidence, past experiences, and/or shared observations to support their conclusions. Students may not agree on the same rankings, which is OK, but they should develop an evidence-based rationale for which solutions they want to continue to support as promising ones.

End of day 2

7 · CONSENSUS DISCUSSION TO CATEGORIZE SOLUTIONS

30 min

MATERIALS: *Carbon Reduction Solution Matrix*, *Carbon Solution Cards*, Rebalancing Carbon chart, sticky notes in multiple colors, markers

Share solutions analysis with original group. Display **slide J.** Give students five minutes to complete the evaluation they worked on in the previous class and to share the information with their original groups.

Convene in a Scientists Circle. Display **slide K**. Ask students to bring their notebook, their *Carbon Reduction Solution Matrix* handout, and their *Carbon Solution Cards* to the Scientists Circle. Bring chart paper and markers to use during the discussion to further categorize the solutions as students share.

KEY IDEAS

Purpose of this discussion: Use the solutions criteria and constraint rankings that student groups developed. By the end of this discussion, the class should come to agree that though doing something is better than doing nothing, if we all just do one of the solutions, we will not be able to make much progress towards rebalancing carbon. We need to implement multiple solutions to make a difference.

Listen for these ideas:
Areas of agreement—

- There are some solutions that are easy to do right now, like eating a plant-rich diet or recycling.
- Only doing one of these easy solutions will not reduce the CO_2 enough to slow the rising temperatures.
- Some solutions would require our community or companies to make changes that are harder to implement.
- There are some cool new inventions to use as solutions for reducing CO_2, but they are still kind of new and could be difficult to implement in time to make a difference before 2050.
- We figure out that multiple methods are proposed for removing carbon from the atmosphere. While multiple methods exist, some of these methods are experimental in nature or are not enough to help with the issue or not accessible to many people.
- We look into other natural solutions that exist (planting trees, etc.) and realize that those alone cannot solve the problem either (Example: It would take over 160 trees per person to draw down what we need to bring out of the atmosphere.).
- We determine that we need multiple solutions.

Possible areas of disagreement or controversy—

- **What we could do now doesn't make much of a difference on the GHG reduction:** What if everyone on the planet took part in this solution? What if we were to implement more than one of the easy solutions at the same time? Even if they have a smaller impact on reducing CO_2, if multiple solutions were implemented, then what happens to the impact on the amount of CO_2 in the air?
- **New technologies are always best and have a larger impact on CO_2:** How many people can implement some of these new technologies? If we are trying to figure out what we can do now, what can we do with these new technologies? How can we implement them?

Introduce the goal of narrowing the list of solutions. Say, *It would be great if we could implement all of these solutions, but as I checked in with your different groups, I noticed that you didn't rank all of the solutions the same. And I heard some great arguments for why the different solutions were ranked the way they were in terms of how well the solution would reduce the CO_2 in the atmosphere and how easy they would be to implement. I heard a lot of talk about what can be done right now. Thinking about what we ranked as solutions we can do now and that would be easy to implement, let's see if we can categorize the solutions into ones we think are good solutions, not sure about, and not good solutions.*

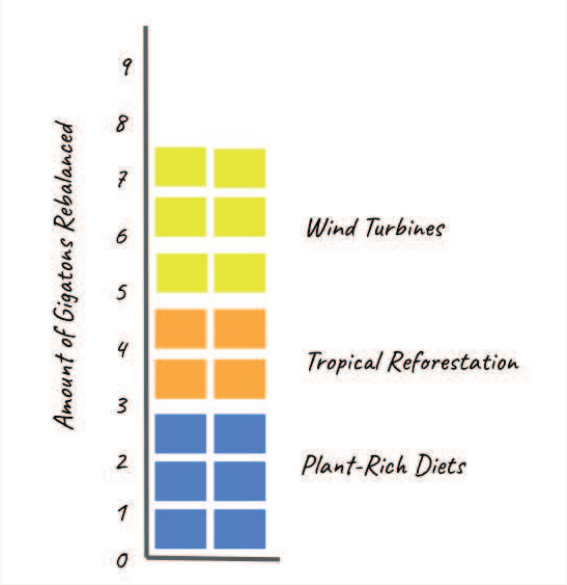
Set up the Categorizing Solutions chart with three columns like this:

Likely solutions	Not sure	Not good solutions

A Categorizing Solutions chart is also provided on **slide K.**

Nominate and argue from evidence for solutions. Let students nominate solutions that they think are likely solutions that can be done easily now. Before adding any to the chart, be sure to ask for consensus from the group. Use questions such as the following:

- Do other people agree with this solution being a likely solution we could start today?
- Can you tell us more about why you are arguing this solution would be a likely solution?
- Why do you disagree with this solution as a likely solution?
- Why are you arguing this solution is not a good solution for us right now?
- What makes you unsure of this solution?



Record solutions once there is agreement on where a solution should be placed on the poster. To help students visualize the impact each solution could have on rebalancing carbon, use the *Rebalancing Carbon* chart. As students try to reach consensus on possible solutions, place sticky notes representing each solution on the chart to help them determine how much each solution could contribute to rebalancing carbon (e.g., one sticky note could represent 1 gigaton of carbon). Try to use a different colored sticky note or alternate colors of sticky notes for each solution. You may have to cut sticky notes in half or more to represent half a gigaton or less of carbon. Remind students that as we work through solutions, we are trying to reduce carbon imbalance. It is possible that there may be a solution or two that students will not agree upon and will argue it might fit in more than one column. This is OK, and you should feel free to place a solution in more than one column if students are arguing for that. An example of a filled-in poster is included below, but it is likely that your students may argue for some of the solutions that might fit in different categories than what is here. Take a moment after the sorting process and make sure that the *Rebalancing Carbon* chart reflects the changes the class feels like it needs to make on the carbon imbalance. Adjust as needed.

Likely solutions	Not sure	Not good solutions
#1 Plant-rich diet #2 Reducing food waste #3 Carpooling #11 Reducing plastic use #7 LED lighting #9 Recycling	#8 Solar panels #5 Onshore wind turbines #14 Planting more trees #11 Reducing plastic use #6 Silvopasture #10 Rainforest restoration #15 Smart thermostat #16 Public transportation	#12 Artificial trees #13 Alternative cement #4 Electric car

Say, *So, it sounds like many of you are arguing that there are a few solutions that are likely that we could easily start, even today.*

Suggested prompts	Sample student responses
What if we all agreed to eat less meat? How might this affect the CO_2 in the atmosphere?	It might make a small difference in our area, but more than just our class would need to do this to make a big effect.
What if we were to do more than one of these likely solutions? What kind of effect would this have on the imbalance of CO_2?	I think that would make more of a difference. Yeah, it seems like if we could all do more than one of these, then the effects could build on each other.
So, which of these likely solutions might you recommend we try to do at the same time?	Well...I could try eating a plant-rich diet and work to not have so much food waste by encouraging my family to not eat out so often. Yeah...and I could try eating more fresh foods instead of packaged foods, and that might help with reducing plastic use.
And for these solutions you are arguing you could try, do you think it would be OK if you did them for a week? Or would you need to do them longer?	We would need to do these things for a long time. Yeah...like it seems like we would need to do them our whole life.
OK, so, it sounds like the solutions we decide to try should be ones we can sustain or do for a long period of time. Are the solutions you have mentioned (or the ones included in our "likely" column) solutions that could be done for a long time?	Yeah...eating more plants I could do for my life as long as there are plants! Reducing food waste and plastic use I could work on doing more and more over my lifetime.

Say, *So, it sounds like these solutions we have in the "likely solutions" column could also lead to us (and others if we can convince them) to change habits—like eating more plants, buying less things in plastic, etc. It also looks like some of these solutions could get us closer to reducing our carbon imbalance to a more manageable level.*

ASSESSMENT OPPORTUNITY	**Building towards:** 14.A Evaluate competing solutions using a systematic process and jointly developed and agreed upon criteria to determine how small changes in behaviors and technologies can add up to larger impacts on reducing CO_2 in the atmosphere. **What to look/listen for:** During the Consensus Discussion, listen for students arguing • for solutions that will reduce carbon emissions, • that multiple solutions would need to be implemented to reduce enough CO_2 to slow or stop the temperatures rising, and • that some small solutions would be easy for everyone to implement, and if everyone did, it would make a difference in the CO_2 in the air. **What to do:** If students aren't suggesting the solutions with a small impact on the amount of CO_2 in the air, ask probing questions about what this impact would be if everyone in our class did it, or everyone in our town, or state, or even the United States. Continue this line of questioning to push students to think about what if everyone were to take part in more than one of the smaller, easier to implement solutions to help students start thinking about the compounding effects of implementing multiple solutions and that this is something they can do with small solutions, such as reducing plastic usage, recycling, eating a more plant-based diet, etc.

8 · UPDATE PROGRESS TRACKERS

5 min

MATERIALS: science notebook

Update individual Progress Trackers for reflection. Project **slide L.** Explain to students that we want to take some individual time to capture what we have figured out about our lesson question: What are large-scale solutions for reducing carbon in the atmosphere?

Have students turn to the Progress Tracker section in their notebooks. Use **slide L** to guide students in drawing a line before the last entry and to complete the 2 columns, filling in both lesson question(s) and their responses. Give students 3-5 minutes to quietly update their Progress Trackers using words and drawings to show what they have figured out. Ask students to draw a line underneath their responses when they are done. Prompt students to use evidence from the *Carbon Solution Cards* and solution matrix.

9 · Navigation

10 min

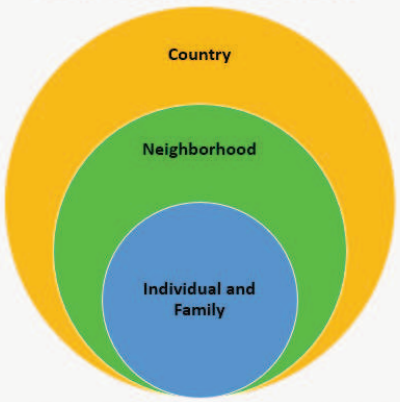
MATERIALS: *Carbon Solution Cards*, *Carbon Reduction Solution Matrix*

Examine the Impact of Solutions on Earth's Systems. Display **slide M**. The slide has an image of the Earth's Systems Model that students co-developed in Lessons 1-11. Say, *Now that we have a list of solutions we think we could likely implement on a large scale, let's see where this impact could happen on our Earth's Systems Model.* Go through the solutions students agreed upon in the "likely solutions" list and facilitate a discussion focused on where the solutions will have the greatest impact. Have the *Carbon Solution Cards* on hand in case any student or group would like to reference specific material while considering if the solution is a "likely solution." Reach consensus that the solutions students have chosen would have an impact on multiple components of Earth's systems.

Suggested prompt	Sample student response

Suggested prompt	Sample student response
We agreed that plant-based diets are a solution we could begin implementing now. Where on our Earth's System's Model where would see the impact of this solution?	Less land would be needed to raise livestock, so there would be more room to grow trees. Less packaging would be needed to keep meat fresh. This would reduce the amount of fossil fuels that we use.
We agreed that using public transportation is a solution we could begin implementing now. Where on our Earths' Systems Model would we see the impact of this solution?	Fewer fossil fuels would need to be extracted for making cars. Fewer fossil fuels would need to be mined to make gas for cars. If there are fewer cars on the road, we will not need to cut down trees to make room for new highways.

Discuss who is responsible for implementing the solutions. Say, *Wow, we found large-scale solutions that would have an impact on multiple components of Earth's systems, but I heard some of you say that it might take more than just our class to really make a difference. Who do we think is responsible then for implementing these solutions?* Accept all student responses. It might be helpful to refer to the conversations students started in Lesson 14 about who is responsible for implementing solutions and at what scale.



Combining solutions at different scales to have greater reductions in carbon emissions

Suggested prompt	Sample student response
Who is responsible for implementing large-scale solutions?	We need everyone in our community to do their part. Support from their local government is necessary to help people understand what they could do. We need big companies to do their part. The president could tell people how important climate change solutions are.
Has anyone seen on TV or read in the news about anything communities, companies, or the government is doing?	Sometimes the US president meets with other country leaders to discuss climate change. I saw a commercial about a company that is encouraging people to recycle.
If we wanted to know what people and companies are doing, what could we do?	We could talk to experts. We could read about what communities are doing.

Tell students that they have great ideas and that in the next lessons, we will have to see what communities are doing to help rebalance carbon in the atmosphere, and we will have to figure out who is responsible for implementing these solutions.

Additional Lesson 15 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA	**CCSS.ELA-LITERACY.RST.6-8.2: Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.** Students are assigned up to 3 solutions from the *Carbon Solution Cards*. They are expected to identify the main ideas from the text about each solution and to communicate those main ideas to members in their small group. Students are expected to read the texts and evaluate solutions based on the class's agreed-upon criteria and constraints, and not based on their own opinions.

LESSON 16: How are these solutions working in our communities?

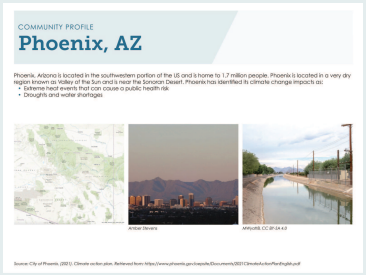
PREVIOUS LESSON

We looked at large-scale solutions for reducing the amount of CO2 in the atmosphere. We defined our criteria and constraints for a successful solution, and decided that solutions should be practical and help rebalance carbon. We organized our information using a Design Matrix, and decided that to meet our criteria, multiple solutions are necessary to rebalance CO2 released into the atmosphere. We wondered what is being done to ensure solutions are implemented and who is responsible.

THIS LESSON

INVESTIGATION

1 day



In this lesson, we obtain information from community plans to determine how the solutions are being used in the communities and how they rebalance carbon and/or help a community to become more resilient to changes already occurring in the community. We use these plans as examples to help motivate the need to evaluate and/or develop a plan for our own community.

NEXT LESSON

We will create a checklist for what a resilience plan for our school and local community should include. We will work in groups to design resilience plans and provide feedback to other groups. We will evaluate the plans by asking questions and brainstorm how to share and communicate our plans to other audiences. We will argue for the one best for our community.

BUILDING TOWARD NGSS

MS-ESS3-1, MS-ESS3-3, MS-ESS3-4, MS-ESS3-5, MS-ETS1-2

WHAT STUDENTS WILL DO

16.A Critically read scientific texts adapted for classroom use to obtain information on how communities are implementing new activities at different scales to mitigate the flow of carbon into and out of the atmosphere and/or adapt to changes in the community.

WHAT STUDENTS WILL FIGURE OUT

- Communities develop plans to rebalance CO_2 levels in the atmosphere while also building a more resilient community by adapting to changes already occurring within the community.
- Plans include many solutions across different parts of the community and at different scales, from individual and family options to large-scale community solutions.

Lesson 16 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	3 min		**NAVIGATION** Recall the class wonderings from the last lesson about who is doing these solutions and where they are happening.	A	
2	5 min		**DEFINE COMMUNITY RESILIENCE** Introduce the term *community resilience* and planning documents.	B	
3	20 min		**JIGSAW COMMUNITY PLANS TO OBTAIN INFORMATION** Work in small groups to obtain and evaluate information about solutions from one community plan.	C-D	*Evaluating Community Solutions*, *Boston: Community Resilience Plan*, *Phoenix: Community Resilience Plan*, *Oscarville: Community Resilience Plan*, *Yakima: Community Resilience Plan*, Earth's Carbon System Model (Lesson 11), Earth's Water System Model (ideally from Lesson 4)
4	15 min		**UPDATE CARBON MODEL WITH NEW SOLUTIONS** Share different community solutions and how they work to help the communities change carbon emissions, uptake, or adapt to changes.	E	*Evaluating Community Solutions*, *Boston: Community Resilience Plan*, *Phoenix: Community Resilience Plan*, *Oscarville: Community Resilience Plan*, *Yakima: Community Resilience Plan*, Carbon System Model (from Lesson 11), Earth's Water System Model (from Lesson 2), sticky notes, markers
5	2 min		**NAVIGATION** Raise curiosities about evaluating an existing local plan, or developing one for the community.	F	

End of day 1

Lesson 16 • Materials List

	per student	per group	per class
Lesson materials	• *Evaluating Community Solutions*	• *Boston: Community Resilience Plan* • *Phoenix: Community Resilience Plan* • *Oscarville: Community Resilience Plan* • *Yakima: Community Resilience Plan*	• Earth's Carbon System Model (Lesson 11) • Earth's Water System Model (ideally from Lesson 4) • Carbon System Model (from Lesson 11) • Earth's Water System Model (from Lesson 2) • sticky notes • markers

Materials preparation (15 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

There are four examples of community resilience plans that can be evaluated by either 4 or 8 groups of students. Determine if you can divide a smaller class into 4 groups (with more students per group) or use 8 groups (with less students per group). Make enough copies of each plan so that students will have a copy of their assigned plan to evaluate. All four plans are included as a reference (in color) in the student edition.

If you live in a community featured in this lesson (e.g., Boston, Phoenix, Oscarville, or Yakima Valley), consider only using three plans for this lesson as you can use your own community plan in Lesson 17. Alternately, students can use their community plan in this lesson, and then design a school plan that aligns with it as part of the design work in Lesson 17.

Some solutions listed on these plans might be entirely new to students or they might not quite understand what the solution entails. Many of these were either explored in Lesson 15 or will be explored in Lesson 17. Students can also research some of these solutions as an extension opportunity if they are curious and want to know more.

Have the Earth's Water System Model (from Lesson 4) and the Earth's Carbon System Model (from Lesson 11) available for students to sort the different solutions onto the parts of the model where the solution is designed to address a problem. For example, solutions that reduce carbon emissions would be placed onto the Earth's Carbon System Model. Solutions designed to prevent damage from a flood would be placed on the Water System Model.

Lesson 16 • Where We Are Going and NOT Going

Where We Are Going

This lesson is focused on highlighting the bolded aspects of the DCIs below around individual, community, and business activities and behavioral changes that are necessary to rebalance carbon in the atmosphere.

- ESS3.C: Typically, as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth, **unless the activities and technologies involved are engineered otherwise.**
- ESS3.D: Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and **other kinds of knowledge, such as understanding human behavior and applying that knowledge wisely in decisions and activities.**

Importantly, the lesson focuses on "community resilience" - a word students encounter at the beginning of the lesson. The lesson uses "resilience" to encompass ways that communities can both rebalance carbon in the atmosphere (i.e., also called mitigation solutions) while also adapting to current changes they may be experiencing with flooding, droughts, or extreme heat (among other impacts of a changing climate).

The lesson emphasizes the practice of obtaining, evaluating, and communicating information. In particular, it focuses on critically reading scientific texts adapted for classroom use. Each community's resilience plan was developed specifically for students based on the longer, more detailed version of the plan. Activities and behaviors from the plans were chosen to highlight some solutions that students have seen already in Lessons 14 and 15, along with introducing new solutions that communities are implementing to adapt to changes in their current water supply (whether they are a community experiencing drought or flooding).

Where We Are NOT Going

This lesson is purposely intended to give students a quick glimpse at real community plans (adapted for classroom use). Students will evaluate their own community plan or design one for their community in Lesson 17 so they will not look at their local plan yet. If you live in one of the communities featured in this lesson, consider holding back that plan until Lesson 17 and use only three plans provided in this lesson.

This lesson does not address the inequities between 'who' produces the most carbon emissions and who is being impacted the most. For example, the community of Oscarville, AK produces little to no carbon emissions, but are being greatly impacted by a changing climate as a result of the higher atmospheric CO_2 levels. If this noticing comes up from students, it provides a good opportunity to emphasize how we are connected in a global system irregardless of who is contributing the most carbon and who is being impacted the most by the changes. However, if you would like to emphasize issues around inequity and environmental justice related to climate change, make sure to allot the proper time and resources to ensure that misconceptions are not created about the people or context of the changes. This includes considering the history and impacts of climate change on marginalized communities and attending to the information presented to make sure that it does not disvalue the culture or experiences of those involved and also respects their cultures and lived experiences as valid and reliable sources of information.

LEARNING PLAN for LESSON 16

1 · NAVIGATION

3 min

MATERIALS: None

Recall where the class left off. Display **slide A**. Ask students, *Can someone remind us what we were curious about last time?* Allow students to share ideas, such as:

- We were wondering if other communities are doing these solutions.
- We were wondering if these solutions are happening anywhere and/or what they look like when they are being done.
- We were wondering who is responsible for doing these solutions.

To transition, say, *OK, so we are curious to see what these solutions look like and who is doing them. Let's explore that more.*

2 · DEFINE COMMUNITY RESILIENCE

5 min

MATERIALS: None

Introduce Community Resilience planning. Say, *We've seen a lot of different solutions and how they might work to rebalance carbon in the atmosphere. We were also wondering if anyone was actually implementing some of these solutions. I've found some community resilience plans that we can look at to determine what communities are doing right now and how they are doing it.*

Display **slide B**. Say, *But before we do that, let's take a moment to think about what the word 'resilience' means*. Give students 1 minute to think silently and then share their thinking with a partner before sharing ideas with the whole class.✱

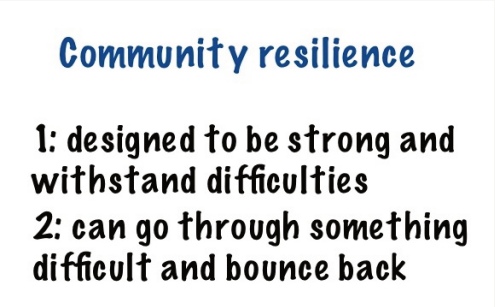
Ask, *So when we hear 'resilience', what do we think of?* Listen for students to share ideas such as:

- Being strong, like withstanding something
- Being tough or able to do something difficult
- To bounce back from something hard

Connect resilience with 'community resilience.' Ask, *So what do we think community resilience would mean?* Listen for ideas like:

- A community can go through hard things and bounce back better.
- A community is designed in a way to withstand bad things (like droughts and floods, or other extreme events).

Add 'community resilience' to the Word Wall.



✱ ATTENDING TO EQUITY

Supporting emerging multilinguals: Before students engage in whole class discussions, it can be helpful to first provide them with the opportunity to work with others - either in pairs, triads, or small groups - on ideas related to their reasoning. These smaller group structures can be especially helpful for emerging multilingual students because they offer students a chance to engage in sensemaking with their peers, and also offers them the space to use their linguistic and nonlinguistic resources to express their ideas (and learn from other students' uses of these resources too).

Cognates are words that are similar in both spelling and meaning. Many science vocabulary have cognates across romance languages (e.g., resilience in English = resiliencia in Spanish). Using cognates, teachers can support emerging multilingual students in making connections between new science vocabulary and their native language(s). This can reduce the vocabulary overload that they may experience in science. Teachers can display cognates by

placing them on word walls alongside the new vocabulary terms or include cognates in text using parentheticals.

3 · JIGSAW COMMUNITY PLANS TO OBTAIN INFORMATION

20 min

MATERIALS: *Evaluating Community Solutions*, *Boston: Community Resilience Plan*, *Phoenix: Community Resilience Plan*, *Oscarville: Community Resilience Plan*, *Yakima: Community Resilience Plan*, Earth's Carbon System Model (Lesson 11), Earth's Water System Model (ideally from Lesson 4)

ADDITIONAL GUIDANCE

Group students into either four or eight groups, depending on class size. For a smaller class, four groups means each group has one plan. If using eight groups, there will be two groups with the same plan. This offers the opportunity for the two groups to share information and come to agreement across the two groups before sharing their shared thinking with the whole class.

Prepare to read and analyze text using a close reading strategy. Display **slide C.** Ask students, *Before we begin digging into these texts, what is it that we hope to gain information about?* Students might say:

- more information about these communities
- what problems the community has identified
- more information about solutions

Gather in small groups to obtain and evaluate a community resilience plan. Place students into small groups and display **slide D** with the close reading instructions. Pass out a copy of one plan to each student in a group. These plans include communities experiencing either floods or droughts, and urban to very rural examples. Encourage students to write on and mark up their plan as they work together.✱ There are copies of the plans in the student edition as a reference. Give students 5-10 minutes to individually read through the community plan before discussing the plan as a group.

Bring groups together to share initial noticings about the plans. Ask students, *What kinds of solutions are you seeing in the plans? Why do you think the communities are doing these things?*

Sample student responses might include:

- Ideas about the different categories on the plans (e.g., buildings, energy efficiency, water and land use, transportation, energy sources, and other solutions).
- Ideas about how all people, organizations, and business are contributing in different ways.
- Ideas about how some solutions are focused on fossil fuel use, but others are focused on responding to droughts, floods, or extreme heat or precipitation.

Say, *So it sounds like these communities are doing a variety of things to address climate change impacts in their community. Some are focused on energy use, but others are focused on becoming more resilient to floods or droughts. Let's sort the solutions and figure out which part of the Earth's Carbon System Model or Earth's Water System Model that the solution would be designed to address*. Use the graphic to represent solutions at different scales, an idea introduced into Lesson 14.

Sort plans into different carbon strategies. Pass out *Evaluating Community Solutions* and have groups work together to sort and organize the different solutions into three options: solutions that reduce carbon emissions; solutions that take carbon out of the atmosphere; and solutions that help the community adapt to changes already happening. Have students work together, using the handouts, to sort each solution and provide a brief rationale to share with the whole class. They will need this information to help map the solutions onto the Carbon System Model in the next activity.✱✱

✱ ATTENDING TO EQUITY

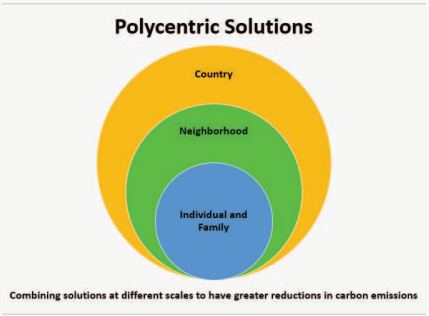
Universal Design for Learning: While students read the texts, encourage students to use colored pencils, highlighters, or pens to mark-up the text and note words they are curious about or questions they have. This is a useful strategy to help readers access *language & symbols* contained in text and *comprehend* the information from the text.

✱ SUPPORTING STUDENTS IN ENGAGING IN ARGUMENT FROM EVIDENCE

Community resilience plans are often long with many details about policy and implementation. These examples have been adapted for classroom use to highlight key actions and behaviors the community is focused on implementing. These have been chosen to highlight different parts of the community (e.g., transportation, building) and different scales of implementation. Support students with prompts such as: What is the solution and how does it work? What part of the community is involved in implementing this solution? Who is involved - individuals, government, business? How do these plans help us understand what we've been working on these last few classes?

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING ENERGY AND MATTER

Students will sort the solutions by how it works to rebalance atmospheric carbon - whether it is lowering emissions of carbon into the atmosphere or designed to take it out. Some solutions might have additional



Combining solutions at different scales to have greater reductions in carbon emissions

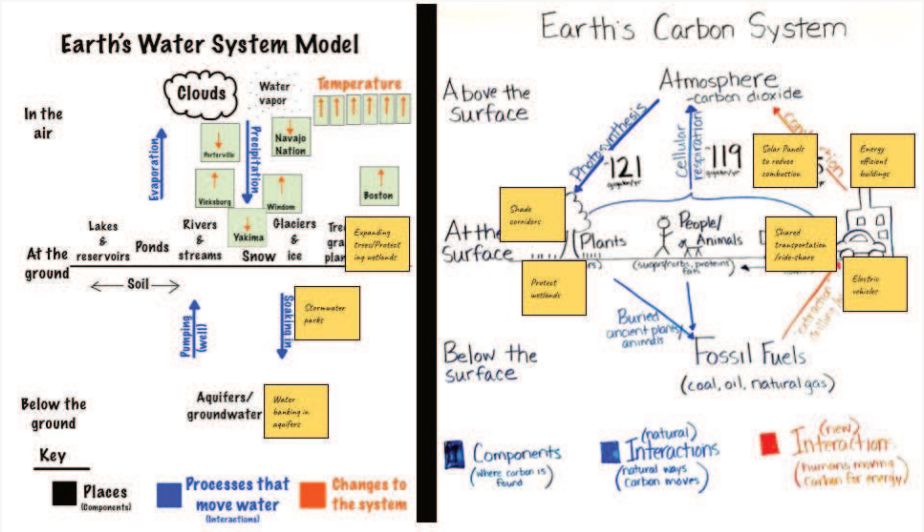
benefits beyond shifting the flow of carbon, such as cooling effects on temperatures or providing drought or flood relief.

4 · UPDATE CARBON MODEL WITH NEW SOLUTIONS

15 min

MATERIALS: *Evaluating Community Solutions*, *Boston: Community Resilience Plan*, *Phoenix: Community Resilience Plan*, *Oscarville: Community Resilience Plan*, *Yakima: Community Resilience Plan*, Carbon System Model (from Lesson 11), Earth's Water System Model (from Lesson 2), sticky notes, markers

Share findings across the whole class. Display **slide E.** Have each group take 2-3 minutes to share a bit about their community and the solutions that are in place in the community. As students share each solution, have them post a sticky note on the Carbon System Model in a place to show how the solution works to mitigate carbon or adapt to changes in the community. Some solutions fits better with the Earth's Water System Model from Lesson 2. Across all four communities, some solutions may overlap - when this happens, just add a + sign to the sticky note to indicate that more than one community is using the solution in some way.✱



✱ SUPPORTING STUDENTS IN DEVELOPING AND USING SCALE, PROPORTION, AND QUANTITY

Use this discussion to highlight the different observed scales at which the solutions operate within a community. For example, some solutions can be done by individuals and families, while other solutions are implemented at larger scales through government or business.

Facilitate a Building Understandings Discussion. Once all communities have been shared and solutions mapped to the model using sticky notes, facilitate a Building Understandings Discussion about the different approaches communities are using to rebalance carbon in our atmosphere and also adapt to changes they are experiencing now.

Update the community resilience word wall card to include images that represent what students learned about community resilience.

KEY IDEAS

Purpose: To highlight the different ways communities are using solutions to rebalance carbon or adapt to changes.

Look for/listen for:

- Ideas about how communities have a diverse number of solutions.
- Ideas about how solutions are implemented at different scales, from individual to large-scale business or government solutions.✱

Suggested prompt	Sample student response
Have we figured out how some of these solutions are being implemented by communities? What do some of the plans focus on?	Some communities are focused on transportation or building new energy efficient buildings.
How are these solutions changing the movement of carbon in and out of the atmosphere?	Some solutions are designed to lower how much carbon is released, like new energy sources or reducing the number of cars driving or electricity we use. Other solutions are focused on taking carbon out of the atmosphere, like keeping greenspaces or changing some of our farming practices.
Are there other community benefits for some of the solutions? For example, how does building new stormwater systems help communities?	For communities that are flooding, the new stormwater systems can help prevent damage to homes and buildings. Green spaces also keep places cooler when it gets really hot. Storing water underground provides a 'bank' of water for a community that may be having a drought.
So how do we see individuals contributing to these plans? What about the community, or larger government or business organizations?	Some solutions can be done by individuals or families, but other ones have to be done by the government or business.

ADDITIONAL GUIDANCE

Encourage students to add any new questions they have (in Part 2 of *Evaluating Community Solutions*) to the DQB. These questions about community resilience plans can be leveraged to motivate their community planning project in Lesson 17.

ASSESSMENT OPPORTUNITY

Building towards: 16.A Critically read scientific texts adapted for classroom use to obtain information on how communities are implementing new activities at different scales to mitigate the flow of carbon into and out of the atmosphere and/or adapt to changes in the community.

Look for/listen for: Students should share ideas about how

- Communities develop plans to rebalance CO_2 levels in the atmosphere while also building a more resilient community adapting to changes already occurring within the community.
- Plans include many solutions across different parts of the community and at different scales, from individual and family options to large-scale community solutions.

ASSESSMENT OPPORTUNITY

Continued from previous page...

What to do: Solutions exist across different parts of the community, from building, to urban planning, to energy use and agriculture. Individuals can contribute to some solutions while some are implemented at the community level or by business or government. Before moving onto Lesson 17, it will be important for students to understand the diverse approach communities take across many different sectors and at different scales (individual, community, business, or government scales). These ideas will help support them as they consider their own local planning.
If students struggle to identify these ideas, ask questions such as:

- Which solutions are focused on energy use? Agriculture? New buildings or how to improve existing buildings? Managing water resources?
- Who is participating in these solutions? Individuals or families, or is the solution being implemented at a larger scale?

5 · NAVIGATION

2 min

MATERIALS: None

Generate interest or ideas for a local community plan. Display **slide F**. Say, *Now that we've seen other community plans, do we have one of our own for our community we could evaluate? How might we do that? Or, could we develop a new plan with some of these solutions and others we identified in earlier lessons?*

Ask students to turn and talk with a neighbor about these questions. Let one or two students share their ideas about either obtaining a community plan to review or developing a new one. More students can share their thinking at the beginning of Lesson 17.

ADDITIONAL GUIDANCE

Consider modifying this navigation move to focus on either looking at an existing community plan, if you have one for your community. Or if there isn't one, focus on how to use the ideas developed over the last several lessons to design a new community plan.

Additional Lesson 16 Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA

CCSS.ELA-LITERACY.RST.6-8.2: Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

CCSS.ELA-LITERACY.RST.6-8.7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

Students will obtain central ideas from a text adapted for classroom use, provide a summary of these ideas, and then integrate the ideas into the existing Carbon System Model.

LESSON 17: What solutions work best for our school or community?

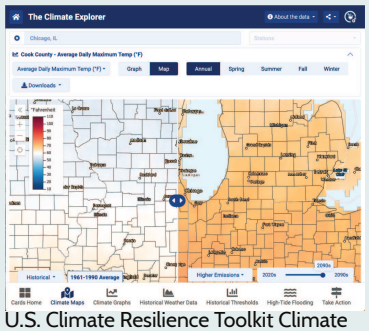
PREVIOUS LESSON

We obtained information from community plans to determine how the solutions are being used in the communities and how they rebalance carbon and/or help a community to become more resilient to changes already occurring in the community. We used these plans as examples to help motivate the need to evaluate and/or develop a plan for our own community.

THIS LESSON

INVESTIGATION, PUTTING PIECES TOGETHER

4 days



U.S. Climate Resilience Toolkit Climate Explorer

We are wondering if our community has a resilience plan or should have a plan. We create a checklist for what a resilience plan for our school and local community should include based on what we saw in resilience plans in the last lesson. We work in groups to design resilience plans that contribute to the long-term rebalancing of carbon and also prepare the community for change. We provide feedback to other groups and evaluate the plans by asking questions. We brainstorm how to communicate our plans to other audiences. We argue for the one best for our community.

NEXT LESSON

We will identify questions from our DQB that we will be able to answer. We will celebrate all that we have learned in this unit and across the school year. We will spend time identifying the questions that we were not able to answer and will build a new DQB of these questions. We will create a plan to answer some of the questions on our own and during the next school year and beyond.

BUILDING TOWARD NGSS

MS-ESS3-1, MS-ESS3-3, MS-ESS3-4, MS-ESS3-5, MS-ETS1-2

WHAT STUDENTS WILL DO

17.A Apply scientific principles to design a process/system that the school can undertake to reduce the vulnerability to climate change impacts (e.g., high heat, changing water resources) in the short-term and contribute to rebalancing carbon in the long-term.

17.B Ask questions to challenge the proposed resilience plan to evaluate whether the solutions meet the class' agreed criteria checklist and will reduce vulnerabilities to climate impacts in the short-term and rebalance carbon in the long-term.

17.C Construct an argument grounded in evidence and scientific reasoning to recommend a design solution that will prepare a community for predicted changes to temperature and/or precipitation (effect).

17.D Communicate information in writing and/or oral presentation about how adopting individual, family, or school solutions (subsystems) to reduce vulnerabilities to climate change and/or rebalance carbon can contribute to broader community resilience (larger system) (optional).

WHAT STUDENTS WILL FIGURE OUT

- Communities can design plans to help rebalance carbon dioxide which will take awhile, but they can also do things to make the community resilient to changes happening now.
- Communities design plans based on community member needs and characteristics of the community itself.
- Some places and people may be more at risk for impacts in the community.
- Solutions adopted at home and school can make the whole community more resilient.

Lesson 17 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	8 min		**NAVIGATION** Revisit ideas for a community resilience plan for your own community.	A-B	Students and Solutions video (optional)
2	22 min		**DEVELOP A CRITERIA CHECKLIST** Co-construct a criteria checklist for what our community resilience plans need to do.	C-F	chart paper, markers
3	15 min		**COME TO CONSENSUS ON CHANGES IN YOUR COMMUNITY** Make observations from the Climate Explorer to get clear on future impacts to your community.	G-I	Climate Explorer tool, computer and projector
					End of day 1
4	5 min		**SUMMARIZE KEY TAKEAWAYS ABOUT THE PROBLEMS** Give students a project planning sheet. Either individually or with a partner, have students review their observations from the Climate Explorer to summarize problems.	J	*Community Resilience Plan: Project Planning Sheet*
5	10 min		**DISCUSS WHO IS AFFECTED MOST** Elicit ideas about who might be affected by climate impacts.	K	*Community Resilience Plan: Project Planning Sheet*, Climate Explorer tool, computer and projector
6	30 min		**INTRODUCE SOLUTIONS AND START THE PLANNING SHEET** Introduce the Water Solution Cards. Provide time for groups to complete Parts 1-4 on their planning sheet. Use the optional Home Learning and Exit tickets as needed.	L-O	*Community Resilience Plan: Project Planning Sheet*, *Project Options*, *Water Solution Cards*, *Carbon Solution Cards* (from Lesson 15), class Criteria Checklist, Community Member chart
					End of day 2
7	15 min		**EVALUATE PLANS BY ASKING QUESTIONS** Have groups jigsaw their plans with other groups. Students will evaluate the plan by asking questions that challenge the plan. Provide your feedback to groups at this time, too.	P	*Community Resilience Plan: Project Planning Sheet*, class Criteria Checklist, *Rubric: Evaluating Solutions by Asking Questions*, *Reference: Peer Feedback Guidelines*
8	Varies min		**GROUP WORK TIME** Give students time to work in groups on developing their project.	Q	*Community Resilience Plan: Project Planning Sheet*, *Rubric: Designing a Community Resilience Plan* with feedback, additional materials will vary according to project platform, class Criteria Checklist
					End of day 3
9	15 min		**GROUP WORK TIME, CONTINUED** Give students time to work in groups on developing their project.	R	*Community Resilience Plan: Project Planning Sheet*, *Designing a Community Resilience Plan: Teacher Feedback* with feedback, Community Resilience Plan (started day 3), class Criteria Checklist, *Rubric: Designing a Community Resilience Plan*
10	10 min		**MAKE A PLAN FOR COMMUNICATION** Give students time to work in groups on developing their project.	S	*Community Resilience Plan: Project Planning Sheet*, Community Resilience Plan (started day 3), class Criteria Checklist

Part	Duration		Summary	Slide	Materials
11	18 min		**SHARE LEARNING ON AN INDIVIDUAL ASSESSMENT** Give students an individual assessment to (1) explain the problems the community is facing, and (2) make an argument for one solution they believe is particularly important for their community to undertake.	T	*Argue for the Best Solution to Solve a Problem in Your Community*, *Rubric: Argue for the Best Solution to Solve a Problem in Your Community* rubric
12	2 min		**NAVIGATION** Prepare to revisit the DQB.	U	Driving Question Board

End of day 4

Lesson 17 • Materials List

	per student	per group	per class
Lesson materials	• science notebook • *Community Resilience Plan: Project Planning Sheet* • *Argue for the Best Solution to Solve a Problem in Your Community*	• *Project Options* • *Water Solution Cards* • *Carbon Solution Cards* (from Lesson 15) • *Rubric: Designing a Community Resilience Plan* with feedback • additional materials will vary according to project platform • *Designing a Community Resilience Plan: Teacher Feedback* with feedback • Community Resilience Plan (started day 3)	• Students and Solutions video (optional) • chart paper • markers • Climate Explorer tool • computer and projector • class Criteria Checklist • Community Member chart • *Rubric: Evaluating Solutions by Asking Questions* • *Reference: Peer Feedback Guidelines* • *Rubric: Designing a Community Resilience Plan* • *Rubric: Argue for the Best Solution to Solve a Problem in Your Community* rubric • Driving Question Board

Materials preparation (120 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Lesson modifications: Resilience Plan. This lesson is project-based and needs to be tailored to your community context. The default lesson plan assumes the community does not have a climate resilience plan in place, and therefore, students design one. However, if your community does have a resilience plan, you will want to modify the activities so that students are redesigning this plan or designing a school plan to align to their communities' existing plan. Likewise, if you examined your community's resilience plan in Lesson 16, modify this lesson so that your students design a school plan aligned to their community's resilience plan. Revise the slides and student handouts as necessary. If your community has a climate resilience plan or climate action plan, locate it prior to the lesson and format it as a 2-page student friendly handout similar to the plans shared in Lesson 16. For large, comprehensive plans, you might need to narrow down the number of solutions students work with from the plan. Plan for ample time to curate this resource for your students.

Water Solution Cards: The Water Solution Cards provide a sample of solutions. You can modify these cards to include additional solutions for your community. Use *Information for Carbon Solution Cards*, *How to create your own solutions cards,* for guidance on what to include.

Assessment and rubric modifications: There are ample opportunities for formative and summative assessment at the group level and individual level. If you modify the assessment plan, ensure that you include a moment to assess both group and individual progress. The rubrics are based on a sample class Criteria Checklist and should be modified to match your class' agreed upon checklist.

Planning and final products. Review and edit the *Community Resilience Plan: Project Planning Sheet* handout. Make sure not to lose the peer feedback part as you edit. Review and edit the *Project Options* handout based on the materials and apps your students have access to. Gather any materials that students will need (chart paper, markers, pencils, etc.) and ensure the groups have computer access if they pursue a digital choice.

Ideas for digital tools. Use *Project Choice and Platform Information* to learn more about digital tool options and modify the handout according to any acceptable use policy or classroom limitations.

Connect to ELA and Math learning goals based on project choices. Use *Potential Accompanying Standards* to identify possible accompanying ELA, Math, and ISTE project standards.

Stakeholder interviews. Identify and alert community and/or school administration that your students might be interviewing them as stakeholders to find out more about community member needs. Stakeholder interviews are an optional extension provided at the end of day 2.

Lesson 17 • Where We Are Going and NOT Going

Where We Are Going

This lesson gives students a platform for communicating about projected climate-related impacts to their communities and solutions that will help the community in the long-and short-term. The lesson is intended to be a meaningful experience about understanding human behaviors, new technologies, combining both long-term and short-term solutions, and how crafting key messages can help communicate their understanding to others. Consider working with your school's social studies teacher(s) to plan and implement these projects. Much of the work in this project is about integrating climate science ideas with social and civic activities.

The overall approach taken in the lesson includes:

- Day 1: Develop a jointly constructed and agreed upon Criteria Checklist and make observations of projections of temperature and precipitation change in your community.
- Day 2: Complete the project planning sheet as a group.
- Day 3: Gather feedback from peers, teacher(s), and community members and work on projects.
- Day 4: Finish project work, plan for communicating projects, and individual assessment.

If you modify the lesson, it is important that you recognize the lesson targets two Performance Expectations:

- MS-ESS3-3. Apply scientific principles to design a method for ~~monitoring and~~ minimizing a human impact on the environment.
- MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

Make sure your modifications are congruent with these Performance Expectations, therefore allowing you to engage students in this kind of three-dimensional learning and to assess student progress on these assessment targets.

This lesson is intended to engage your students in (1) designing solutions in the form of a community resilience plan, (2) evaluating the community resilience plans by asking questions that challenge them, (3) developing an argument for the most important solution for your community, and (4) planning how to communicate the plans to external audiences. Each of these practices include specific scaffolds at the moment of their use as shown in the project planning sheet, discussion prompts, and feedback tools. You may want to include your students in identifying what they need to do in each of these steps as opposed to giving them a pre-constructed planning sheet. This would be one way to fade a scaffold for students.

The crosscutting concepts you may find most useful in this lesson include Stability and Change, Cause and Effect, and Systems and System Models. Support your students in using a Stability and Change lens to think about how their resilience plans can contribute to both the long-term rebalancing of carbon while also meeting the communities' short-term needs for climate adaptation now. There are prompts for discussion on day 1 and guidance for planning on Part 4 of the planning sheet. Encourage students to use the lens of Cause and Effect as they develop their arguments for community solutions. If your students engage in communicating their plans to an external audience, support your students in Systems thinking about how individuals, family units, or school units are subsystems that are part of the larger community system. This can help them make a convincing communication plan for how solutions taken at the subsystem level contribute to the larger system's needs and goals.

Where We Are NOT Going

This lesson is not intended to create a sense of activism among students, although some students may naturally adopt this approach. Carefully consider your school and community context so that you can guide students in their selection of solutions to include in the resilience plans, why it makes sense for their community, and how to develop a clear and convincing communication plan. Focus students on the scientific evidence and community benefits to support their resilience plan, and a rationale for communication about it. Students can then decide whether they want to take the next step to share it with their school administration, families, or the larger community.

LEARNING PLAN for LESSON 17

1 · NAVIGATION

8 min

MATERIALS: Students and Solutions video (optional)

ALTERNATE ACTIVITY

There are different ways to frame this navigation into Lesson 17 depending on how you will approach this project with your students. Modify **slides A** and **B** accordingly.

If your community has an existing plan:

- Modify **slide A** with the prompt, *Why would it be important for us to better understand our own community's plan?*
- Modify **slide B** with the prompt, *If we design a school plan to contribute to our community's existing plan, what more information do we need to know to design a meaningful school plan?*

If your community does not have an existing plan, you have an option to design either a school-level plan or a community-level plan. A community-level plan may make more sense for smaller communities where the students predominantly live in the same community. A school-level plan may make more sense for a context in which students live in different 'sub-communities' of the larger communities. Adjust the slides, question prompts, and handouts accordingly.

Revisit the idea of a community resilience plan. Show **slide A.** Say, *Last time, we wondered if our community had a resilience plan or if we could develop one for our community*. Ask the prompt on the slide and elicit 2-3 responses.

Suggested prompt	Sample student response
Why would it be important for our community to have a plan?	Answers will vary depending on the prior experiences of your students and the climate impacts in your region. Some students may point to flooding that has occurred, to droughts, to heat waves, or to damage that changing temperature and precipitation has caused for crops and/or livestock.

Show **slide B.** Elicit suggestions from students about what makes the most sense for them to design - either a school-level or community-level plan. If you've already predetermined this choice, adjust the slide to ask, *If we design a [school plan or community plan] what could be easy or difficult about this task?*

Suggested prompt	Sample student response
Should we make a community plan or school plan? What would be easier or more difficult about each option? ✱	We've seen other community plans so we kind of know what they look like. But it might be hard if we don't all come from the same community or if we are new to the community. We all know our school and we can think about things we experience here. But it might be hard because it could limit our options.

Make a decision about what the class will design.

✱ ATTENDING TO EQUITY

Supporting Empathy and Emotions: Students may feel like they do not have any power or hope to change or feel constrained in terms of what is possible in the context of their school or community. This is a normal reaction to a very large, complex problem. This lesson is designed to help students focus on the future, imagine new possibilities, and to be thoughtful about what steps could be taken to benefit them and their community.

ALTERNATE ACTIVITY

Extension Opportunity: Giving students a vision for what is possible can give them a sense of empowerment and motivate their efforts on this project. If your students are expressing a sense of despair or feeling powerless, take time to watch and discuss the videos such as these::

- *Imagine the Future* located at https://www.youtube.com/watch?v=GBeU6UZyPjY&feature=emb_logo
- *Young Voices* located at https://www.youtube.com/watch?v=_N1_EhJvwII

Use the following discussion prompts:

- What did you notice in the video that surprised you?
- What actions or technologies gave you some new ideas?
- What inspired you?
- What did you see that mattered to you, our class, our project ideas, or our community?

There is one part of one of the videos that shows activism by youth. We encourage you to watch the video prior to showing it to students to make sure it will fit within your community context. This lesson is not intended to promote activism or protesting. It is intended to focus students on solutions that will rebalance carbon or make their communities resilient. This video provides a lot of possibilities in a relatively short clip, presented in a compelling way by a young person. If you think this portion of the clip could be problematic, edit the clip or skip over that section.

2 · DEVELOP A CRITERIA CHECKLIST

22 min

MATERIALS: chart paper, markers

Reflect on plans students looked at in the previous class. Gather students in a Scientists Circle. Show **slide C**. Have students share what they noticed from the previous plans and what those plans were trying to communicate to their audiences.

Suggested prompt	Sample student response
What did you notice about the plans we've already seen?	They focused on different parts of the community, like transportation or food or water. Some solutions were about reducing CO_2 from going into the atmosphere. Other solutions were about other things, like protecting the community from flooding.
How do you think those communities decided what to include in their plans?	They included things the city was doing that would make a big difference. They included things that people in the community were worried about. Their community must have tried to decide what was important to fix and then tried to figure out how to fix it.

✱ SUPPORTING STUDENTS IN ENGAGING IN ARGUMENT FROM EVIDENCE

This checklist will serve as a guide as students design their resilience plans, but will also be used as a tool for evaluation of each other's plans. Allowing students to co-construct this evaluation criteria gives them the opportunity to jointly construct and agree upon the criteria they want to include.

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING STABILITY AND CHANGE

Use this moment to elevate Stability and Change as a lens for thinking about resilience plans. Guide students to consider how their designed resilience plans can be constructed by examining the changes over different time scales, such as what their community can do to contribute to the long-term

Suggested prompt	Sample student response
Who was the audience and what did the authors try to communicate to the audience?	Their audiences might have been businesses in the community or people who live near or in the community. They were trying to communicate that their community was doing something about climate change. They were trying to let their audience know that there are things they (the people in the community) can do to help.

Transition what makes a plan effective. Display **slide D.** Have students turn and talk about what they noticed that made the example plans effective. Bring students back together and elicit their ideas. Listen for students to suggest ideas related to the following components:

- *defining the problems for their communities*
- *explaining some of the causes of the problem*
- *sharing goals and solutions that the community is taking*
- *showing different kinds of solutions*
- *being clear in their information*

Co-create a criteria checklist for the design of a plan.✱ Show **slide E**. Title a piece of chart paper, *An effective community/school resilience plan*. Say, *Now that we've seen some plans in the last class and we have some initial ideas about what makes for an effective plan, we need to decide specifically what we need to include in our plans so they are effective too.*

ASSESSMENT OPPORTUNITY

Building towards: 17.A Apply scientific principles to design a process/system that the school can undertake to reduce the vulnerability to climate change impacts (e.g., high heat, changing water resources) in the short-term and contribute to rebalancing carbon in the long-term.

What to look/listen for: The example plan below shows suggested ideas.

What to do: If students don't immediately know what to list for a 'checklist' item, offer the first example. When you share the first example, explain how the checklist item would help meet the criteria. Then allow students to talk with a partner to brainstorm the next checklist item. You may need to revisit a resilience plan from Lesson 16 as a concrete example to look at as the class builds the checklist.

Orient them to the left column, criteria of what an effective plan does, and the right column, their checklist for what to include to meet the criteria.

What an effective plan does (criteria)	What we should include (checklist)

Say, *One thing that we said that makes an effective plan is that it explains the problem that needs to be solved to the community. Let's add "Defines the problem we're trying to solve" to our criteria of what makes a plan effective. What could we specifically explain in our plans to help define the problem for our community?* Listen for students to suggest:

- *Problems with changing precipitation, such as droughts, floods, less snowpack, reduced groundwater, etc.*
- *Problems with rising temperatures and/or more frequent heat events.*
- *Problems with certain areas of town or certain industries being more affected than others.*

rebalancing of carbon but also to respond to the changes in precipitation and temperatures happening right now.

Add these ideas to the checklist (as shown in the example below).

Add additional criteria and checklist items. Follow your students' ideas, but you can also suggest ideas to students as you move through the co-construction process. As you complete the criteria checklist, intersperse opportunities for students to turn and talk or convene with a smaller group before sharing ideas aloud in whole group discussion.

As you build a list with your class, aim for inclusion of the following three components:

- Defining the problem or problems/Tell people about the problem.
- Teaching people about what's causing the problem(s).
- Directing people to solutions and telling them what solutions could be taken.

Students may also suggest:

- Getting people to care about the problem.
- Being clear and specific about solutions to the problem.
- Including solutions in different parts or sectors of the community.

A final class checklist might look like the example below. Your class' checklist could include more or different examples depending on the identified needs of your community. This checklist will become an important class artifact because (1) it represents the evaluation criteria that students have jointly agreed upon, and (2) can serve as a rubric for you to assess students' plans.

What an effective plan does	What we should include
Tells people about the problem(s).	• Our community will experience more drought or flood, or both. • Some seasons might become drier or wetter than before. • Some areas or some people in our community might be at more risk or more impacted.
Teaches people about what's causing the problem.	• Carbon dioxide is building up in the atmosphere. • Carbon dioxide traps energy in the atmosphere that causes temperatures to rise. • Warmer temperatures means more evaporation and water vapor in the atmosphere, but it doesn't fall evenly. • Photosynthesis is one way to take CO_2 out of the atmosphere but there are also ways to reduce putting it in the atmosphere. Some combination is necessary to solve the problem.

Directs people to solutions.	• Share solutions their community can take to:
	  • reduce CO_2 going into air or take CO_2 out of air
	  • be prepared for higher temperatures
	  • be prepared for more/less precipitation
	• Give people more than one way to help.
	• Include different actions that different people can take in different situations.

When you get to the "Direct people to solutions" display **slide F**. Use the following prompts to scaffold student ideas for solutions:

- What were the different kinds of solutions we saw in the example resilience plans?
- What solutions make sense for our community given the changes we are experiencing?
- What can we do for long-term carbon rebalancing? What can we do for changes happening right now?✱
- Can everyone participate in these solutions? Who can and who can't?

Upon completion, point out to students that the class now has a checklist for what should go into their plans. Say, *There are still some decisions your group will need to make, like how to present this information in a way that people will find convincing.* You can either keep the checklist your class co-constructs as a public artifact for groups to reference as they work or turn it into a rubric handout that you provide to students on days 2 and 3 as they work on their plans.

3 · COME TO CONSENSUS ON CHANGES IN YOUR COMMUNITY

15 min

MATERIALS: science notebook, Climate Explorer tool, computer and projector

Summarize what we know about changes in our community. Remain in a Scientists Circle. Display **slide G**. Elicit from students what they already know and have learned about changing precipitation and temperature in their communities.✱

Listen for ideas such as:

- *We know temperatures are going up because we examined 100 years of temperature data.*
- *We know we are having more overall precipitation because we examined 100 years of precipitation data.*
- *We know we are experiencing droughts because the data we examined showed less precipitation and we've talked about our experiences with drought.*
- *We are getting less snow in our area which means the rivers aren't flowing as much in the summers either.*

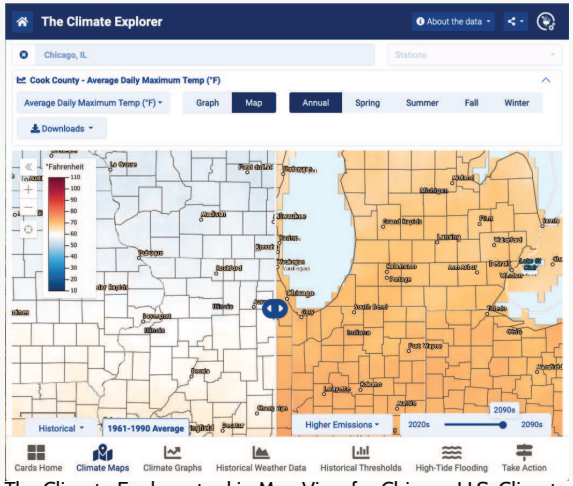
Say, *We've mainly looked at historical data for temperature and precipitation, but we haven't considered how temperature and precipitation might change in our future. What additional information might be helpful to us as we make our plans with the future of our community in mind?*

Listen for ideas like:

- *predictions for temperature and precipitation*
- *what scientists think it'll be like in the future*
- *what our community is preparing for in the future based on what they think will happen*

Introduce the Climate Explorer and make noticings of projections. Navigate to Climate Explorer at https://crt-climate-explorer.nemac.org/. Explain that this new tool contains projections of temperature and precipitation based on trends in the past. Use **slide H** to orient students to the tool. Have students set up their science notebooks to make new noticings of projections about temperature and precipitation.

- Option 1: Make observations from the Climate Explorer together as a whole class. Give students time to make noticings in their notebooks of changes in temperature, precipitation, and seasonal differences, selecting both the high and low emission scenarios. Then share aloud.
- Option 2: Arrange students in partners to investigate with the Climate Explorer tool. Students will record new noticings in their science notebooks. Then reconvene the students to share noticings.



The Climate Explorer tool in Map View for Chicago U.S. Climate Resilience Toolkit Climate Explorer

Display **slide I** with prompts to elicit new noticings and support noticings by referencing what they see in the projections.

Revisit the criteria checklist. Revisit the section, "Tell people about the problem." Ask students to review what they agreed upon previously and suggest any changes they want to make given their new evidence from the projections.

As a class, revisit the last bullet point on the checklist around actions people can take. Add a sub bullet point to include some short term actions that can be taken to help with the identified precipitation and temperature changes. Prompt students to consider if this is the only action that needs to be taken. Remind them of the carbon imbalance problem if needed and add another sub-bullet point around the long term actions that can be taken to help with the carbon imbalance.

✱ ATTENDING TO EQUITY

Supporting empathy and emotions: At this point in the unit, students will transition to focusing on local impacts that spark interest or curiosity. If your community has experienced any recent hazards, like severe drought, flooding, or a heat wave, be mindful that some students might have traumatic experiences that may surface, particularly those that caused damage to property and loss of life. Better understanding the impacts and developing solutions to prepare for them might empower students and help them feel less anxious. They'll know how to respond in the future. It might be better for some students to choose impacts that will be felt in other communities with less emotional connections. Opening the opportunity to explore other communities might not be local, but will still allow students to prepare for changes they may experience in the future.

ADDITIONAL GUIDANCE	The US Climate Resilience Toolkit is a large repository of case studies, tools, and other resources for designing resilience plans located at https://toolkit.climate.gov/. This toolkit includes additional resources that you may want to engage your students with, including case studies in your region and/or problem specific tools and visualizations.

Navigate to the next class period. Continue to display **slide I**. Say, *Now that we have a clearer sense of the problems that may impact our community now and in the future, who do we think is most vulnerable or could be most affected by these changes. Who should we focus on informing?*

Give students 1 minute to either turn and talk with a partner or stop and jot an initial idea about who may be impacted most and/or who needs to be informed.

ADDITIONAL GUIDANCE	Now that you know where your class is headed with the community/school resilience plan project, make adjustments to the student planning sheet and rubric before the next class.

End of day 1

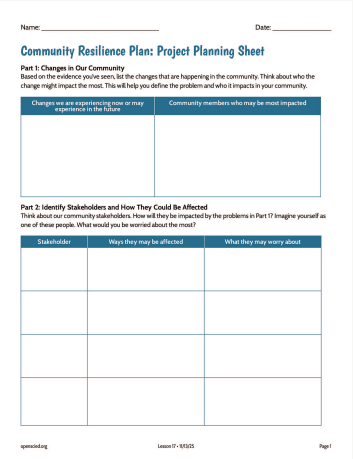
4 · SUMMARIZE KEY TAKEAWAYS ABOUT THE PROBLEMS

5 min

MATERIALS: science notebook, *Community Resilience Plan: Project Planning Sheet*

Summarize important takeaways about the problem. Display **slide J**. Arrange students as partners or to work on their own. Provide each student with 1 copy of the *Community Resilience Plan: Project Planning Sheet*. Direct their attention to Part 1. Say, *We agreed in the last class that our community/school resilience plan needs to tell people about the problem(s) our community is facing. We looked at more evidence for these problems. In thinking about the plan you design, what problem or problems do you want to communicate?*

Give students time to review their notes from the previous class. They should record the problems they want to include in their plans and the evidence to support them in Part 1.



Name: _____ Date: _____

Community Resilience Plan: Project Planning Sheet

Part 1: Changes in Our Community

Based on the evidence you've seen, list the changes that are happening in the community. Think about who the change might impact the most. This will help you define the problem and who it impacts in your community.

Changes we are experiencing now or may experience in the future	Community members who may be most impacted

Part 2: Identify Stakeholders and How They Could Be Affected

Think about our community stakeholders. How will they be impacted by the problems in Part 1? Imagine yourself as one of these people. What would you be worried about the most?

Stakeholder	Ways they may be affected	What they may worry about

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5 · DISCUSS WHO IS AFFECTED MOST

10 min

MATERIALS: science notebook, *Community Resilience Plan: Project Planning Sheet*, Climate Explorer tool, computer and projector

Determine who is affected by the changes. Project **slide K.** Say, *So far, we have determined that we should communicate about _____ and _____ problems that will affect us. Based on what we know about the problems and what we observed in the Climate Explorer, who in our community may be more directly impacted? Who may be more vulnerable in the event of a [flood, drought, heat wave]? Who should be informed about it and why?* Give students a moment to turn and talk to a partner.

As students share, record a Community Member chart. Students should be able to identify a list of stakeholders like homeowners, business owners, and people from our agricultural communities. This list is not all-inclusive and could be expanded depending on student experiences with varied members of the community.

If you are focused on a school plan	If you are focused on a community plan
• Middle school students • Student groups (e.g., student council, outdoor club) • Parents/caregivers • School administrators • Teachers • Other school staff	• Farmers/ranchers, farm workers • Business owners • Community residents • City/community government • Community groups/organizations • Community developers

Transition to who may be more vulnerable to these problems and add to the list.✱ Be ready to project the Climate Explorer tool during this discussion to back up students' suggestions. For example, if students are worried about high heat in the summer for people who work outdoors, look at the projections for summertime temperatures.

If you are focused on a school plan	If you are focused on a community plan
• Younger students • Grandparents or elderly caregivers • Those who don't speak the dominant language • Those who don't have a lot of transportation options • Those who have to work at the school in the summers • Those who take care of school grounds (not in A/C or heat) • Those who do maintenance around the school (not in A/C/heat)	• Elderly or older citizens • Ill citizens • Young children • Pet owners • Those who do not speak the dominant language • Those without vehicles or means of transportation • Those without options to leave their homes if something happens • Those without A/C or cooling in summer • Those without heating in winter • Those who live near rivers or low areas that flood • Those who have to keep crops or animals alive

After students share, ask students if we have a term for the people who are directly affected by this hazard and might benefit from this information. Remind students that we have called this group of people our stakeholders. Reference back to the *Tsunami Unit* or the *Palm Oil Unit* to call to mind the meaning of stakeholder. Students should be familiar with the term.

Preview with students that they will need to think about these community members on Part 2 of their planning sheet. They do not need to complete it now.

✱ ATTENDING TO EQUITY

If students are uncertain whether a group is more vulnerable to the changes, compare two different stakeholder groups from the list to spur the discussion about stakeholder needs and concerns. For example, you might say, *Let's compare the elderly and children. How might they be impacted in the event of a _____? What might they worry about in the event of _____?*

6 · INTRODUCE SOLUTIONS AND START THE PLANNING SHEET

30 min

MATERIALS: science notebook, *Community Resilience Plan: Project Planning Sheet*, *Project Options*, *Water Solution Cards*, *Carbon Solution Cards* (from Lesson 15), class Criteria Checklist, Community Member chart

Elicits ideas for long-term and short-term solutions. Say, *We've already investigated a lot of solutions to rebalance the carbon cycle. We saw that communities were including these solutions in their plans, but they were also including other solutions to prepare or adapt to change. What were some of the solutions we've seen?*

Create a T-chart on the class whiteboard with a few examples. Keep this brief but use this sharing to prime students' thinking. As students share, probe why the solution either rebalances carbon (in the long-term) or prepares the community to adapt to changes (short-term).

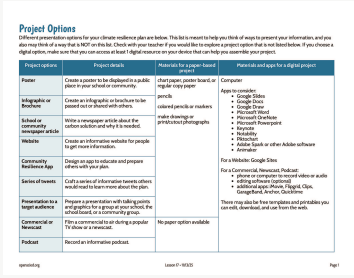
Rebalance carbon	*Prepare or adapt to change*
Energy efficient buildings	*Better stormwater system*
Better public transportation	*Gathering rainwater or storing water underground.*
Planting trees	*Cool pavements and roofs*

Have students summarize again (from Lessons 15 and 16) why it's important for a community to include both kinds of solutions. Listen for ideas:

- *Because we need to do things to stop CO_2 going up, but we also need to prepare for problems already happening.*
- *Carbon solutions will take a long time before we feel their impact. There are problems happening in our communities now.*

Introduce students to the *Water Solution Cards*. Display **slide L.** Use the example to orient students to the new solution deck they can work with. Some of these solutions will already be familiar to students.

Prepare for group work. Arrange students in groups. Provide each group with 1 packet of the *Water Solution Cards*, 1 packet of *Carbon Solution Cards* from Lesson 15, and 1 copy of the *Project Options* handout. Each student should also bring their science notebook and *Community Resilience Plan: Project Planning Sheet* to the group. Make sure the class Criteria Checklist and Community Member is visible to all groups. Display **slide M** to review the group task.


Project Options

Different presentation options for your climate resilience plan are below. This list is meant to help you think of ways to present your information, and you also may think of a way that is NOT on this list. Check with your teacher if you would like to explore a project option that is not listed below. If you choose a digital option, make sure that you can access at least 1 digital resource on your device that can help you assemble your project.

Project options	Project details	Materials for a paper-based project	Materials and apps for a digital project
Poster	Create a poster to be displayed in a public place in your school or community.	chart paper, poster board, or regular copy paper pencils colored pencils or markers make drawings or print/cutout photographs	Computer Apps to consider: • Google Slides • Google Docs • Google Draw • Microsoft Word • Microsoft OneNote • Microsoft Powerpoint • Keynote • Notability • Procreate • Adobe Spark or other Adobe software • Animaker For a Website: Google Sites For a Commercial, Newscast, Podcast: • iMovie (Mac computers) to record video or audio • editing software options: • additional apps: iMovie, Flipgrid, Clips, GarageBand, Anchor, Quicktime There may also be free templates and printables you can edit, download, and use from the web.
Infographic or Brochure	Create an infographic or brochure to be passed out or shared with others.		
School or community newspaper article	Write a newspaper article about the carbon solution and why it is needed.		
Website	Create an informative website for people to get more information.		
Community Resilience App	Design an app to educate and prepare others with your plan.		
Series of tweets	Craft a series of informative tweets others would read to learn more about the plan.		
Presentation to a target audience	Prepare a presentation with talking points and graphics for a group at your school, the school board, or a community group.		
Commercial or Newscast	Film a commercial to air during a popular TV show or a newscast.	No paper option available	
Podcast	Record an informative podcast.		

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Ask for clarifying questions. Have groups review Parts 1-4 of their planning sheet and the Water Solution Cards. Ask groups for any clarifying questions.

Begin Group Work. Have groups work through Parts 1-4 of *Community Resilience Plan: Project Planning Sheet*. Circulate to groups to probe their thinking. This probing can inform your assessment of student understanding of assessment moment 17.A and give you a chance to review with or reteach before groups begin the final plans:

- Ask them how the science ideas will help a community member make sense of the community problems.
- Check that they are including solutions for long-term rebalancing of carbon and adaptation to changes happening now. See the callout box to the right for probing questions.✱
- Ask them how they are choosing their solutions given the most impacted and/or vulnerable community members they brainstormed.✱ Prompt students to provide their reasoning, using questions such as the following:
  - Why do you think that solution will work for _____ (stakeholder)?
  - Why won't that solution work for _____ (stakeholder)?

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING STABILITY AND CHANGE

If you notice students struggling to include both long-term mitigation solutions and short-term adaptation solutions, use the following probing questions:

- What strategies could our community do to reduce carbon emissions or take carbon out of the atmosphere? How long might these solutions take for us to feel their effects?
- What things might our community members want us to do right now to prepare so that we are ready when a [flood, drought, heat wave] hits?
- What if we only plan for long-term solutions? How might community members feel about that?
- What if we only plan for short-term water and heat solutions? How might community members feel about that?

✱ ATTENDING TO EQUITY

Universal Design for Learning: Students are asked to consider the authentic needs and vulnerabilities of the community members. Placing the community resilience plan in a local context provides relevance for both students and stakeholders. Assessing the needs of the stakeholders identifies additional value to the community and creates an authentic project that can be utilized both inside and outside of the classroom.

Supporting Emerging Multilingual Students: This could be an opportunity to highlight the benefits of multilingual communication in our global world because expressing ideas across many languages can help reach larger and broader audiences. This would also be particularly beneficial if the stakeholder

- If _____(solution) negatively impacts _____(stakeholder), should we cut it out as an option? Why should we also consider keeping it?
- How many stakeholders groups might adopt _____ (solution)?
- Is _____ (solution) feasible for _____ (stakeholder)? Why or why not?
- Which solution out of these three might be most feasible for the largest number of stakeholders? Why?

- If students express uncertainty about stakeholders, ask the following prompts and assign home learning:
  - How could we get that information? (if we don't know it)
  - Do you think talking to a stakeholder might help our planning process?

Toward the end of the group planning time, ask the groups to look over the *Project Options* handout and have 1 group member inform you of the group's choice so that you can prepare the appropriate resources for the next class. Students should consider their time and expertise before choosing a project option and platform.

Collect project plans from at least 1 group member. You can use this plan for initial evaluation to provide feedback. Use *Designing a Community Resilience Plan: Teacher Feedback*.

Use **slide O** for a brief, but useful, self-assessment from students.

ASSESSMENT OPPORTUNITY

Building towards: 17.A Apply scientific principles to design a process/system that the school can undertake to reduce the vulnerability to climate change impacts (e.g., high heat, changing water resources) in the short-term and contribute to rebalancing carbon in the long-term.

What to look/listen for: See guidance on *Designing a Community Resilience Plan: Teacher Feedback*. This feedback sheet should closely match your class' Criteria Checklist.

What to do: Provide feedback to each group using *Designing a Community Resilience Plan: Teacher Feedback*. Meet with each group for 2-3 minutes during the group work time, to go over your feedback and give them a chance to ask you clarifying questions.

Examine students' individual exit tickets. Depending on responses, either arrange for a one-on-one conference with students needing extra support or pair up students needing extra support with those more confident about the task for a short mentoring session to ask and answer questions.

HOME LEARNING OPPORTUNITY

If you want students to interview stakeholders to inform their plans, assign home learning before the end of class. Optional **slide N** is provided. The goal is for students to gather questions that stakeholders would have about the proposed plan. Groups can revise the plan to include more information to answer the questions.

If you want students more involved in the planning of the interviews, adjust **slide N** and ask students:
- What information do you need from stakeholders?
- How could you go about getting that information?

Sample student ideas might include the following:
- We need to ask them if they are worried and what about.
- We could ask them the questions they have.
- We could look up information online.
- We could talk to people in our school or community.

group(s) speak a primary language other than English. Consider encouraging your emerging multilingual students—who feel comfortable doing so—to develop a communication project that includes key messaging in their home language or multiple languages.

End of day 2

7 · EVALUATE PLANS BY ASKING QUESTIONS

15 min

MATERIALS: *Community Resilience Plan: Project Planning Sheet*, class Criteria Checklist, *Rubric: Evaluating Solutions by Asking Questions*, *Reference: Peer Feedback Guidelines*

Remind students of the class Criteria Checklist. This is the criteria students jointly agreed upon.

Jigsaw plans. Have 1 group member exchange their plans with a member from all the other groups (not just a single group exchanging plans with another single group). Direct students to Part 5 of the handout. Display **slide P**. Say, *We are going to evaluate each other's plans not on whether they picked the 'best' solutions, but rather if they took into account the problems in our community and stakeholders at risk, and whether they are bringing helpful science ideas to explain what's happening.*

Review the goals of evaluating the plans to (1) take the stance of a community member who is skeptical of the need for a plan or the solutions being proposed. With this perspective, they ask questions to challenge the plan, and then (2) take the position of a thought partner to offer suggestions to help the group better meet the class' agreed upon Criteria Checklist. Have students spend 12 minutes reviewing and recording feedback to each other.

Return plans with feedback and provide teacher feedback too.

ASSESSMENT OPPORTUNITY

Building towards: 17.B Ask questions to challenge the proposed resilience plan to evaluate whether the solutions meet the class' agreed criteria checklist and will reduce vulnerabilities to climate impacts in the short-term and rebalance carbon in the long-term.

What to look/listen for: use *Rubric: Evaluating Solutions by Asking Questions* as an example of how to monitor student progress on this LLPE. Modify according to your class' Criteria Checklist.

What to do: If you anticipate that students will need more support providing specific and clear feedback, see *Reference: Peer Feedback Guidelines* for ideas for how to more fully support feedback between students. If students are uncertain about the kinds of questions to ask, revisit the DQB and think about the kinds of questions they had early on in the unit. Ask students to review the DQB to see if there are questions on it that may be ones members of the community have too. If students are uncertain about evaluating the entirety of the plan, it may help to focus them on evaluating 1 or 2 parts of it. For example, you may want to focus students on providing feedback as to whether the mix of solutions (Part 4) will solve the stakeholders' concerns (Part 2) or whether the mix of solutions (Part 4) will solve the community's problem (Part 1). Having students evaluate only certain parts of the plan can make the evaluation task more accessible, particularly to students who may be overwhelmed by evaluating the whole thing.

Provide students feedback on their evaluations using *Rubric: Evaluating Solutions by Asking Questions*. Give students an opportunity to revise parts of the feedback to be more specific and targeted. This will help students work with the feedback they receive from you to iteratively improve on giving feedback to classmates.

8 · GROUP WORK TIME

Varies min

MATERIALS: science notebook, *Community Resilience Plan: Project Planning Sheet*, *Rubric: Designing a Community Resilience Plan* with feedback, additional materials will vary according to project platform, class Criteria Checklist

Go over the goals and expectations for a final product. Display **slide Q.** Preview how students will use feedback from peers, you, and community members to adjust their plans and get started on a final product.✱ Direct them to where to find resources and your expectations for group work. Referencing the class norms may be particularly helpful at the start of group work and encourage students to select a norm to focus on for the group project.

Decide on how long students have to work on the project. Give students the remaining time on day 3 and additional class time in school or time out of school time to work on the projects.

Collect home learning to create a public record. While students work, collect any home learning and make these publicly available, via hanging on the wall or in a digital space for others to review and reference.

✱ ATTENDING TO EQUITY

Universal Design for Learning: This project provides multiple opportunities to support the principles of Universal Design for Learning, including the following:

- Multiple means of *engagement* by *recruiting interes*t through student choice and autonomy (i.e., which hazard they investigate; choosing the format for the communication plan); *sustaining effort and persistence* through collaboration and community work together to develop their projects and provide peer feedback; *self-regulation* through self-assessment of one's ability to provide feedback to peers.
- Multiple means of *action and expression* by: providing options for *expression and communication* through student choice of multiple media for communication; and promoting *executive function* by providing support for planning and strategy development.

End of day 3

9 · GROUP WORK TIME, CONTINUED

15 min

MATERIALS: science notebook, *Community Resilience Plan: Project Planning Sheet*, *Designing a Community Resilience Plan: Teacher Feedback* with feedback, Community Resilience Plan (started day 3), class Criteria Checklist, *Rubric: Designing a Community Resilience Plan*

Check against the agreed upon criteria. Display **slide R.** Give students time to reconvene in groups to finish their final touches to their community resilience plans. Prompt them to check their plan against the class' Criteria Checklist and the *Designing a Community Resilience Plan: Teacher Feedback* where you provided feedback to students in the previous class. They should work through the list and identify where in their plan they met the criteria and responded to feedback.

Collect final products from students now or after they share and communicate them to an external audience.

ASSESSMENT OPPORTUNITY

Building towards: 17.A Apply scientific principles to design a process/system that the school can undertake to reduce the vulnerability to climate change impacts (e.g., high heat, changing water resources) in the short-term and contribute to rebalancing carbon in the long-term.

What to look/listen for: see *Rubric: Designing a Community Resilience Plan*. Modify according to your class' Criteria Checklist.

What to do: Use the rubric to provide feedback to students. Allow students to review the feedback. Give students the opportunity to respond to the following prompts to improve their plans:

- What is one piece of feedback you received?
- What did you add or change to address this feedback?

10 · MAKE A PLAN FOR COMMUNICATION

10 min

MATERIALS: science notebook, *Community Resilience Plan: Project Planning Sheet*, Community Resilience Plan (started day 3), class Criteria Checklist

Celebrate the class's accomplishments on their Community Resilience Plans. Say, *We've learned a lot about the problems happening in our community and what is causing those problems. And importantly, we figured out and communicated ideas for how to address this problem using solutions already available to us today. We have done some great work taking our science ideas and crafting realistic plans for our community!*

Discuss how to share plans with external audiences. Display **slide S**. Ask students, *Who do you want to see our plans?* Listen for ideas like:

- *Our families and neighbors*
- *Others in our school, like students or teachers in other grades*
- *People in our communities*
- *Everyone!*

Work with students to discuss how best to share them and how to gather feedback from community members when they are shared. See extension opportunity below.

ALTERNATE ACTIVITY

Extension opportunity: Carrying out communication of the community resilience plan can happen in a number of ways using different platforms, from hanging posters around the school hallways, to presenting to school administrators, to writing letters and sharing plans with city officials and planners. Taking on this extension will deepen students' experience of the project and increase authenticity by sharing the plans with community stakeholders.

If you complete this extension, there is an additional LLPE to guide your assessment target and an example rubric, *Rubric: Communicating Our Community Resilience Plans*. We encourage you to discuss with your class what would make for a successful communication with the target stakeholders and co-construct the rubric together as a class.

Note that this extension opportunity should prompt your students to bring a lens of Systems Thinking to their communication plan. They should consider how individuals, family units, or school units are subsystems that are part of the larger community system. This can help them make a convincing communication plan for how solutions taken at the subsystem level contribute to the larger system's needs and goals.

See the lesson level performance expectation 17.D and *Rubric: Communicating Our Community Resilience Plans* for more information.

11 · SHARE LEARNING ON AN INDIVIDUAL ASSESSMENT

18 min

MATERIALS: *Argue for the Best Solution to Solve a Problem in Your Community*, *Rubric: Argue for the Best Solution to Solve a Problem in Your Community* rubric

Introduce the individual assessment.✱ Say, *We've been doing a lot of work in groups. Group work is valuable because we can bounce ideas off each other and our collective thinking helps to advance everyone's understanding. Now you'll have the opportunity to share what you're thinking personally about solutions that could benefit our community.* Display **slide T.** Allow students to use evidence and science ideas recorded in their notebooks to support both their explanation of the problems and their arguments for a solution.

ASSESSMENT OPPORTUNITY

Building towards: 17.C Construct an argument grounded in evidence and scientific reasoning to recommend a design solution that will prepare a community for predicted changes to temperature and/or precipitation (effect).

What to look for/listen for: see *Rubric: Argue for the Best Solution to Solve a Problem in Your Community*.

What to do: Use the rubric to provide feedback to students. Allow students to review the feedback. Give students the opportunity to respond to the following prompts to improve their plans: (1) What is one piece of feedback you received? (2) What did you add or change to address this feedback?

12 · NAVIGATION

2 min

MATERIALS: Driving Question Board

Reflect on DQB progress. Display **slide U**. Have students look back to the first questions they posed on the DQB. If time permits, have a few students share a few of those first questions aloud. Say, *We have accomplished so much. In the next class, we'll take stock of all the questions we've answered and think about what comes next.*

Additional Lesson 17 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA

See *Potential Accompanying Standards* for a complete list of connections to ELA standards.

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN MATH

See *Potential Accompanying Standards* for a complete list of connections to Mathematics and Technology standards.

LESSON 18: What can we explain now, and what questions do we still have?

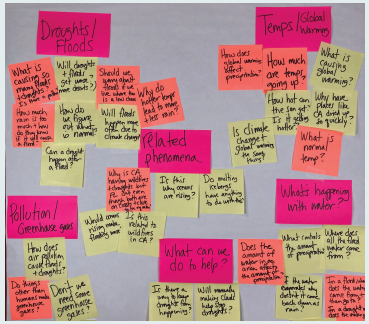
PREVIOUS LESSON

We wondered if our community has a resilience plan or should have a plan. We created a checklist for what a resilience plan for our school and local community should include. We worked in groups to design resilience plans and provide feedback to other groups. We evaluated the plans by asking questions and brainstormed how to share and communicate our plans to other audiences. We argued for the one best for our community.

THIS LESSON

PUTTING PIECES TOGETHER

1 day



We identify the questions from our DQB that we can now answer. We celebrate all that we have learned in this unit and across the school year. We spend time identifying the questions that we did not answer and build a new DQB of these questions. We create a plan to answer some of the questions on our own and during the next school year and beyond.

NEXT LESSON

There is no next lesson.

BUILDING TOWARD NGSS

MS-ESS3-1, MS-ESS3-3, MS-ESS3-4, MS-ESS3-5, MS-ETS1-2

WHAT STUDENTS WILL DO

18.A Communicate scientific information orally about the patterns of class questions that have been explained with sufficient evidence about the impact of a changing climate and community solutions, and ask additional questions that require appropriate and sufficient evidence to answer.

WHAT STUDENTS WILL FIGURE OUT

- Science learning is about asking questions and gathering evidence to answer those questions.
- As some questions get answered, new questions come up.

Lesson 18 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	10 min		**EVALUATE OUR DQB QUESTIONS** In pairs, students evaluate our list of questions for ones they think we have made progress on. Then students place sticky dots on the questions they think we have made progress on and move into their Scientists Circle.	A-B	*Reviewing Our Driving Question Board*, 10 sticky dots, Driving Question Board
2	10 min		**REVISIT THE DRIVING QUESTION BOARD (DQB)** Revisit the DQB with the whole class and take stock of all of the questions we've now answered.	C	
3	5 min		**ADD TO OUR PROGRESS TRACKERS (OPTIONAL)** Allow time for students to update their 2-column Progress Trackers.	D	
4	20 min		**CELEBRATING OUR YEAR OF SCIENCE LEARNING** Reflect on science learning through a "Tweet Blizzard." Build a new Driving Question Board.	E-F	piece of scrap paper, sticky notes, marker

End of day 1

Lesson 18 • Materials List

	per student	per group	per class
Lesson materials	• science notebook • *Reviewing Our Driving Question Board* • 10 sticky dots • piece of scrap paper • sticky notes • marker		• Driving Question Board

Materials preparation (25 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

There are several options provided in this lesson and doing all of them will require 2 full class periods. Read through the teacher guide, judge the time you have remaining, and modify this lesson accordingly.

- If you have 2 full class periods, complete all steps and give each step more time than is allotted in the Learning Plan.
- If you only have one class period, skip the "Evaluate our DQB" small group work and "Progress Tracker." Instead, move straight to the "Revisit the DQB" in a Scientists Circle. Allow students to post sticky dots on questions that they believe are answered and to discuss those. Complete the "Celebrate our Science Learning," which involves a tweet blizzard reflection and building a new DQB of questions.

If completing the "Evaluate our DQB" in small groups, type up the questions from the DQB or take a high resolution photograph of all of the questions on the DQB. If typing up the questions, modify the handout, *Reviewing Our Driving Question Board*, with the questions. If you take a photograph, insert the photograph in place of the table on a handout. If using the table format, add as many rows as needed to the table.

Make sure the DQB is displayed and space is available for the class to gather in a Scientists Circle. Display all previous classroom consensus models around the room.

Lesson 18 • Where We Are Going and NOT Going

This lesson provides an opportunity for students to evaluate the Driving Question Board (DQB). This lesson focuses on patterns in questions we are now able to answer related to climate change and its impact on our communities, questions we can partially answer, and those we still have not been able to answer. Through this evaluation of our DQB, we can pose new questions or insights for future solutions that have the potential for greater impact on our communities.

LEARNING PLAN for LESSON 18

[practice-elements]	
8.5	Students practice communicating orally which questions they feel they answered with sufficient evidence, and which questions they feel remain unanswered or they need additional evidence to answer. This is an important aspect of scientific communication; that is, determining what questions are answered and unanswered through a series of scientific investigations.
1.5	When generating a new DQB, students ask questions related to climate change and its impact on our communities that can be investigated in the future. Students may want to add other questions from the school year that went unanswered or add new questions that they generated as they became curious about a new phenomenon.

1 · EVALUATE OUR DQB QUESTIONS

10 min

MATERIALS: science notebook, *Reviewing Our Driving Question Board*, 10 sticky dots, Driving Question Board

Connect to the last lesson. Say, *We were successful in developing and describing a plan for our community in the last lesson. At the end of the lesson, we looked briefly at the DQB and celebrated what we have learned. Let's return to the DQB and evaluate the questions more in depth.*

Have students work in pairs to evaluate what questions the class has answered from the DQB. Display **slide A**. Provide students with one copy of *Reviewing Our Driving Question Board*, which you created to contain all of the student questions from the DQB, and have students tape it into their science notebooks. Have students work with a partner to mark questions they think the class has answered:

- We did not answer this question or any parts of it yet: **O** or **?**
- Our class answered some parts of this question, or I think I could answer some parts of this question: ✓
- Our class answered this question, or using the ideas we have developed, I could now answer this question: ✓✓

(Optional, depending on time) **Have students answer three questions of their choice.** Have students pick three questions they think the class has answered. Tell students to use the space on the handout *Reviewing Our Driving Question Board* to write down the answer to those questions.

ASSESSMENT OPPORTUNITY

If you choose to do this optional step, this provides a good individual assessment opportunity.
Look/listen for:

- evidence from the activities and lessons they have done in the unit to support their answers and
- logical reasoning connecting the evidence to their answers.

What to do:

- If students struggle providing the evidence and reasoning, give students examples and use questions to guide them. Ask them, *How do you know that? What did we do in class that made you answer that way? How did that activity change your thinking?*
- If students need more challenges, ask them to connect their answers to the models or sketch the part of the model that their answer is about.

✱ ATTENDING TO EQUITY

Revisiting the DQB is important for students to feel as though their questions are valued and recognized. While not all questions will have been addressed (it's more likely that 50-75 percent will be at least partially answered), this helps students see that they have done this hard work to answer many of their own questions.

Review and share the questions that students think we have answered. Present **slide B** and have students mark on the class DQB with sticky dots the questions that they think we have made progress on.✱ Then have students move into their Scientists Circle.

2 · REVISIT THE DRIVING QUESTION BOARD (DQB)

10 min

MATERIALS: science notebook

Look for patterns using the sticky dots. In the Scientists Circle, focus on the questions that have the most number of sticky dots.✱

Discuss as a class the questions that the class can now answer. Present **slide C** if needed. Have the class discuss the answers to those questions. If you have space, you might make a "Takeaways" board that has a record of the answers with which the class comes up.✱

Pose the unit question. To close out the discussion, pose the DQB question, *How do changes in Earth's system impact our communities and what can we do about it?* Elicit students' new ideas to this question to prime students' thinking for adding a final entry to their Progress Tracker.

ASSESSMENT OPPORTUNITY

Building towards: 18.A.1 Communicate scientific information orally about the patterns of class questions that have been explained with sufficient evidence about the impact of a changing climate and community solutions, and ask additional questions that require appropriate and sufficient evidence to answer.

Look/listen for:

- We can clearly answer some of the questions through ideas learned throughout the unit.
- Some questions we can partially answer with some of our ideas learned, but they require more information/evidence.

What to do: If students struggle to answer questions from the DQB, place them in partners or small groups with one question or cluster of similar questions assigned to the group. Have them (1) locate where the questions most closely relate to the class's consensus models from either Lesson 4, Lesson 5, Lesson 11, or Lesson 12 and then (2) examine their science notebooks and other documents to search for evidence that could answer or partially answer the question. Ask the group to co-construct, in writing or orally, an explanation to the question(s) using evidence from their previous work. Remind students what makes a good explanation is a how or why causal account that can be supported with evidence.

✱ ATTENDING TO EQUITY

Revisiting the DQB is an important process in allowing students to feel their thoughts and questions are valued and recognized. This part of the lesson helps students see the hard work they have done to answer many of their own questions.

✱ SUPPORTING STUDENTS IN ENGAGING IN ASKING QUESTIONS AND DEFINING PROBLEMS

Revisiting the DQB at the end of the unit helps students see the progress they have made toward answering questions that were important to them. Students were tasked with asking questions "that required sufficient and appropriate evidence to answer." Through the investigations in the unit and individual and whole group sensemaking, they can now answer many of the questions.

3 · ADD TO OUR PROGRESS TRACKERS (OPTIONAL)

5 min

MATERIALS: science notebook

Add any new insights to the Progress Trackers. If time permits, have your students add a final entry to their Progress Tracker. If time does not permit, skip, and complete the whole group reflection, which comes next. Present **slide D** and modify the slide depending on the entry you want students to complete. Have students either make an entry about new insights about the unit question or add an entry about new ideas or insights that may have surfaced during the DQB discussion. Have the students update their 2-column Progress Trackers with any additional ideas that they think are important.

4 · CELEBRATING OUR YEAR OF SCIENCE LEARNING

20 min

MATERIALS: science notebook, piece of scrap paper, sticky notes, marker

Tweet Blizzard reflection. Display **slide E**. Students will take 2-3 minutes to reflect on their own highlights/takeaways for the year in the format of writing a "tweet" on a piece of scrap paper, complete with hashtags of their choosing. Tweets can be about:

- a big idea you learned in this unit or school year that will always be with you,
- a challenge you faced in this unit or school year that you overcame, or
- something rewarding about this unit or school year that you want to share.

Have students crumple up their tweet into a "snowball," toss the snowball in the air, and pick up a new snowball to share with the class. Facilitate a sharing of tweets in a Scientist Circle.

ALTERNATE ACTIVITY

To modify the blizzard activity, have students complete the reflection as a Quickwrite in their science notebook or virtual learning space. Ask students to write their reflection as a "tweet" with hashtags. If you are in a remote learning setting, have the students write their tweet in a Jamboard space or create a slide deck where each student is assigned a slide. If using slides or Jamboard, students can also add images of their favorite activity in the unit or the school year. Play the slide deck as a celebration of learning.

Generate New DQB.✱ After students have shared their tweets, ask students to think about the questions that remain unanswered in the unit or across the school year. Display **slide F**. Pose the question, *What questions did we pose this year that we didn't answer, but we want to carry forward into future science learning?*

Give students time to write 1-2 new questions. Encourage students to write down questions that went unanswered in previous units and/or new questions that came up about phenomena they have observed in the world and want to explain. Have students post their questions to a new DQB.

Cluster the questions by OpenSciEd units taught this year and/or phenomena-based clusters.

Ask students to share their questions, and how they may go about answering those questions on their own, and/or as part of their science learning in future years. Encourage students to recommend investigations that would provide evidence to answer the questions.

ASSESSMENT OPPORTUNITY

Building towards: 18.A.2 Communicate scientific information orally about the patterns of class questions that have been explained with sufficient evidence about the impact of a changing climate and community solutions, and ask additional questions that require appropriate and sufficient evidence to answer.

Look/listen for:

- New questions arise from investigations, or some existing questions may remain unanswered or need additional evidence to answer.

What to do: Encourage students to first think of unanswered or new questions related to the impact of changing climate and community solutions to this problem. Then move to questions beyond this unit. If you still have the DQBs from other units from this school year, post them to remind students of their questions and ones they might not have answered. If students are struggling to think of new questions, ask them to review the DQBs and their notebooks for questions that are unanswered or to spark ideas for new questions they want to investigate. Ask students to also post ideas for gathering evidence to answer the questions they post by writing their ideas on a new sticky note that they post with their question or by indicating their ideas on the question sticky note.

✱ SUPPORTING STUDENTS IN ENGAGING IN ASKING QUESTIONS AND DEFINING PROBLEMS

Generating a new DQB allows students to revisit the element of this practice: *Ask questions that require sufficient and appropriate empirical evidence to answer.* In science, asking and answering questions often leads to generating new questions to explore, even at the end of a unit of study. This reflection and generating a new DQB gives students a moment to raise new questions or highlight questions they are still curious to explore in later grades.

Unit 7.6 Teacher Reference Materials

ASSESSMENT SYSTEM OVERVIEW

Each OpenSciEd unit includes an assessment system that offers many opportunities for different types of assessments throughout the lessons, including pre-assessment, formative assessment, summative assessment, and student self assessment. Formative assessments are embedded and called out directly in the lesson plans. Please look for the "Assessment Icon" in the teacher support boxes to identify places for assessments. In addition, the table below outlines where each type of assessment can be found in the unit.

Overall Unit Assessment

When	Assessment and Scoring Guidance	Purpose of Assessment

Lesson 1	Initial models in science notebooks
	
	Driving Question Board
		Pre-Assessment
		The student work in Lesson 1 available for assessment should be considered a pre-assessment. It is an opportunity to learn more about the ideas that your students bring to this unit. Revealing these ideas early on can help you be more strategic in how to build from and leverage student ideas across the unit.
		
		The initial models developed in this lesson are an opportunity to pre-assess student understanding of how small changes in temperature could affect Earth's water system, as well as what leads to those changes. Additionally, it is an opportunity to pre-assess relevant weather-related ideas from previous OpenSciEd units. Look at the individual models developed on day 2 and the class consensus model developed on days 2 and 3.
		• For the first part of the model regarding how warmer temperatures could lead to both floods and droughts, look for students to use the following:
		  • Water cycling processes, such as evaporation and precipitation, in their initial causal accounts of floods and droughts. See if students are connecting temperature change to a change in these processes.
		  • Look at how students' individual models accounted for these changes in temperature and water cycling processes compared to the model co-constructed by the class. This will give you insight as to where each individual student is in their initial understanding of the phenomenon and their modeling practice to explain it.
		  • Look at students' causal accounts to see if they use single words, like "evaporation," as a "sufficient" causal explanation or if they elaborate on a mechanism for how temperature change could affect a water cycle process.
		• For the second part of the model regarding what is causing warmer temperatures, look for students to explain what is causing temperatures to rise, using language or images that link the cause (e.g., greenhouse gases, pollution, carbon dioxide, etc.) to the effect (rising temperatures).
		  • If students focus on mechanisms like the Sun's temperature or distance to Earth or the ozone hole, there is a modification you can make at the start of Lesson 6.
		  • If students focus on gases in the atmosphere as a cause of temperature rise, probe deeper to see what they know about how gases, temperature, and energy of molecules/particles relate to each other.
		
		The Driving Question Board is another opportunity for pre-assessment. Reinforce for students to generate open-ended questions, such as "how" and "why" questions, to post to the board, but celebrate any questions that students share even if they are close-ended questions. If your students are asking mostly closed questions, you can provide a copy of a photo of the questions on the Driving Question Board, and ask them to work on refining three or more of these questions so that they become "how" and "why" questions. Listen for questions that address both parts of our model, and, if a part of the model has few or no questions, prompt students to generate more questions in this space so that each part of the model has a set of questions with which to guide investigations.

When	Assessment and Scoring Guidance	Purpose of Assessment
Lesson 5	*Revised Water Story Explanation* *Scoring Guidance for Case Site Explanations* *Peer Feedback Guidelines* *Peer Feedback Instructions* Exit Ticket (**slide I)** and self-reflection questions on their revised explanation	**Formative Assessment, Peer Feedback, Self-Assessment** Students will individually construct an explanation, using evidence, about how changes in temperature are having impacts on the water stories in our case site communities. Students synthesize key model ideas from Lessons 2-4 to construct an explanation for how water is changing in one community that they choose to explain. After developing an initial explanation, they give written feedback to two other students using the guiding questions on the *Peer Feedback Instructions* and *Peer Feedback Guidelines.* They will then revise their explanations, reflect on changes made, and can self-assess their comfort with explanation using **slide H**. Students can choose the modality for communicating their thinking. They can explain the phenomenon through written explanation or using a diagrammatic explanatory model or infographic. This explanation provides formative information and practice before students transfer their understanding to a new case in Lesson 6. If your students have not developed a written scientific explanation, there is a Building Prerequisite Understanding option for you to model and co-construct an explanation together before they write their own individually. *Scoring Guidance for Case Site Explanations* can be used to assess student progress and includes samples of initial explanations, sample feedback, and the revised explanation. It is recommended that you provide feedback to students' explanations prior to their transfer task (Lesson 6) and that students be able to use their written explanations with feedback from you (and peers) to help them craft their explanation in Lesson 6.
Lesson 6	*Alaska Wildfire and Sea Ice Transfer Task* *Alaska Wildfires and Sea Ice Key*	**Summative Assessment** On days 2 and 3 of Lesson 6, students construct another explanation for an Alaskan community experiencing related changes to the other case sites. This is a transfer task that asks students to draw upon ideas developed in Lessons 2-5 but with the addition of new climate impacts: sea ice decline and wildfires. On day 2, students revisit the Alaskan headline and learn about different claims made by an Alaskan elder regarding their changing environment. Students identify the data needed to determine if these cases are similar or different and if they have the same causes. In small groups, students analyze data to look for similarities and differences in the Alaskan claim data. They determine that, while they may have differences, the claims are similar in their cause. Students then compare the Alaskan claims to the previous work done on the *Alaska Wildfire and Sea Ice Transfer Task* to determine the similarities and differences between the Alaskan claims and their case site claims. Students determine that all cases are impacted by increasing temperatures. The *Alaska Wildfires and Sea Ice Key* can be used to assess student progress.
Lesson 12	*Version 1: Social Media Post Assessment* or *Version 2: Social Media Post Assessment* *Tweet Claims Assessment Key*	**Summative Assessment** There is an individual assessment task on day 2 of Lesson 12, which marks the end of Lesson Set 2. To set students up for this task, on day 1, the class examines a sample social media post to identify claims being made, which of those claims match our science ideas (supporting), and which claims are in need of clarification or explanation (refuting). Then, on day 2, students individually complete the *Social Media Post Assessment*. Version 1 of this assessment is intended for use by the broader classroom and is considered to be the assessment on level with current student understanding, while Version 2 offers an additional challenge.

When	Assessment and Scoring Guidance	Purpose of Assessment
Lesson 17	*Community Resilience Plan: Project Planning Sheet* All, but especially part 5. *Designing a Community Resilience Plan: Teacher Feedback* *Rubric: Designing a Community Resilience Plan* *Rubric: Argue for the Best Solution to Solve a Problem in Your Community* *Rubric: Evaluating Solutions by Asking Questions* *Rubric: Evaluating Solutions by Asking Questions* Exit Ticket (**slide O**) *Reference: Peer Feedback Guidelines*	**Instructionally-Embedded Design Task with Group and Individual Formative + Summative, Peer Feedback, Self-Assessment** Lesson 17 includes instructionally-embedded tasks within the context of students designing a climate resilience plan for their school or community. The 4-day design task and optional extension build towards: • MS-ESS3-3. Apply scientific principles to design a method for ~~monitoring and~~ minimizing a human impact on the environment. • MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. To monitor group progress, use the following assessment opportunities: • Day 1 (formative): listening to students share ideas for the Criteria Checklist and their rationale for including it. • Day 2 (formative): circulate among groups listening in and probing their ideas as they complete the *Community Resilience Plan: Project Planning Sheet* handout. • Day 3 (formative): you will provide feedback on groups' plans before they begin their final projects using *Designing a Community Resilience Plan: Teacher Feedback*. • Day 4 (summative): you will evaluate groups' final resilience plans using *Community Resilience Plan: Project Planning Sheet*. • Extension (summative or formative): using *Rubric: Communicating Our Community Resilience Plans* to provide feedback for groups on their communication plan and implementation. To monitor individual progress using the following assessment opportunities: • Anytime (formative): as a student shares ideas in whole group and small group discussion. • Day 2 (formative): individual exit ticket, see **slide O**. • Day 3 (formative and/or summative): using *Rubric: Evaluating Solutions by Asking Questions*, provide students feedback on their progress toward providing evaluative feedback to other students. • Day 4 (summative): using *Argue for the Best Solution to Solve a Problem in Your Community* and *Rubric: Argue for the Best Solution to Solve a Problem in Your Community* to assess individual progress and provide feedback. Feedback opportunities include: • Teacher feedback is critical between days 2 and 3 using *Designing a Community Resilience Plan: Teacher Feedback*. • Peer feedback is critical at the start of day 3 using Part 5 of *Community Resilience Plan: Project Planning Sheet*. • Self-assessment is encouraged at the end of day 2 using **slide O**. Using the exit ticket early during students' project work to have students reflect on their comfort with their progress will also give you additional information about whether students need more support.
After each lesson	*Lesson Performance Expectation Assessment Guidance*—See below.	**Formative Assessment** Use this document to see which parts of lessons or student activity sheets can be used as embedded formative assessments.

When	Assessment and Scoring Guidance	Purpose of Assessment
Occurs in some lessons	Progress Tracker	**Formative and Student Self-Assessment** The Progress Tracker is a thinking tool that was designed to help students keep track of important discoveries that the class makes while investigating phenomena and figuring out how to prioritize and use those discoveries to develop a model to explain phenomena. It is important that what the students write in the Progress Tracker reflects their own thinking at that particular moment. We strongly suggest that it is not collected for a summative "grade" other than for completion. The Progress Tracker is already included in Lessons 2, 4, 7, and 9, but can be added to the other lessons or as a home learning reflection assignment.
Anytime after a discussion	*Student Self-Assessment Discussion Rubric*	**Student Self-Assessment** The *Student Self-Assessment Discussion Rubric* can be used anytime after a discussion to help students reflect on their participation in the class that day. Choose to use this at least once a week or once every other week. Initially, you might give students ideas for what they can try next time to improve, such as sentence starters for discussions. As students gain practice and proficiency with discussions, ask for their ideas about how the classroom and small-group discussions can be more productive. We suggest the following lessons as good opportunities to incorporate this tool: • Lesson 2, day 3, after students analyze data and determine long-term trends are changing in their own communities and in other communities. • Lesson 5 using the final exit ticket. • Lesson 7 after the Building Understandings Discussion. • Lesson 12 after they engage in the cause-and-effect diagram consensus model. • Lesson 15 after the day 3 Consensus Discussion where they agree upon promising solutions. • Lesson 17 using **slide O**.
After students complete substantial, meaningful work	*Lessons 5 and 17 Peer Feedback Guidelines* *Peer Feedback Instructions* *Lesson 5,* ***slide H***	There will be times in your classroom when facilitating students to give each other feedback will be very valuable for their three-dimensional learning. The Teacher Reference: *Peer Feedback Guidelines* document is designed to give you options for how to support this in your classroom. It also includes student-facing materials to support giving and receiving feedback, along with self-assessment rubrics on which students can reflect on their experience with the process. Peer feedback is most useful when there are complex and diverse ideas visible in student work and not all work is the same. Student models or explanations are good times to use a peer feedback protocol. They do not need to be final pieces of student work, rather, peer feedback will be more valuable to students if they have time to revise after receiving the peer feedback. It should be a formative, not summative, type of assessment. It is also necessary for students to have experience with past investigations, observations, and activities where they can use these experiences as evidence for their feedback. Below are two opportunities in which both Peer Feedback and Self-Assessment are already built into the lessons: • Lesson 5, Reflection on explanation and **slide H** • Lesson 17, Using Part 5 of *Community Resilience Plan: Project Planning Sheet*

For more information about the OpenSciEd approach to assessment and general program rubrics, visit the OpenSciEd Teacher Handbook.

Lesson-by-Lesson Assessment Opportunities

Every OpenSciEd lesson includes one or more lesson-level performance expectations (LLPEs). The structure of every LLPE is designed to be a three-dimensional learning, combining elements of science and engineering practices, disciplinary core ideas and cross cutting concepts. The font used in the LLPE indicates the source/alignment of each piece of the text used in the statement as it relates to the NGSS dimensions: alignment to Science and Engineering Practice(s), alignment to Cross-Cutting Concept(s), and alignment to the Disciplinary Core Ideas.

The table below summarizes opportunities in each lesson for assessing every lesson-level performance expectation (LLPE). Examples of these opportunities include student handouts, home learning assignments, progress trackers, or student discussions. Most LLPEs are recommended as potential formative assessments. Assessing every LLPE listed can be logistically difficult. Strategically picking which LLPEs to assess and how to provide timely and informative feedback to students on their progress toward meeting these is left to the teacher's discretion.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 1	1.A Develop a model to explain how a small change in temperature can cause large scale changes in precipitation leading to floods and droughts. 1.B Develop a model to explain what could cause an increase in temperatures that are linked to an increase in floods and droughts. 1.C Ask questions that arise from initial observations of stories and headlines about rising temperatures, floods, and droughts to clarify whether increasing temperatures are related to or causing both floods and droughts.	**1.A Developing and Using Models; Stability and Change** **When to check for understanding:** Collect students' initial models at the end of day 2. **What to look/listen for:** Look for students to use: • Water cycling processes, such as evaporation and precipitation, in their initial causal accounts of floods and droughts. See if students are connecting temperature change to a change in these processes. • Look at how students' individual models accounted for changes in temperature and water cycling processes compared to the model co-constructed by the class. This will give you insight as to where each individual student is in their initial understanding of the phenomenon and their modeling practice to explain it. • Look at students' causal accounts to see if they use single words, like evaporation, as a "sufficient" causal explanation, or if they elaborate on a mechanism for how temperature change could affect a water cycle process. **1.B Developing and Using Models; Cause and Effect** **When to check for understanding:** Collect students' initial models at the end of day 2. **What to look for/listen for:** Look for students to explain what is causing temperatures to rise, using language or images that link the cause (e.g., greenhouse gases, pollution, carbon dioxide, etc.) to the effect (rising temperatures). **1.C Asking Questions; Cause and Effect** **When to check for understanding:** when students generate questions on sticky notes with their initials on the back. You may also want to look through student notebooks to see their individual ideas for future investigations to pursue. **What to look for/listen for:** Listen for questions that are open (how/why) versus closed (yes/no), and also questions that are testable in the classroom. See the related assessment callout box for additional guidance.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 2	2.A Develop and use a model to describe the components, interactions, and processes of water distribution and movement on Earth. 2.B Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal patterns in temperature, total precipitation, and seasonal precipitation in the local community and at case sites. 2.C Analyze and interpret data about patterns in rates of change and numerical relationships to determine similarities and differences between drought and flood sites.	**2.A Developing and Using Models; Systems and System Models** **When to check for understanding**: day 1 when students develop the Earth's Water System Model. **What to look/listen for:** ideas from earlier grades about different locations for where water is distributed on Earth, new ideas about how those places are in the air, at the surface, or underground, and how these places interact through water cycling processes to move water from one location to another. **2.B Analyzing and Interpreting Data; Patterns** **When to check for understanding:** day 2, during the Building Understandings Discussion. **What to look/listen for:** • General ideas about the trends in temperature and precipitation for your community (this will vary depending on your location). • Ideas about the data serving as evidence that it is getting wetter, drier, warmer, or cooler in the community. Or maybe, overall, it is about the same over time with just a tiny change. • Questions about the variability and overall trends in the data set. **2.C Analyzing and Interpreting Data; Patterns** **When to check for understanding:** on day 3, using parts 3 and 4 of their case site handout during the Consensus Discussion. **What to look/listen for:** • Ideas about how some places show greater or lesser increase or decrease in precipitation and temperature. • Ideas about how all places are showing temperatures going up, and importantly, most of this change in temperature is in recent years. • Ideas about how precipitation is increasing and the rate of storm events are going up (happening more often) for flood places. • Ideas about how drought places are experiencing a combination of less precipitation, less snowpack, and less groundwater. These places are experiencing more frequent "dry" conditions than before.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 3	3.A Analyze evaporation investigation data for patterns to provide evidence that increased temperatures cause an increase in evaporation leading to more water vapor entering the atmosphere. 3.B Modify a model - based on evidence - to match how a change in atmospheric temperature causes a change in evaporation in Earth's water system.	**3.A Analyzing and Interpreting Data; Patterns** **When to check for understanding:** At the start of day 2, when students discuss temperature and humidity lab data in partners and then with the whole class. **What to look/listen for:** • All conditions saw an increase in humidity, even the dry soil conditions. • Wet soil conditions had a greater humidity increase than dry soil conditions. • Heated conditions had a greater humidity increase than non-heated conditions. • Increasing humidity in the bottle is an indication of evaporation occurring, so a larger change in humidity indicates more evaporation occurred in the same period of time. **3.B Developing and Using Models; Cause and Effect** **When to check for understanding:** on day 2 when students update their Progress Trackers individually and update the Earth's Water System model together. **What to look/listen for:** • Increased temperatures cause an increase in evaporation and more water vapor in the atmosphere. • Students citing data from the bottle setups to support that this is a causal relationship. • Students citing evidence from the NASA Water Temperature and Water Vapor visualization as additional evidence that increased temperatures cause more evaporation. • Some students may bring their understanding of energy transfer to explain the causal relationship between increased temperature and increased evaporation if they have experienced the *Cup Design Unit* and *Storms Unit*. • Students making suggestions for how to modify the model to show changes to evaporation (e.g., suggesting up arrows to show an increase) and changes in precipitation (e.g., suggesting that winds influence where water vapor moves in the atmosphere, therefore where there may be more or less precipitation).
Lesson 4	4.A Integrate scientific information with media and graphical displays of data to clarify how a small change in temperature affects components of Earth's water system.	**4.A Obtaining, Evaluating, and Communicating Information; Stability and Change** **When to check for understanding:** the last question on *Obtaining Information about Other Components* and during the Consensus Discussion. **What to look/listen for:** • students to evaluate the claim(s) by scientists about how warmer temperatures impact the component of Earth's water system they investigate, • students to conclude that the scientists' claims are supported by data that has been collected over many years from multiple sites, and • students to conclude that different components of Earth's water system are changing in different ways (mostly decreasing, but with rising seas), which impacts communities in different ways.

Lesson 5	5.A Construct a scientific explanation based on valid and reliable evidence that changes in temperature can have impacts on the water sources available for communities.	**5.A Constructing Explanations and Designing Solutions; Stability and Change**
		When to check for understanding: The initial and revised case site explanations on day 1.
		What to look/listen for:
		• a "how" explanation that draws upon science ideas and is supported with evidence, including:
		  • how temperature, precipitation, and other water sources are changing in the communities,
		  • how those changes are connected to one another in Earth's Water System Model, and
		  • how changes in one or more components of the system can impact changes in another part of the system.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 6	6.A Compare graphs and charts depicting a changing climate in Alaska looking for similarities and differences to determine that trend lines and patterns across Alaskan claims are caused by increasing temperatures. 6.B Analyze graphs and charts from multiple claims to identify the similarities and differences in patterns to determine that changes in the environments are caused by increasing temperatures.	**6.A Analyzing and Interpreting Data; Patterns** **When to check for understanding:** Day 2 after the completion of *Alaska Graph Notes*. **What to look/listen for:** • Increasing wildfires can be partially attributed to the decrease in precipitation. • The increase in temperatures contributes to the increase in wildfires, changes in precipitation, and decreases in sea ice age and amount. • The drier than normal conditions in Alaska contribute to wildfires increasing and can be explained by decreasing precipitation. • The two sets of claims are related. The changes seen in the environment are all caused by increasing temperatures. **6.B Analyzing and Interpreting Data; Patterns** **When to check for understanding:** On day 3 after students complete *Alaska Wildfires and Sea Ice*. **What to look/listen for:** See *Alaska Wildfires and Sea Ice Key* for information regarding assessment guidance.
Lesson 7	7.A Apply mathematical concepts of percent to understand the proportion and quantity of and stability and/or change in the concentration of gases in the atmosphere over time.	**7.A Using Mathematics and Computational Thinking; Scale, Proportion, and Quantity; Stability and Change** **When to check for understanding:** use the conclusion section on the *Concentration of Gases in the Atmosphere Over Time* handout and during the Building Understandings Discussion. **What to look/listen for:** • students to identify that nitrogen and oxygen are mostly stable and not changing over time (note: oxygen is decreasing slightly, but not a notable percent change); • students to identify that carbon dioxide and methane are increasing by a high percentage; • the change in water vapor is provided to students, but students should classify this as "changing a little;" and • students conclude that, while carbon dioxide and methane make up a small quantity of gas in the atmosphere, the change over time for both types of gas is unusually high.
Lesson 8	8.A Develop and use a model to describe how greenhouse gas molecules respond to energy transfer from Earth to the atmosphere and cause the temperatures to rise.	**8.A Developing and Using Models; Matter and Energy; Cause and Effect** **When to check for understanding:** on day 2 when updating the Progress Tracker during the discussion and in individual student entries. **What to look/listen for:** • Students explain and model GHGs as the cause of atmospheric warming. • Students describe and/or model how GHGs absorb energy, vibrate, and release energy into the atmosphere. • Students identify common GHGs (water vapor, carbon dioxide, methane). • Students describe and/or model that non GHGs (nitrogen gas, oxygen gas) do not absorb energy in the same way as GHG molecules. Non-GHG molecules do not release energy back into the atmosphere. • Students describe and/or model the idea that increasing the amount of GHGs causes warmer temperatures.
Lesson 9	9.A Analyze and interpret data on graphs of carbon dioxide levels collected from ice cores to collect evidence of whether the changes in these levels are cyclical in nature and a normal occurrence or are changing at an non-normal rate.	**9.A Analyzing and Interpreting Data; Stability and Change** **When to check for understanding:** at the end of the lesson. **What to look/listen for:** When students are working with their partner to analyze the data, listen for them to notice that there have been normal, or cyclical, increases and decreases in the amount of carbon dioxide in the atmosphere over time, but the increase that is happening right now is not normal. Students should also notice that the first graph does show an increase in carbon dioxide since the 1950s, but the amount of increase that is represented since then in the second graph is much steeper when it is compared to 800,000 years ago. They should argue that this is another piece of data that shows this increase is not normal.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 10	10.A Integrate qualitative and quantitative scientific information in written text with digital tools to analyze trends of atmospheric CO_2 levels, energy consumption, and human population over time to determine a correlation between human activities and CO_2 emissions. 10.B Ask questions that require sufficient and appropriate evidence as to whether CO_2 comes from combustion of fossil fuels for energy, and is causing the rising CO_2 levels in the atmosphere .	**10.A Obtaining, Evaluating, and Communicating Information; Mathematics and Computational Thinking; Cause and Effect** **When to check for understanding:** on question 2 of *Population, CO2 Levels, and Fuel Consumption* and during the Building Understandings Discussion across the Tuva graphs of population growth, energy consumption, and CO_2 emissions. **What to look/listen for:** • Student ideas about the pattern *in each individual graph*. This pattern shows slightly increasing levels in population, energy consumption, and CO_2 emissions in the 1700s and 1800s, with a steep rise starting in the mid-1900s. • Student ideas about a correlation in the patterns *across the graphs*. The graphs follow a similar trend - all three factors (population, fuel consumptions, and CO_2 emissions) all increase in the same pattern. • Student initial ideas and curiosities about how a growing population that consumes large amounts of mineral resources is correlated with the rapid increases in CO_2 in Earth's atmosphere. **10.B Asking Questions and Defining Problems; Matter and Energy; Cause and Effect** **When to check for understanding:** on day 2 during the navigation as you prepare for the combustion demonstration and the subsequent Building Understandings Discussion following the demonstration. **What to look/listen for:** • students asking for evidence for the products of the combustion of fossil fuels, • students being skeptical because there is not sufficient evidence to convince them that fossil fuels in general produce CO_2 and water when they burn, • students requesting or asking questions to get more evidence to support their findings—evidence that is sufficient to make a claim that CO_2 and water are products of the combustion of a variety of fossil fuels, • students recognizing that energy is a product of the combustion reactions, as well as matter that comes from the reactants, and • students recognizing that the combustion of fossil fuels *causes* an increase in CO_2.

Lesson 11	11.A Apply mathematical concepts to compare the rate of combustion and cellular respiration putting CO_2 into the atmosphere to the rate for photosynthesis taking CO_2 out of the atmosphere leading to an imbalance in the system.	**11.A Using Mathematics and Computational Thinking; Systems and System Models; Scale, Proportion, and Quantity**
		When to check for understanding: during the Building Understandings Discussion.
		What to look/listen for:
		• Students to apply the concept of rate to make sense of the imbalance that occurs when comparing the rate of CO_2 entering the atmosphere from combustion combined with cellular respiration versus the rate of CO_2 taken out of the atmosphere from photosynthesis.
		• Students to use the lens of systems thinking to articulate what has changed in the carbon system due to human activity (i.e., combustion).
		• Students to conclude the following science ideas:
		  • photosynthesis and cellular respiration seem to give off and take up CO_2 from the atmosphere at a similar rate,
		  • combustion is putting CO_2 into the atmosphere without any process to take it out except photosynthesis,
		  • photosynthesis takes CO_2 out of the atmosphere, but the rate of photosynthesis is not enough to take up CO_2 from combustion of fossil fuels and cellular respiration combined,
		  • combustion of fossil fuels is creating a carbon imbalance in the atmosphere, and
		  • the carbon once stored underground from long ago is going into the atmosphere when we burn fossil fuels.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 12	12.A Develop a model to describe how fossil fuel use causes changes to the climate, which affects community water resources. 12.B Construct an argument supported by science ideas to refute and clarify claims through an explanation of the causal chain of events between the changing climate and water resources.	**12.A Developing and Using Models; Cause and Effect** **When to check for understanding:** on day 1, as students work in groups to develop the causal relationship between fossil fuel use and rising air temperatures, causing the changing of community water resources. **What to look/listen for:** • Arrows between each box should show the causal chain between fossil fuel use and changing water resources. • Fossil fuel use causes increased levels of carbon dioxide in our atmosphere. • Increased carbon dioxide in the atmosphere leads to an increase in temperatures. • Look for each box to be supported by the corresponding science ideas from the Model Ideas list. **12.B Engaging in Argument from Evidence; Cause and Effect** **When to check for understanding:** on day 2, on *Version 1: Social Media Post Assessment* or *Version 2: Social Media Post Assessment*. **What to look/listen for:** See *Tweet Claims Assessment Key* for guidance on anticipated student responses.
Lesson 13	13.A Use the carbon dioxide model simulation to generate data and test ideas about different emissions rates scenarios to determine how to reach carbon dioxide equilibrium in the atmosphere.	**13.A Developing and Using Models; Stability and Change** **When to check for understanding:** on day 1 as students discuss the findings from the *UCAR Simple Climate Model*. **What to look/listen for:** Listen for students to determine that, even by cutting emissions in half, the global temperature will still increase. Students should identify that an emissions cut of 9 gigatons per year will need to be made to reach CO_2 equilibrium in the atmosphere.
Lesson 14	14.A Apply mathematical concepts to calculate an average carbon impact and possible carbon reduction solutions and scale those reductions to see what would happen if more people were to change their behaviors.	**15.A Using Mathematics and Computational Thinking; Scale, Proportion, and Quantity** **When to check for understanding:** during the Building Understandings Discussion when the class calculates the compounding impact of behavior and activity changes. **What to look/listen for:** • students calculating the 'carbon savings' from their carbon reduction priorities list, • students multiplying this savings by different population sizes, and • students recognizing that their calculations are based on getting 100% of people to make changes, and to recalculate a more realistic percentage.
Lesson 15	15.A Evaluate competing solutions using a systematic process and jointly develop agreed upon criteria to determine how small changes in behaviors and technologies can add up to larger impacts on reducing CO_2 in the atmosphere.	**14.A Engaging in Argumentation from Evidence; Stability and Change** **When to check for understanding:** at the end of day 3 during the Consensus Discussion. **What to look/listen for:** Students arguing: • for solutions that will reduce carbon emissions, • that multiple solutions would need to be implemented to reduce enough CO_2 to slow or stop the temperatures rising, • with evidence from their solutions handouts to support why they believe some solutions are better than other solutions, and, • that some small solutions would be easy for everyone to implement, and if everyone did, it would make a difference in rebalancing carbon.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 16	16.A Critically read scientific texts adapted for classroom use to obtain information on how communities are implementing new activities at different scales to mitigate the flow of carbon into and out of the atmosphere and/or adapt to changes in the community.	**16.A Obtain, Evaluate, and Communicate Information; Matter and Energy** **When to check for understanding:** As students work in small groups and obtain and evaluate solutions and then map those back to the class Carbon System Model. **What to look/listen for:** • Students recognize that communities have solutions across different sectors of the economy (e.g., transportation, building, greenspaces, food, etc.). • Students recognize that solutions exist at different scales, from individual action to community-level action and beyond. • Students are able to correctly identify which part of the Carbon System Model that the solution is designed to rebalance. Importantly, they use 'matter and energy' as a lens for how the solution works for community resilience.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance

Lesson 17	17.A Apply scientific principles to design a process/system that the school can undertake to reduce the vulnerability to climate change impacts (e.g., high heat, changing water resources) in the short-term and contribute to rebalancing carbon in the long-term.
	
	17.B Ask questions to challenge the proposed resilience plan to evaluate whether the solutions meet the class' agreed criteria checklist and will reduce vulnerabilities to climate impacts in the short-term and rebalance carbon in the long-term.
	
	17.C Construct an argument grounded in evidence and scientific reasoning to recommend a design solution that will prepare a community for predicted changes to temperature and/or precipitation (effect).
	
	17.D Communicate information in writing and/or oral presentation about how adopting individual, family, or school solutions (subsystems) to reduce vulnerabilities to climate change and/or rebalance carbon can contribute to broader community resilience (larger system) (optional).
		17.A Constructing Explanations and Designing Solutions; Stability and Change
		When to check for understanding: Below are opportunities for both formative and summative assessment and group versus individual progress.
		• Group progress
		  • Day 1: (formative) when students share ideas to collaboratively build the Criteria Checklist.
		  • Day 2: (formative) listening in and probing groups as they complete their planning sheet.
		  • Day 3: (formative) using *Designing a Community Resilience Plan: Teacher Feedback* to provide feedback to groups before they make their final product.
		  • Day 4: (summative) using *Rubric: Designing a Community Resilience Plan* to provide feedback on final group products.
		• Individual progress
		  • Anytime: (formative) as a student shares ideas in whole group and small group discussion.
		  • Day 2: (formative) individual exit ticket, see **slide O**.
		  • Day 4: (summative) using *Argue for the Best Solution to Solve a Problem in Your Community* and *Rubric: Argue for the Best Solution to Solve a Problem in Your Community* to assess individual progress and provide feedback.
		What to look/listen for:
		• See *Designing a Community Resilience Plan: Teacher Feedback*, *Rubric: Designing a Community Resilience Plan*, and *Rubric: Argue for the Best Solution to Solve a Problem in Your Community* for specific guidance. These rubrics are based on a sample Criteria Checklist. You will need to adjust them based on your class' agreed upon Criteria Checklist.
		
		17.B Asking Questions and Defining Problems; Stability and Change
		When to check for understanding: this is an individual assessment. On day 3 students ask questions to challenge each other's plans and provide peer feedback. See *Community Resilience Plan: Project Planning Sheet*, Part 5.
		What to look/listen for: use *Rubric: Evaluating Solutions by Asking Questions* to check individual progress on this LLPE and to provide feedback. The rubric should be modified to match your class' Criteria Checklist and your expectations for their evaluations of each other's work.
		
		17.C Arguments from Evidence; Stability and Change
		When to check for understanding: On the individually constructed argument on day 4 using *Argue for the Best Solution to Solve a Problem in Your Community*.
		What to look/listen for: A rubric is provided to guide you through assessing students' individual arguments. See *Rubric: Argue for the Best Solution to Solve a Problem in Your Community*.
		
		17.D Obtaining, Evaluating, and Communicating Information; Systems and System Model
		When to check for understanding: this assessment is optional depending on how much time you provide to students to communicate their plans. If students present their plans to each other or an external audience, use this LLPE as an assessment target.
		What to look/listen for: see *Rubric: Communicating Our Community Resilience Plans* for guidance. Depending on the format of communication you may need to adjust the rubric to match your class' agreed upon expectations.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 18	18.A Communicate scientific information orally about the patterns of class questions that have been explained with sufficient evidence about the impact of a changing climate and community solutions, and ask additional questions that require appropriate and sufficient evidence to answer.	**18.A Obtaining, Evaluating, & Communicating Information; Asking Questions and Defining Problems; Patterns** **When to check for understanding:** while revisiting the DQB and when building the next DQB. **What to look/listen for:** • We can clearly answer some of the questions through ideas learned throughout the unit. • Some questions we can partially answer with some of our ideas learned, but they require more information/evidence.

Lesson-Specific Teacher Materials

Example Student Questions

Below is a list of student questions compiled from piloting the anchoring phenomenon routine for this unit. These examples can help you anticipate some of the questions that your students may share as initial questions on the Driving Question Board (DQB).

What is happening with temperatures/global warming/climate change?

- How much are temperatures increasing?
- What is causing global warming?
- How does global warming affect precipitation?
- How do the extra heat/heat waves cause rain and storms?
- How hot can the sun get? Is it getting hotter? Closer?
- Why have places like California dried up so quickly? Has the climate always changed this fast?
- Will floods be more common due to global warming (raising the sea level and flooding land closer to the sea)?
- Does climate change increase or decrease precipitation?
- If temperatures keep rising will we have more of these problems?

What do pollution/greenhouse gases have to do with this?

- How does air pollution connect to droughts and floods?
- How does CO_2 trap warm air?
- What is a greenhouse gas?
- Why do we make pollution if it's bad?
- Do things other than humans make greenhouse gases?
- Don't we need some greenhouse gases?

What is causing droughts and floods?

- Is it global warming that causes all of these events?
- What is causing so many floods and droughts all over the country? Is there a pattern?
- Why does the hotter temperature lead to more and less precipitation?
- Will floods happen more often due to climate change?
- Will droughts and floods worsen in the future to create more deserts and receding coastlines?
- Should people in areas with low chance of floods prepare and/or worry about floods?
- Doesn't the water just balance out where it goes with floods and droughts?
- Does there have to be a certain climate for droughts and floods to occur?

Where does the water come from and where does it go?

- Where does all of the flood water come from?
- What controls the amount of precipitation?
- How much does the sun play into evaporation?
- Does the amount of water in an area affect the amount of precipitation that falls?
- Can colder temperatures cause there to be more precipitation?
- In a flood, where does the water come from and then go to? In a drought, where does the water go?
- Why doesn't the evaporated water in the dry areas go back down as rain in the same area?
- Why is there so much humidity?

What can we do to help?

- Can we stop this from happening?
- What is something we can do to help control climate change?
- How can we stop these record-breaking heat waves?
- Is there a way to keep droughts from happening?
- If a drought happens in one place and that town takes water from another town, could it lead the other town to a water shortage?
- Will manually inducing clouds with water help stop droughts?
- What are some man-made ways we can stop floods/droughts?
- Why can't we just pipe more water in?

How is this related to other phenomena?

- Why is California suffering from wildfires and droughts, but somewhere like Florida isn't, even though both states are on the coast and close to the Equator?
- Is this related to the fires in California?
- Do melting icebergs have anything to do with this?
- Is this why the oceans are rising?
- Would oceans rising make flooding worse?
- Why have there been so many hurricanes lately?

Other questions about droughts and floods:

- Can droughts only happen in the summer?
- Why are droughts and floods becoming more and more normal?
- Could places close to a body of water have a drought depending on the climate?
- Can a drought happen after a flood?
- How much precipitation is considered too much and how do they determine that the rain is going to cause a flood?
- Do floods happen mostly near bodies of water?
- How much damage do the floods cause?
- Is it as common for floods and droughts to occur in winter?
- What is normal?
- How do we figure out what is normal?

Lesson 1 Teacher Reference

Natural Resources Guidance and Extension Opportunities

Lessons 2-5 and 10 include a set of Additional Guidance callout boxes with suggestions and activities designed to support students in deepening their understanding of natural resources. Look for Additional Guidance with the heading "Natural Resources guidance and extension opportunity". There may be optional handouts associated with these Additional Guidance boxes. There may be discussion prompts included on slides, or in the learning plan, to facilitate discussion within the lessons, too.

Freshwater resources

Lesson 2

In class learning:
Porterville, California is a location highly dependent on groundwater for it's community water. Students observed this in lesson 1 when they learned that the wells were going dry. As students explore the "Groundwater Reserves" graph for Porterville, there is an opportunity to delve deeper into issues around how people use groundwater even when those resources are not being replenished at the same rate of use.

Probe students' sensemaking of the groundwater data with the following questions:

- How do you think the wells in Porterville continue to get water?
- What kinds of activities in the city and area pump water from these wells?
- How does the amount of precipitation in the area affect the water people can get from wells?

Home Learning or Extension opportunity:
Lesson 2 includes an additional reading, *Changes to Groundwater*. This reading provides background information about groundwater. The reading can be used to deepen students' understanding of how the stability of groundwater resources are determined by a balance of use by people and refilling from natural processes.

Lesson 3

In class learning:
Slide Q includes the following discussion prompts

- There is more water vapor in the atmosphere overall, but there is not equal precipitation everywhere. What new information might we want to add on the precipitation side of our model?
- How are we seeing the uneven precipitation impacting people's water resources?

These discussion prompts will have students share ideas related to ESS3.A. Natural Resources. Because of changes to precipitation patterns, some communities are experiencing less replenishment of freshwater resources, while other communities are dealing with the opposition problem. To go further with ESS3.A consider adding a focused in class discussion using these prompts:

- How do humans depend on regular patterns in water cycling processes, like evaporation and precipitation?
- What problems are we seeing in our water resources when the patterns change?
- For people who get water from wells dug in the ground, how does their water source fill up? What happens when nothing is refilling it? How is this different from people who get their water from a city system? Where is the city getting its water, do we think?
- When there is less water available, who decides how it is shared among everyone who needs it?

Lesson 4

Glaciers provide freshwater resources to human communities around the world and are a source of water from hundreds to thousands of years ago. While glaciers are not a primary water source for the contingent United States, over a billion people worldwide rely on this freshwater resources, which is retreating or losing mass at a faster rate than replenishment in this warmer climate. The following is a home learning or extension opportunity that will engage your students in thinking about how human communities rely on glacier resources for water.

Home Learning or Extension Opportunity
Assign *Glaciers and Water Supply* as an at home reading or an extension activity in class. Use the prompts with the reading to discuss:

- How is the amount of glacier water changing as temperatures warm up?
- Think about what you've learned about changes to glaciers. How might these changes affect water supplies for people?

Lesson 5

In class learning:
The final slide of the slide deck, **slide E2**, can be used to help students bolster their explanations of changing water stories. It is particularly relevant for locations in which water resources are not replenishing as fast as people are using them. This applies directly to communities that are experiencing more frequent drought conditions, such as Portersville (groundwater) and Yakima (snowmelt and glaciers). If this option is selected, place slide E2 following slide E to help students prepare for including these additional ideas in their explanations. Adjust the teacher key to include science ideas your students have developed in connection to ESS3.A Natural Resources that you want to assess students progress toward.

Mineral resources

Lesson 10

Extension opportunity:
There is an extension opportunity offered in this lesson to more fully address ESS3.A Natural Resources with respect to mineral resources. See *Extension Opportunity: Uneven Distribution of Fossil Fuel Resources* and **Lesson 10 slides U-AB** for more information. Should you choose to complete this extension, navigation into the extension will use the Driving Question Board for students to add new questions to motivate further investigations. Print double-sided copies of *Fossil Fuel Formation Illustrations* for each student and enough double-sided copies of the 3 readings found in *Fossil Fuels Long Ago and Today* for student choice of what they want to read more about. The extension is designed to (1) allow students to connect to prior knowledge and experiences about fossil fuels, (2) ask new questions which are added to the DQB, (3) investigate using illustrations and readings to make sense of how fossil fuels form and where they are found, and (4) broaden to related phenomena of uneven distribution of other resources. Alternatively, if you cannot take a full class period for the extension, assign the readings as home learning and facilitate a class discussion about what students learned from the readings at the start of the next class period.

Lesson 2 Teacher Reference

Rationale for Case Sites

The case sites in the StoryMap were purposefully chosen for this lesson to introduce important aspects of droughts and floods in the United States without overly complicating the data for students. They were purposely chosen from different regions of the US as well. In general, locations in the Midwest and Northeast will show places experiencing more severe flooding/increasing precipitation, and locations in the Western US, and particularly the Southwest, will show longer or more severe droughts/decreasing precipitation. The information in this teacher reference is provided so that you can know more about why each site was chosen for this lesson, and how your local case site might be similar to or different from these six sites.

- **Temperature:** All case sites in the lesson show increasing trends in temperature, which is representative of the vast majority of the US. There are a few locations that might have flat or decreasing trends, but this is not a common result. Overall surface air temperatures are increasing globally.
- **Precipitation:** Data for precipitation is much more complex, in that some places are seeing wide-ranging variability in data but almost no change in long-term trend. Where water is located for communities varies greatly. Some communities depend on snowpack accumulating in the winter to slowly release water as snowmelt in the spring. Some communities depend on the recharging of groundwater supplies from steady precipitation throughout the year. Groundwater supplies are declining as a result of growing populations needing access to water and agricultural communities needing to offset losses in rainfall by pumping more groundwater for crops. But perhaps the most important overall change in precipitation is the increased frequency of very short, heavy precipitation events, which run off the surface quickly and do not allow for normal replenishment of moisture to the soil and groundwater systems. These complex situations are not visible by viewing total annual precipitation alone. As such, students are given additional snowpack, groundwater, flood/storm frequency, and the Palmer Drought Severity Index in order to provide more information for students to consider.
- **Palmer Drought Severity Index:** The Palmer Drought Severity Index (PDSI) is not available at the county level, but it is available at the climate-division level within each state. The PDSI is a combination of temperature and precipitation data to estimate relative dryness in a climate division. It is a standardized index that generally spans -10 (dry) to +10 (wet). Most places stay within -4 to +4, but the data will show more extreme measurements in places experiencing higher or lower wetness indicators. One drawback to PDSI is that it does not account for delayed runoff from melting snow or ice.
- **General note about the data:** The Dust Bowl period is visible in almost all the case sites. Students might notice extended periods of drought or lower precipitation during the 1930s.

Rationale for each case site:

1. Porterville, CA: This site has seen increasing temperatures over time and longer periods of drought, according to the temperature trends graph and the PDSI graph. Overall precipitation has not changed significantly over the last 125 years. However, groundwater reserves are diminishing rapidly because the aquifers under the Central Valley region of California support the towns and the agricultural production of the region. Short, heavy rain events run off more quickly, not allowing for as much replenishment of the aquifers or soil moisture in the region. So, even though total precipitation hasn't changed much, the amount and timing of the precipitation has changed, not allowing for normal ground and surface water storage to replenish.

2. Vicksburg, MS: This site has seen both increasing temperature and precipitation over the last 125 years, and the PDSI also shows great periods of wetness in recent years. However, Vicksburg's floods are also exacerbated by upstream increases in heavy precipitation and flood events, such as those in Windom, MN. The Mississippi River Basin accumulates water from all upstream sources. Increased precipitation trends are seen throughout the basin, which all flows downstream through Vicksburg.

3. Navajo Nation: This site is located in part of the most severe region of long-term drought in the United States. The data will show increasing temperatures, decreasing precipitation, and also dry scores on the PDSI graphs. The drought in the Navajo Nation is also complicated by part of the region being located near high elevations and dependent on snowpack that is decreasing. Likewise, groundwater reserves are very deep and expensive to tap, creating a situation in which local residents do not have easy access to alternative sources of water beyond the normal precipitation they depend upon. Many sites in the US Southwest will show similar trends in the data, but the video that accompanies this site discusses the change in precipitation over time.

4. Boston, MA: This site has seen increasing temperatures, precipitation, and flood events in recent years, with a PDSI graph also showing high levels of wetness in recent years. Boston's flooding is exacerbated by two conditions: (1) increasing winter precipitation falling in the form of heavy rain instead of snow and (2) increasing sea levels that cause both tidal flooding and storm surge during events. Sea-level rise will be addressed in Lesson 6 but will be one small piece added to this site that can be revisited after Lesson 6.

5. Yakima, WA: This part of Washington is on the eastern side of the Cascade Range and would typically receive less precipitation because of the "rain shadow" effect of mountains. However, the very vibrant agricultural region has long depended on slow snowmelt from the Cascades to provide spring and summer water to the region. As snowpack in the Cascades declines so does the surface water supply to the Yakima Valley. The data for Yakima shows increasing temperatures, but precipitation is not obviously decreasing. The story for this site is more focused on the loss of snowfall in the mountains, which causes decreasing surface water when it melts.

6. Windom, MN: This case site represents many towns in the upper Midwest that have experienced higher precipitation totals and more severe events and flooding in recent years. They have not experienced a lot of extreme floods; but the precipitation and temperatures continue to increase, and they experience more flood events overall. This site also represents the upstream sites in the large Mississippi River Basin that are experiencing heavier precipitation that eventually flows downstream to places like Vicksburg.

Instructions for Accessing Local Data

These instructions can also be seen by watching the screencast at https://youtu.be/V0ytqQu07KI. Note: The website has updated since this video was made and some options have changed.

1. Navigate to https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/county/time-series. This site is hosted by the National Oceanic and Atmospheric Administration (NOAA), a trusted source for weather and climate data. NOAA has weather monitoring stations throughout the US and the repository of data to study climate is 125 years of measured readings.

To get **long-term** temperature and precipitation graphs:

- be sure you select "Country Time Series"
- under Parameter, choose "Average Temperature,"
- under Time Scale, choose "12-month,"
- under Month, choose any month to display. This will place 1 data point per year. If you choose "All Months" you will not be able to display a trend over time.
- under Start Date, choose "1895" (for long-term graph with full data set),
- under End Date, choose "2021," or the most recent year available,
- under State, choose your state,
- under County, choose your county,
- uncheck "Display Base Period:" for long-term graphs, check "Display Trend" and make sure the years match 1895 to 2020,
- select Plot,
- right click near the title on the graph and select "View as png,"
- right click again and save the image,
- repeat for Precipitation by changing Parameter to "Precipitation" and clicking "Plot,"
- save this image.

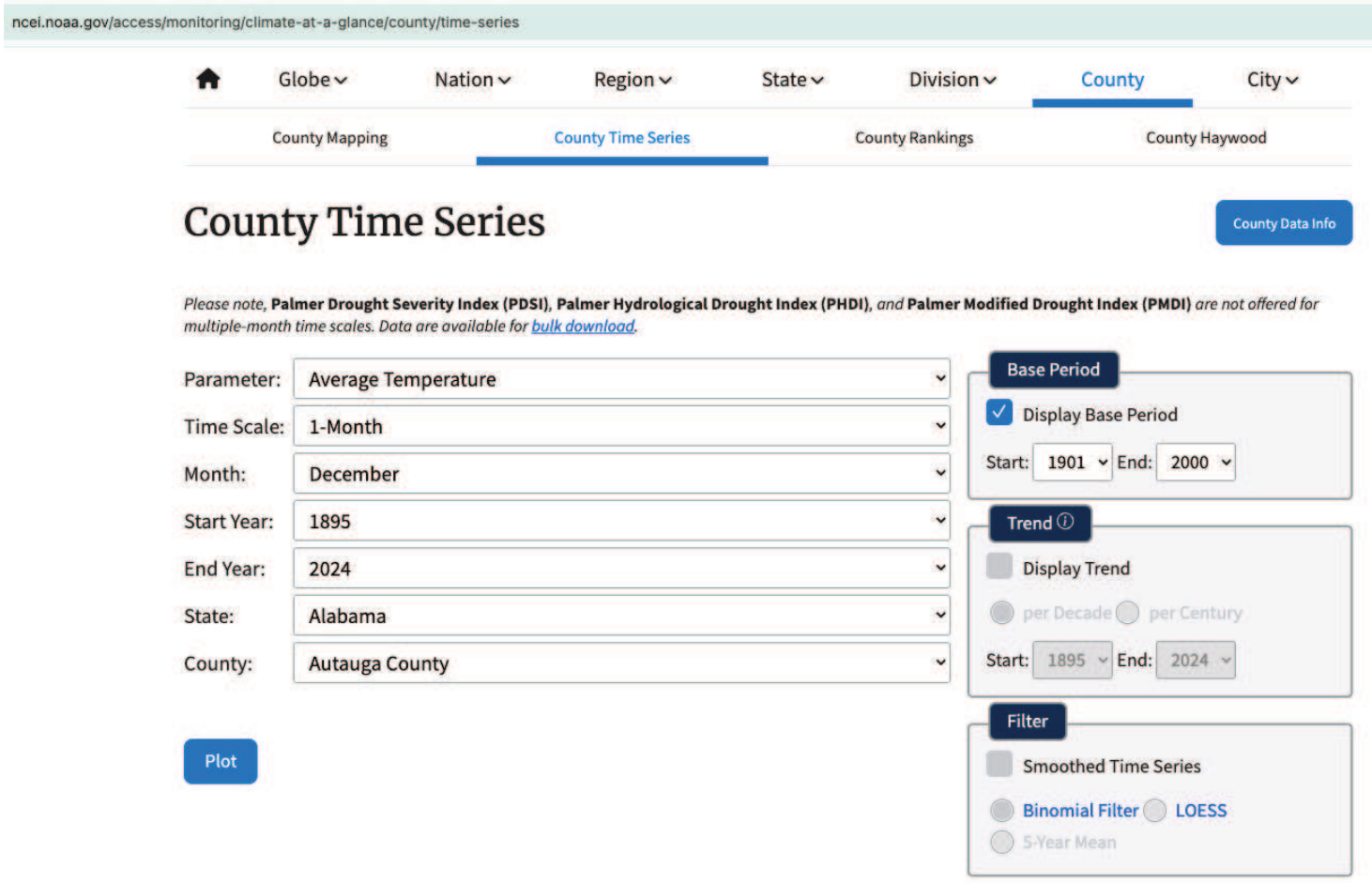
To get **short-term** temperature and precipitation graphs:

- be sure you select "County" level data and "Time-series,"
- under Parameter, choose "Average Temperature,"
- under Time Scale, choose "12-month,"
- under Month, choose any month to display. This will place 1 data point per year. If you choose "All Months" you will not be able to display a trend over time.
- under Start Date, choose "2011" or 10 years prior to the most recent year available (for short-term graph),
- under End Date, choose "2021," or the most recent year available,
- under State, choose your state,
- under County, choose your county,
- uncheck "Display Base Period:" for short-term graphs, also make sure "Display Trend" is **not** checked,
- select Plot,
- right click on the graph and select "View as png,"
- right click again and save the image,
- repeat for Precipitation by changing Parameter to "Precipitation" and clicking "Plot," and
- save this image.

To get Palmer-Drought Severity Index (PDSI) data graphs:

- under Parameter, choose "Palmer Drought Severity Index,"
- under Time Scale, choose "One Month,"
- under Month, choose "January" (this is the month used for the six case sites in the lesson),
- under Start Year, choose the years 10 years prior to the most recent year available, for the short-term graph (change this to 1895 for the long-term graph),
- under End Date, choose the most recent year.
- under State, choose your state,
- under County, choose your county,
- uncheck "Display Base Period:" for both short-and long-term graphs,
- for the **long-term** graph, check "Display Trend" and make sure the years match 1895 to 2020,
- select Plot,
- right click on the graph and select "View as png,"
- right click again and save the image,
- make both short-and long-term graphs.

See the screen capture below is the main page where you will find the data needed to make the graphs.



NOAA

Lesson 2 Teacher Reference

Analyzing Our Local Data

Location: _____

Part 1: Prepare to Analyze and Interpret Data.

Before you analyze the data, do the following:	Your notes:
1. **Read about the first three data sources** on *About the Data*. • Consider your purpose: Why are you using this data? How might it help you understand floods and droughts?	

Part 2: Analyze and Interpret Data: Long-Term Data Set. Write or annotate on the graphs on the next page as you consider what you notice or see in the data (WIS) and what it means (WIM).

As you analyze the data, do the following:
2. **Annotate (write and draw) on the graphs "what I see" statements (WIS)** to highlight your observations of the data shown in part 2. Observations might include high points in the data, low points in the data, the direction of data lines, or other observations you might have about the data you see on the graphs or maps. Write the WIS statement directly on the graph near your observation. Draw an arrow to indicate exactly what data or part of the graph you are writing about.
3. Begin **interpreting what you think the data means by writing a "what it means" statement (WIM)** for your case site on the data in part 2. For each of your WIS statements, write a WIM statement as an interpretation of what you see and the data you reference. WIM statements can also include overall trends you see across the data set or specific patterns in the data. Try to describe what the data means to you.

Part 2 continued: Data to Investigate. Write or annotate on these graphs as you consider what you notice in the data (WIS) and what it means (WIM).

Total Annual Precipitation (1895-2020)	Average Annual Temperature (1895-2020)
Insert Local Data Graph	Insert Local Data Graph
Palmer Drought Severity Index (1895-2020)	**Additional Data (optional)**
Insert Local Data Graph	Insert Local Data Graph

Lesson 5: Answer Key 1

Scoring Guidance for Case Site Explanations

Allow your students to choose the modality for communicating their thinking. They can explain the phenomenon through written explanation or using a diagrammatic explanatory model or infographic. Guidance is provided depending on the modality students choose to use.

This assessment can be used to assess student progress on the LLPE. This LLPE is an integration of elements from the three dimensions.

5.A Construct a scientific explanation based on valid and reliable evidence that changes in temperature can have impacts on the water sources available for communities.

SEPs	DCIs	CCCs
6.3 Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. Students started to engage with this element in Lesson 2 when they analyzed and interpreted data from several reliable sources (e.g., NOAA and affiliated agencies). They added data from their own experiment in Lesson 3 and obtained additional information from informational texts in Lesson 4. This explanation task challenges students to synthesize evidence from these sources and integrate it with natural laws for water cycling on Earth to explain why water sources are changing in one community. Look for how students apply science ideas to support their explanations. There should be clear references to different data sets and sources of evidence. Are there patterns in science ideas present or missing from all students' explanations? Students may also bring evidence from the classroom or their experiences to bolster their explanations.	**ESS2.C.** Water continually cycles among land, ~~ocean,~~ and atmosphere via ~~transpiration~~, evaporation, condensation and ~~crystallization~~, and precipitation, ~~as well as downhill flows on land~~. **ESS2.C.** The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, ~~landforms, and ocean temperatures and currents~~, are major determinants of local weather patterns. **ESS2.D** ~~Weather and~~ climate are influenced by interactions involving sunlight, ~~the ocean~~, the atmosphere, ~~ice, landforms, and living things.~~ These interactions vary with ~~latitude, altitude, and~~ local and regional geography, ~~all of which can affect oceanic~~ and atmospheric flow patterns. Students should use their prior understanding of how water cycles on Earth, especially the role of energy (i.e., temperature) in this process, to explain what water sources are changing in these communities. This is a fundamental idea behind climate change. Students need to establish the normal cycle of water on Earth and then explain which parts of that system are showing changes. *If slide E2 is used, consider modifying this key to include science ideas from ESS3.A Natural Resources (focused on freshwater resources) that match the learning experiences your students have had in Lessons 2-4.	**7.2** Small changes in one part of a system might cause large changes in another part. Stability and change is the focal CCC for this assessment as students bring together ideas about what would be "normal" (i.e., stable) for a community and what is changing in the community. Importantly, the data shows that small changes in temperature can lead to big impacts on communities. Students might communicate this idea by citing evidence from the data sets, investigations, or readings.

The scoring guidance provided below uses a + and ++ notation that can help you identify different ideas that students should (or could) include in their responses.

- If several of the ideas marked with a + are missing from a student's response, this may indicate the student has not mastered the science ideas or that the student may be struggling to bring those ideas together in a written explanation or model. Additional probing of their thinking can provide insight about whether the student is struggling with a science practice or science idea or both.

- If all or almost all of the ideas marked with a + are present in a student's response, this may indicate the student has mastered the science ideas and is able to use them in a written explanation or explanatory model.
- If the ideas marked with a ++ are present in a student's response, this indicates that the student is bringing a deeper understanding of the science ideas or a deeper engagement with the practice to their response. Students should not be marked off if ideas marked with a ++ are not present in their response.

If students choose a diagrammatic explanatory model, infographic, or written response, look for these ideas represented in their response:
+ a statement or idea about normal precipitation for a place with evidence of the type of precipitation and how much would be expected.
+ a statement or idea about what is different about precipitation in a place with evidence to show greater or lesser precipitation, change in type, timing, or intensity of precipitation.
+ a statement or idea about normal temperature ranges and any change in the pattern of temperature in a place.
+ a statement or idea that explains how increasing temperatures increase evaporation rates, and, therefore, change the water vapor and/or precipitation available for a place.
+ ideas or statements that explain where typical water sources are for a community and how those sources are changing.

More sophisticated understandings may include:
++ ideas about how temperature and/or precipitation remained stable (within a certain range) until recent years.
++ ideas about how small changes in one variable can have big changes in another variable.
++ ideas about how the timing or type of precipitation is changing as a result of changing temperature patterns.

Demonstrates Developing Ideas and What to Do	Demonstrates Mastery in Some Areas and What to Do	Demonstrates Mastery in Most Areas and What to Do
If students are still developing the ideas listed above, the explanation might look like: • Reporting only the data, but not adding an interpretation of the data or an explanation of the causes behind the change. • No mention of what is normal or not normal for the place. • Inclusion of only one variable (e.g., the amount of precipitation, but no mention of temperatures, storm events, groundwater, etc.)	If students are demonstrating mastery of some of the ideas listed above, the explanation might look like: • Reporting the data and the interpretation, but not the "why" or causes of what is behind the changing pattern. • May mention normal and not normal patterns. • Limited integration of ideas across precipitation, surface water sources, and temperature.	If students are demonstrating mastery of most or all of the above ideas, the explanation might look like: • Clear reporting of the data, the interpretation, and the mechanism for what is causing that to happen. • Clear statement of what is considered normal and how the current situation is not normal. • Integration of ideas across what causes precipitation and surface water changes with reference to the community's main sources of surface water.
Ways to frame feedback or provide students with prompts to consider: • What data supports this idea? • What is causing ___ to change (e.g., temperature, precipitation)? How might you include that idea in your explanation? • What was the precipitation like in this community before? What is it like now? Are there some ideas we have about what is causing the change?	Ways to frame feedback or provide students with prompts to consider: • I see the precipitation is decreasing and it means that they are in a drought. Can you include some ideas for what is causing the precipitation to decrease? • How is that ___ source of water changing? Why do you think that is happening?	To push student responses to even more sophisticated levels, consider prompts such as: • Are there ideas we can include about how the timing of the precipitation is changing each year? • Can we explain all the different natural ways water is stored or provided to this community throughout the year? • Could you project or predict how this community might need to adapt if it continues to experience droughts or floods?

Below is an example of how two case sites might look as they go from an initial explanation, peer reviewed, and then revised. These are only examples. Your students will express their ideas in different ways and in different formats. Students should provide at least two pieces of feedback on a peer's work.

Example initial explanation	Example peer feedback	Example revised explanation
Headline: Water Shortages in East Porterville are the result of more dry years. Paragraph: The community of East Porterville is experiencing rising temperatures and more dry years than what they normally expect. Since the community relies on pumping groundwater, especially during dry years, the community is now experiencing water shortages in homes that do not have deep enough wells. Not all years are dry in East Porterville though. But even when they get more rain, it isn't enough to refill the aquifer.	Headline: Water Shortages in Porterville are the result of more dry years. *What about groundwater?* The community of East Porterville is experiencing rising temperatures and more dry years than what they normally expect. *Can you add science ideas about evaporation and water vapor? Can you include evidence from drought data?* Since the community relies on pumping groundwater, especially during dry years, the community is now experiencing water shortages in homes that do not have deep enough wells. *Why do they pump more water in dry years?* Not all years are dry in East Porterville though. But even when they get more rain, it isn't enough to refill the aquifer. *Can you give evidence for this statement?*	Headline: Water Shortages in East Porterville are the result of more dry years and less groundwater. Paragraph: The community of East Porterville is experiencing rising temperatures and more dry years than what they normally expect. The PDSI graph shows that Porterville had several very dry years recently. There is also less water vapor in the air, so there isn't a source of water for it to rain much either. Even though there is evaporation, the wind takes the water vapor to another place. Since the community relies on pumping groundwater, especially during dry years when they do not get as much rain, the community is now experiencing water shortages in homes that do not have deep enough wells. Not all years are dry in East Porterville though. But even when they get more rain, it isn't enough to refill the aquifer. The groundwater graph showed that the levels of the aquifer are declining, even during years with more rain.

Example initial explanation	Example peer feedback	Example revised explanation
Headline: More heavy rain and storm events are leading to more frequent floods in Vicksburg. Paragraph: Temperatures and precipitation are not normal for the area of Vicksburg. Vicksburg seems to be getting warmer and humid (high water vapor) air masses, which leads to more precipitation in the area. Because the town is settled along the Mississippi River, when it has heavy rain, it tends to flood. To make the situation worse, all the heavy rain from upstream flows downstream through Vicksburg, often making the flooding even worse. The data shows that the town has experienced more floods lately.	Headline: More heavy rain and storm events are leading to more frequent floods in Vicksburg. *What about temperature?* Paragraph: Temperatures and precipitation are not normal for the area of Vicksburg. *Can you add evidence from the graphs?* Vicksburg seems to be getting warmer and humid (high water vapor) air masses, which leads to more precipitation in the area. *Can you explain why?* Because the town is settled along the Mississippi River, when it has heavy rain, it tends to flood. To make the situation worse, all the heavy rain from upstream flows downstream through Vicksburg, often making the flooding even worse. *Where did you see this?* The data shows that the town has experienced more floods lately. *Can you add specific times or amounts to this?*	Headline: More heavy rain and storm events are leading to more frequent floods in Vicksburg. Paragraph: Temperatures and precipitation are not normal for the area of Vicksburg. Vicksburg seems to be getting warmer and humid (high water vapor) air masses, which leads to more precipitation in the area. When temperatures are warmer and there is a source of water, evaporation rates increase, causing more water vapor in the air. A NASA simulation showed that a lot of this water vapor comes from warmer oceans on the east side of the United States. This water vapor can fall as rain. The more there is in the air, the more rain that will fall. The video showed that the town's located right next to the Mississippi River, which means when the river floods, the town might flood, too. To make the situation worse, all the heavy rain from upstream flows downstream through Vicksburg, often making the flooding even worse. The data shows that the town has experienced more frequent floods in the last couple of decades.

Lesson 6 Teacher Reference

DQB Check-In

Let's take a moment to look back at our questions from the Driving Question Board. Read each question and determine if we have made progress on the question. Put a check mark in the appropriate box.

Question from the DQB	Answered	Partially Answered	Not Answered Yet

Revisar el RPM

Tomemos un momento para revisar nuestras preguntas del Registro de preguntas motivadoras. Lea cada pregunta y determine si hemos progresado en la pregunta. Ponga una marca de verificación en la casilla correspondiente.

Pregunta del RPM	Respondida	Parcialmente respondida	Aún no respondida

Lesson 6: Answer Key 1

Alaska Wildfires and Sea Ice Key

This assessment can be used to assess student progress on the LLPE. This LLPE is an integration of elements from the three dimensions.

6.B Analyze graphs and charts from multiple claims to identify the similarities and differences in patterns to determine that changes in the environments are caused by increasing temperatures.

SEPs	DCIs	CCCs
4.7 Analyze and interpret data to determine similarities and differences in findings. Students begin to build this skill in Lesson 2 as they analyze graphs presented for 6 different case sites. These graphs are compared for trends that might help explain why some locations experience changes in precipitation. In Lesson 3, students consider the influence of precipitation patterns that might cause a change in precipitation patterns that affect different locations. In Lesson 4, students gain more information from data over sea ice that can be interpreted as being influenced by increasing temperatures. In this lesson, students are presented with additional information and data in regards to wildfires and sea ice loss. Students are then asked to determine if any of these changes in Alaska are related to any changes seen in case sites, using previously collected data from their case sites. By using skills from Lesson 2 in analyzing data and interpretation skills from Lessons 3-4 in addition to the ice data in Lesson 4, students are able to synthesize this new information to provide evidence that sea ice is decreasing and wildfires are increasing due to the increasing temperatures. Further, students are able to make a connection, as in Lesson 2, that the precipitation patterns, which are influenced by increasing temperatures, are exacerbating the environmental changes seen in the claims.	**ESS2.C.** Water continually cycles among land, ~~ocean,~~ and atmosphere via ~~transpiration~~, evaporation, condensation and ~~crystallization~~, and precipitation, ~~as well as downhill flows on land~~. **ESS2.C.** The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, ~~landforms, and ocean temperatures and currents~~, are major determinants of local weather patterns. **ESS2.D** ~~Weather and~~ climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ~~ice, landforms, and living things~~. These interactions vary with ~~latitude, altitude, and~~ local and regional geography, ~~all of which can affect oceanic~~ and atmospheric flow patterns. Students should use their prior understanding of the increase in temperatures on ice, ocean temperatures, and atmospheric water vapor patterns to help explain why multi-year sea ice amounts are diminishing and wildfires could be occurring more frequently. The understanding of the increase of temperatures to these atmospheric patterns to cause increased droughts is also utilized as students explain the drought conditions in Alaska that contribute to an increase in wildfires. Students also make the connection that these seemingly unrelated phenomena are connected to other changes in water vapor patterns occurring at the case sites studied.	**1.4** Graphs, charts, and images can be used to identify patterns in data. The use of patterns presents itself continually in this assessment. As students analyze graphs and data from the wildfire reading, students look for patterns in trend data, and if differences exist in the data, students consider the potential cause-and-effect implications of the graphical datasets. The pattern of increased temperatures across Alaska has led to an increase in wildfires and a decrease in sea ice, along with less-than-average precipitation and drier conditions in the area. Patterns in declining precipitation are seen to influence the patterns of increased wildfires and increased drought conditions. Students will communicate these ideas by explaining these connections in part 1 of the assessment and applying these ideas to explain how decreasing sea ice and increasing wildfires are connected to increasing temperatures in part 2 of the assessment. Students will also make connections between the patterns in rising temperatures seen at the case sites and the Alaskan data.

The scoring guidance provided below uses a + and ++ notation that can help you identify different ideas that students should (or could) include in their responses.

- If several of the ideas marked with a + are missing from a student's response, this may indicate that the student has not mastered the science ideas or that the student may be struggling to bring those ideas together in a written explanation or model. Additional probing of their thinking can provide insight about whether the student is struggling with a science practice or science idea, or both.

- If all or almost all of the ideas marked with a + are present in a student's response, this may indicate that the student has mastered the science ideas and is able to use them in a written explanation or explanatory model.
- If the ideas marked with a ++ are present in a student's response, this indicates that the student is bringing a deeper understanding of the science ideas or a deeper engagement with the practice to their response. Students should not be marked off if ideas marked with a ++ are not present in their response.

Part 1: Explaining the Headlines and Elder Stories

Last class period, we investigated claims from headlines and an Alaskan whaler. Look back at your observation table from yesterday. Are these claims from the headline and the whaler related or unrelated? Are these headline claims and indigenous whaler claims also related to our other case sites? Answer the questions below to help determine if these changes are related, and what their potential cause could be.

Alaskan Headline Claims	Alaskan Whaler Claims
Alaska is experiencing bad wildfires. It is dry and hot in the arctic.	Older, multi-year ice is disappearing. There is less multi-year sea ice than before. There is more water where the sea ice should be.

Communicate Claims and Evidence	Your Explanation
What do you think is happening to cause the headline claims below: • Alaska is experiencing bad wildfires. • It is dry and hot in the arctic. How does the data from the last class period support your ideas?	*Student responses should include:* + Bigger and more frequent wildfires and the drought in Alaska are related to an increase in temperature and a decrease in precipitation. *Data to support the claim:* + The precipitation data graphs show precipitation is decreasing, which could be helping to dry out Alaska. + The temperature graphs show that the temperatures are increasing, making it warmer than before in Alaska. + The wildfires graph shows that the frequency and size of the wildfires is increasing. + The paragraph about wildfires says that they are more frequent. + The drought map shows that Alaska had lower-than-average rainfall during the time the headline was written. + As the temperature graphs increase, the precipitation graph decreases. + As the temperature graphs increase, the wildfire frequency and size also increase. + In 2019, when temperatures were higher than average, Alaska received less precipitation than normal. ++ The paragraph about wildfires says that the majority of wildfires are caused by lightning, and the precipitation could be changing to more thunderstorms than snowstorms, creating more lightning to start the wildfires.

What do you think is happening to cause the whaler claims below? • Older, multi-year ice is disappearing. • There is less sea ice than before. • There is more water where the sea ice should be. How does the data from last class period support your ideas?	*Student responses should include:* + The sea ice is decreasing in age and in amount over time. The increasing temperatures in Alaska are causing ice to melt away, and the sea ice cannot exist continually year after year to become multi-year ice. *Data to support the claim:* + The temperatures are increasing in Alaska, which could be melting the ice. + The sea ice graph shows that the amount of sea ice is going down. + Sea ice is decreasing in age. + As the temperatures increase on the temperature graph, the sea ice amount and sea ice age graphs decrease. ++ Most of the sea ice is now 0-1 years old, but about 30 years ago, most of the sea ice was over a year old.

Part 2: Explaining the Connection Between Wildfires, Sea Ice and Case Sites

The increasing wildfires and decreasing sea ice claims can appear to be very different phenomena. How might the loss in multi-year sea ice phenomenon be related to the wildfire phenomenon? Write a clear and convincing explanation to others to (1) explain how or why the disappearing sea ice is related to an increase in wildfires and (2) support how these are related with evidence.

Student responses should include:
+ The loss of sea ice and increase in wildfires are both related to each other by rising temperatures.

Student explanations on how the phenomena are related should include:
How or why this is connected:
+ Ice melts more with increasing temperatures.
+ The increasing temperatures make it to where there is less old sea ice every year, which decreases the amount of sea ice each year.
++ Note: Do not mark students down if they connect sea ice to lack of precipitation. While sea ice is formed by freezing in the upper layers of the ocean, this process was not investigated by students; therefore, it's possible that students will think sea ice forms due to precipitation. Focus your analysis on the connection students articulate between sea ice and temperature. Sea ice will be explored and the idea of formation will be clarified further in high school as they experience Performance Expectation HS-ESS2-4.

Wildfire connection to increasing temperatures:
+ Wildfires are occurring more frequently due to the land getting drier.
+ The drier land is a result of decreased precipitation.
+ The precipitation patterns are changing because of the increase in temperature.
+ The increase in temperature is also causing evaporation to happen at a higher rate, making the dry areas drier.
+ Because these events are all related to each other since they are caused by increasing temperatures, we can say that they are related or connected phenomena.

Student sources of evidence could include:
+ The temperature graph for Alaska is trending upward.
+ The precipitation graph is trending downward.
+ The map of Alaska shows that, during the reported wildfires, the state had lower than normal precipitation.
+ The sea ice amount graph shows a decreasing trend in the amount of sea ice each year.

+ The sea ice age graph shows a decreasing trend in the age of sea ice from year to year.

Do you think these changes are related to any of the changes we are seeing at our case sites? Use data from the graphs and any information from *Initial Water Story Explanation* to support your answer.
Student responses should include:
+ The Arctic phenomena and the case sites are all related to each other by rising temperatures.

Student explanations on how the phenomena are related should include:
+ Sea ice melts more with increasing temperatures. Sea ice and wildfires are caused by increasing temperatures.
+ Students should cite changes in precipitation that are occurring at their chosen case site and that those changes correspond with the increase in temperatures.
+ All the changes seen at the case sites and in Alaska are related by the increase in temperature.

Student sources of evidence could include:
+ All temperature graphs are trending upward.
+ The precipitation graph for each location and Alaska is changing.

Do you think these changes will continue to occur in the future? Use data from the graphs to support your answer.

Note that this question is meant to aid in navigation to the second lesson set. This question does not have to be formally assessed and is meant to get students thinking about whether the warming trends are going to continue, and what might be causing the increase in temperatures.

Student responses should include:
+ These changes could continue to occur in the future.

Students may use any of the data below to support their answer:
+ Temperatures are increasing and look like they will continue to increase in the future.
+ The sea ice is decreasing as temperatures rise. If temperatures continue to rise, more sea ice will melt.
+ The wildfires are increasing as temperatures rise. If temperatures continue to rise, more wildfires may happen.
+ The droughts are increasing as temperatures rise. If temperatures continue to rise, droughts could get worse.
+ The precipitation for all case sites is changing as temperatures rise. If the temperatures continue to rise, precipitation could keep changing.
+ If temperatures continue to rise, then the changes will continue to occur in the future.
++ Any connections between the 6 case sites studied in Lessons 1-5 and the Alaskan case site data trends.

Lesson 7 Teacher Reference

Exploring Possible Causes of Warming

Background

In pilot studies of Lesson 1, most students identified "pollution," "carbon dioxide," and "greenhouse gases" as the cause of temperature change. That is the reason Lesson 7 focuses directly on what's happening in the atmosphere. It is possible that your students may believe that the sun is getting warmer or closer to Earth or that warming temperatures are caused by the ozone hole. If your students identified these as possible warming mechanisms, it is important to explore them briefly to help students recognize that neither one is causing rising temperatures. Use the guidance below to adjust Lesson 7.

Time

This will add 1 instructional class period OR can be assigned for home learning or independent learning.

Materials and Advanced Preparation

Computer or device with access to the internet OR print as handouts

NASA Climate website Frequently Asked Questions

- *Is the sun causing global warming?* located at https://climate.nasa.gov/faq/14/is-the-sun-causing-global-warming/
- *Is the ozone hole causing climate change?* located at https://climate.nasa.gov/faq/15/is-the-ozone-hole-causing-climate-change/

The reading level of these short explanations may be higher than is accessible for some of your students. Below are options to make these articles more accessible:

- Make a handout using the text from these webpages. Modify the text to be more accessible by shortening sentences and replacing unnecessary vocabulary (e.g., replace "stratosphere" with "upper atmosphere" and replace "troposphere" with "lower atmosphere."
- Have students complete these readings in partners and discuss confusing sentences as they read.
- This site provides free readability testing and makes specific suggestions on how to change the text: https://rewordify.com/

Warning

Both texts "give away" some of the science that students will figure out in the rest of Lessons 7 and 8 - that greenhouse gases are causing the warmer temperatures. The mention of greenhouse gases in these articles are brief and the articles do not explain the mechanism for how greenhouse gases cause warming. If possible, try to avoid emphasizing these parts of the readings. If you make handouts, delete these references as they are not important.

Activity 1: Revisit Lesson 1 Initial Model (5 min)

Use students' initial models to focus them on different mechanisms they thought could be important to investigate.

Say, *At the start of the unit we brainstormed some different ideas that could be causing temperatures to go up. In this lesson, we'll investigate those different possible mechanisms.*

- Ask students who thought the sun may be causing warming to explain their thinking again.
- Repeat with students who thought it could be related to the ozone hole.

Say, *I found a resource from NASA where other people have asked NASA Scientists these same questions. We're going to read the scientists' responses and see if this can clarify the role of the Sun and the role of the ozone hole in these warming temperatures.*

Activity 2: Individual or Partner Reading (20 min)

Introduce students to the two texts that they will read.

- *Is the sun causing global warming?* located at https://climate.nasa.gov/faq/14/is-the-sun-causing-global-warming/
- *Is the ozone hole causing climate change?* located at https://climate.nasa.gov/faq/15/is-the-ozone-hole-causing-climate-change/

Set the purpose of the reading. Say, *We're trying to figure out if either one of these is causing a change in temperature or causing temperatures to go up. As we read, what should we pay attention to to help us answer our questions?*

Listen for students to suggest

- *If the scientists say whether that thing affects temperature on Earth.*
- *If the scientists say whether it is related or not related to the temperatures going up.*
- *If the scientists give evidence to support what they claim.*

Prepare students to read 1 of the 2 articles and get them started.

- Assign students to read individually or in partners.
- Have them read online or from a printed handout.
- Allow students to choose which one they want to read more about and why. Make sure that at least some students are reading each of the articles.
- Preview your class' close reading protocol with students and how you want them to annotate text.
- Give students up to 15 minutes to read.
- If students read individually, allow them time to discuss their ideas with a peer before whole group discussion.

Activity 3: Facilitate a Consensus Discussion and Update Model (15 min)

Facilitate a sharing of what was learned from each article.

Focus on one mechanism at a time. Allow several students or partners to share what they learned about the mechanism answering the following questions:

- Does it relate to temperature changes on Earth?
- Is it related to or causing temperatures to go up right now?
- What is the evidence to support the explanation?

Ask the students to co-construct a conclusion about the mechanism: Is it causing the temperature to go up? And how do we know? Have one student write down the class' conclusion on a sticky note and post it to the class' initial model from Lesson 1, where that mechanism was on the model.

Repeat for the second mechanism.

Answer questions on the DQB. Locate questions from the DQB that are related to these mechanisms. Have students discuss how they would now answer those questions. Place a check mark on them and/or move them to the location for answered questions.

Activity 4: Identify what other mechanisms remain (5 min)

Have students take another look at the remaining mechanisms on their initial consensus model. They can add new ones or clarify their thinking about the existing ones on the model.

Say, *It looks like the other possible mechanisms for warming we have relate to things that could be happening in the atmosphere. Let's investigate those in the next class period to see if changes in the atmosphere may be related to the rising temperatures.*

Lab Instructions for Comparing Frozen Carbonated with Non-Carbonated Water

**Note: This investigation uses materials that are included in prior 7th grade OpenSciEd units. The ice cube trays referred to here are the larger-sized ice cube trays used in *OpenSciEd Unit 7.1: How can we make something new that was not there before? (Bath Bombs Unit)*. The carbon dioxide detector is also used in both *OpenSciEd Unit 7.3: How do things inside our bodies work together to make us feel the way we do? (Inside Our Bodies Unit)* and *OpenSciEd Unit 7.4: Where does food come from, and where does it go next? (Maple Syrup Unit)*. If you are not teaching the OpenSciEd units according to the scope and sequence, you will need to make sure you have these materials.

Prior to class you will want to:

- Fill an ice cube tray filled with carbonated water and freeze it overnight.
- Fill an ice cube tray filled with non-carbonated water and freeze it overnight.
- Ensure that the carbon dioxide (CO_2) detector is in working condition.

ALTERNATE ACTIVITY

If you do not have a CO_2 detector but have Bromothymol blue (BTB), you can use this in place of the CO_2 detector, but you will need to run the experiment longer to get results. If using BTB, make a solution of diluted BTB by adding 5 mL of BTB (straight from the container) to a 250-400 mL beaker. Add water to the beaker until it reaches the 200 mL line. The BTB solution should appear lighter blue in color. If it does not, it is possibly over-contaminated with carbon dioxide, so pour it into a container and leave it open to the air so that the carbon dioxide can dissipate. ****Be sure to test a small sample of your tap water to make sure that no color change occurs. Some tap and bottled water have additional minerals in them that will change the color of the BTB. If this is the case, try changing your water source to using a different filtered or deionized water.*

On the day of the lab you will want the following supplies ready to use with the class:

- 2 1-gallon sized plastic baggies
- 3 ice cubes of carbonated water and 3 ice cubes of non-carbonated water
- heating pad that can be plugged in and that the class can gather around (see example to right)
- CO_2 detector

Use this video as an example of how to run this investigation: https://youtu.be/PQ3GNMTi_-4.

The instructions below are the steps to follow during the class discussion around whether gases can be trapped in ice. Turn the heating pad to high before beginning the discussion about this investigation.

You will want to do one of the types of ice cubes at a time so that the class can watch for any changes in the readings on the carbon dioxide detector. This will take a few minutes, so as the class watches, ask a few students to share what they notice happening. Once there is evident melting and reading fluctuations, the class can switch to collecting data for the other baggie. You do not need to wait until the ice cubes are fully melted.

1. Label one of the 1-gallon baggies “non-carbonated ice cubes.” Label the other 1-gallon baggie “carbonated ice cubes.”

2. Place 2 ice cubes of non-carbonated water in the baggie labeled “non-carbonated ice cubes” and be sure to seal it closed. Do not insert the CO_2 probe yet.

3. Place 2 ice cubes of carbonated water in the baggie labeled “carbonated ice cubes” and be sure to seal it closed. Do not insert the CO_2 probe yet.

4. Place both of the baggies on top of the heating pad and make sure that the heating pad is set to high and has been turned on before this discussion.

5. Wait 3-4 minutes. During these few minutes, have students share what they notice happening in the baggie.

6. After 3-4 minutes, make observations of the readings on the detector in the classroom. Then place the detector in the carbonated water baggie and watch it for 30 seconds to a minute. After this time, make observations of the reading. It may be helpful to ask a student to record it on a whiteboard or piece of paper to be able to refer to later if needed.

7. Next, remove the detector from this baggie and place it on the table in the classroom. Let the readings acclimate back to the classroom before placing the detector inside the second baggie. After about 3-4 minutes, the numbers should decrease and you can place it in the second baggie of non carbonated water. Then place this baggie on the heating pad. Watch the readings in the baggie again for 30 seconds to a minute. Record the carbon dioxide reading for this baggie.

8. Use the readings on the CO_2 detector to discuss whether gases can be trapped in ice.

Alternate investigation using BTB is included below. Use this video as an example of how to run this investigation: https://youtu.be/fogyXRAsdDE.
You will want to follow the directions below to set up one set of baggies ahead of time so that the ice cubes will have about an hour to melt and release any gas to interact with the BTB.

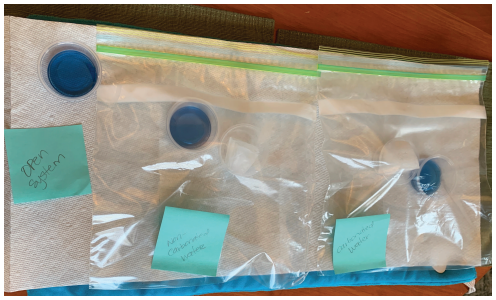
1. Label one of the 1-gallon baggies "non-carbonated ice cubes." Label the other 1-gallon baggie "carbonated ice cubes."

2. Place 2 ice cubes of non-carbonated water in the baggie labeled "non-carbonated ice cubes" and be sure to seal it closed. Insert 1 small cup of 10 mL of BTB solution into the bag.

3. Place 2 ice cubes of carbonated water in the baggie labeled "carbonated ice cubes" and be sure to seal it closed. Insert 1 small cup of 10 mL of BTB solution into the bag.

4. Place both of the baggies on top of the heating pad and make sure the pad is still set to high. If your heating pad is darker in color and/or blue in color, which might make it difficult to see the BTB in the small container, you might place a light colored paper towel on top of the heating pad so that the color of the BTB can be seen clearly.

5. Once the baggies are placed on the heating pad, it will take about an hour to see any changes. Have students share what they notice happening in the baggie. Set this aside and bring out the one that you set up ahead of time.



6. Make observations of color change in the one you set up ahead of time and use this to discuss whether gas can be trapped in ice.

Extension Opportunity with Tuva

If doing version 2 of the StoryMap with the embedded Tuva data set (located at https://arcg.is/18SHfO2), use the following guidelines to facilitate students through creating and analyzing the graphs.

Prepare to analyze data. Set the stage for analyzing long-term CO_2 data by saying, *We know these scientists are collecting all this data from the air bubbles trapped in the ice cores. What do we think they can learn from this data?* Let some students share their ideas, such as:

- What the air was made of at the time the air bubble was trapped in ice.
- How much CO_2 is in the air of the air bubble.

Prepare students to explore a Tuva dataset embedded at the end of the StoryMap at https://arcg.is/18SHfO2. The Tuva platform will allow students to create the graphs and analyze the trends. They can also manipulate the axes or annotate the graph as they want.

Use the following strategy to guide student creation and analysis of the graph, particularly focused on choosing independent and dependent variables, and then to guide observation and interpretation of the results. It might be helpful to build the graph together if this is your students' first time making line graphs. Conversely, if students have experience making graphs, consider removing this scaffold and allowing them to practice independently.

Decide which variable is on the *x*- and *y*-axes. Students worked with independent and dependent variables in both the *Cup Design Unit*, *Storms Unit*, and *Tsunami Unit*, so this might not be their first time considering which variable is independent or on the *x*-axis and which is dependent or on the *y*-axis.
Nevertheless, here is optional scaffolding to help create the graphs. For students who already understand independent and dependent variables, consider removing the scaffolds. For students who might struggle with this work, consider providing the prompts in science notebooks with two colors of highlighters or pencils so they can circle or highlight the *x*-axis variable in one color and the *y*-axis variable, as illustrated below.

- How do carbon dioxide levels (dependent variable on *y*-axis) vary over time (independent variable on *y*-axis)?

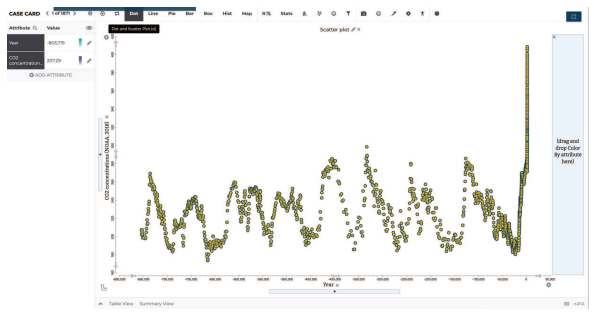
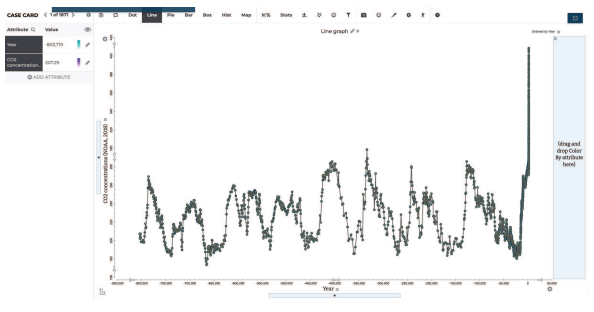
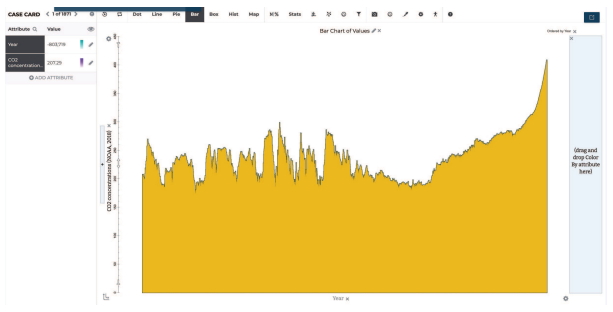
If students struggle with why time is the independent variable and carbon dioxide is dependent, ask the following questions:

- Which one can we change? (Carbon dioxide levels)
- Which one cannot we not control? (Time)

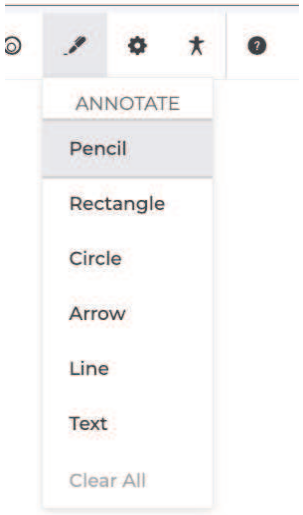
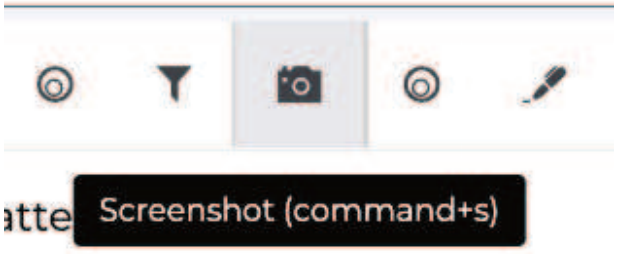
Say, *So "time" is independent because it will happen no matter what is going on. But "carbon dioxide levels" are dependent because they can change year to year.*

Create and analyze the graphs. Have students drag the variables to the *x*- and *y*-axes and then write down their noticings and wonderings in their science notebooks. Students can manipulate the Tuva graph to further explore the data by either changing the way it is represented or displayed (see next page for different examples).

Change the representation of the data.

Dot graph	Line Graph	Bar Chart (by value)
		

Interact with the graph.

Change the axis range	Annotate the graph	Take a screenshot to embed in a digital notebook
		

Lesson 10 Teacher Reference

Burning Fuels Instructions

Purpose of Demonstration

To give students convincing evidence that the products of a combustion reaction of fossil fuels are carbon dioxide and water.

The amount of evidence necessary to convince students that the combustion of many common fossil fuels produces the same two products—carbon dioxide and water—will vary. There are two examples in the teacher's guide and other options included here if your students need more evidence.

No-Flame Policy

If your school has a no-flame policy, use the *Burning Fuels Demonstration* video located here: https://youtu.be/gub7jM9B6O4, or pre-record your own video for students to make observations from.

SAFETY PRECAUTIONS

If you are able to do the demonstration in your classroom, follow these safety guidelines.
For the safety of the teacher and student volunteers

- move all flammable materials away from the demonstration area and
- tie back long hair, secure loose clothing, and remove dangling jewelry.

All students (even those just observing) and the teacher should wear safety goggles during the demonstration.

Preparation notes

Note: This demonstration uses materials that are included in prior 7th grade OpenSciEd units. The carbon dioxide detector and bromothymol blue (BTB) are used in both *OpenSciEd Unit 7.3: How do things inside our bodies work together to make us feel the way we do? (Inside Our Bodies Unit)* and *OpenSciEd Unit 7.4: Where does food come from, and where does it go next? (Maple Syrup Unit)*. If you are not teaching the OpenSciEd units according to the scope and sequence, you will need to make sure you have these materials.

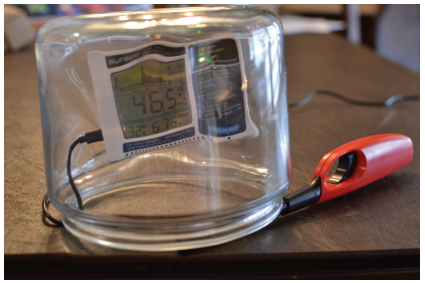
Prior to class

- Ensure that the carbon dioxide (CO_2) detector is in working condition.
- (Optional Alternate): Dilute BTB if you are using it. Gather 2 petri dishes.
  - The ratio of dilution for BTB is 5 mL of BTB in water to make 200 mL of solution. Add 5 mL of BTB to a graduated beaker and fill to the 200 mL mark with water.
- You may need to adjust the placement of the CO_2 detector, as water vapor will be produced during the reaction and can make it difficult to read the sensor based on placement.

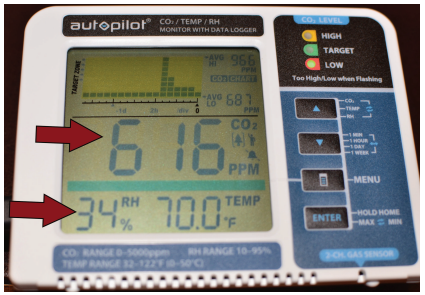
Setup for Class Demonstration 1 (Butane and CO_2 sensor)

Use the *Burning Fuels Setup* video located at https://youtu.be/pBZfrkwqX2w to guide you through the setup and demonstration. Watch it before you do the demonstration with your class. If your school has a no-flame policy, this is the video you will show instead of doing the demonstration. Students will still be able to make readings every 10 seconds but will make them from the video. The steps below are the same as what appears in the teacher's guide.

1. Place the CO2 humidity detector on a flat surface. Arrange the clear glass bowl (or inverted aquarium) and lighter as shown in the image to the right. In the set up shown, the CO2 detector is taped to the sides of the container.



2. Choose four student volunteers. Have them get ready to read off carbon dioxide and humidity values from the monitor every 10 seconds when you say "Go." The class can look for other changes in the system that might indicate changes in humidity levels. Have one person read off carbon dioxide readings, one person read off relative humidity readings, and one person say "Now" every 10 seconds. Alternatively, you can use a document projector so that all of the class can see the readings. Have another student record these on the board or on a piece of chart paper for the class to reference.



3. Light the butane lighter and hold the lighter so that the flame burns continuously. Ensure the flame does not burn the detector. (Note: The image below shows the flame very close to the detector but in reality there is about 3 inches between the flame and the detector.) Keep the flame going on the lighter for the duration of the readings. The bowl can rest on the lighter and you can allow the bowl to extend slightly over the edge of the table to allow more air to enter the system. This is not an airtight system, but you will get good results with this setup. Say, "Go." Now have students read off and record carbon dioxide readings every 10 seconds.

4. After about a minute, the carbon dioxide reading in the container will get above 4,000 ppm. This will be the last reading students will be able to report before the “high” warning light comes on.

Setup for Class Demonstration 1 (Butane and BTB)

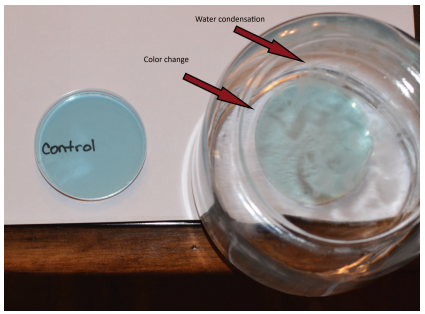
Prepare two dishes (a petri dish is good) of diluted BTB solution according to the instructions above.

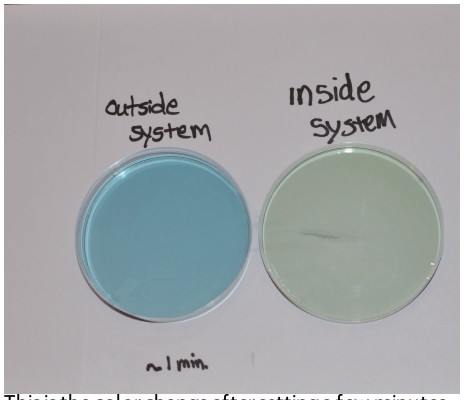
2. Place the dishes of diluted BTB on a flat surface. Place one dish outside of the system on white paper to use as a comparison. Mark this dish the control. The other dish will go under the clear bowl and also on white paper. Arrange the clear glass bowl and lighter as shown in the image to the right.

3. Choose three student volunteers. Have them get ready to describe any color change in the BTB every 10 seconds when you say “Go.” The class can look for other changes in the system that might indicate changes in humidity levels. Note: The dish of BTB placed outside of the system should be close to the bowl to use as a reference for color changes. Have one person describe color changes in the BTB, one person read off relative humidity readings, and one person say “Now” every 10 seconds. Alternatively, you can use a document projector so that all of the class can see color changes. Have another student record these on the board or on a piece of chart paper for the class to reference.

4. Light the butane lighter. Keep the flame going on the lighter for the duration of the observations. The bowl can rest on the lighter. You may want to let the bowl hang off the table slightly so that more air can enter the system. This is not an airtight system, but you will get good results with this setup. Say, “Go.” Now have students read off and record the color of the BTB every 10 seconds.

5. You will see color changes in the BTB solution after about 1 minute. Allow the flame to burn under the glass bowl until students are convinced that a color change has occurred. Once the flame has gone out (because of lack of oxygen), remove the lighter but leave the set up as is. The color of the BTB will continue to change as more CO2 is absorbed into the solution.

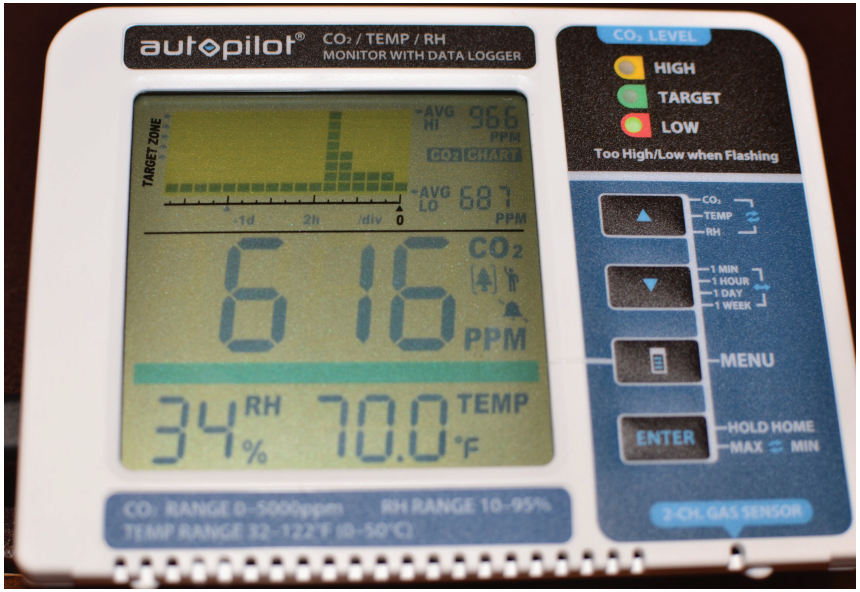




This is the color change after setting a few minutes once the flame has gone out. Swirl the dish to even out the color.

Setup for Class Demonstration 2 (Methanol fuel gel and CO_2 Sensor)

Fuel gel is made from various fuels—usually methanol or ethanol. Ethanol is most often made from plant-based biomass and is not made from fossil fuels. Methanol, however, is often made from fossil fuels. Be sure to use fuel gel made with methanol even though the products will be the same. Use the butane lighter to light the surface of the gel.

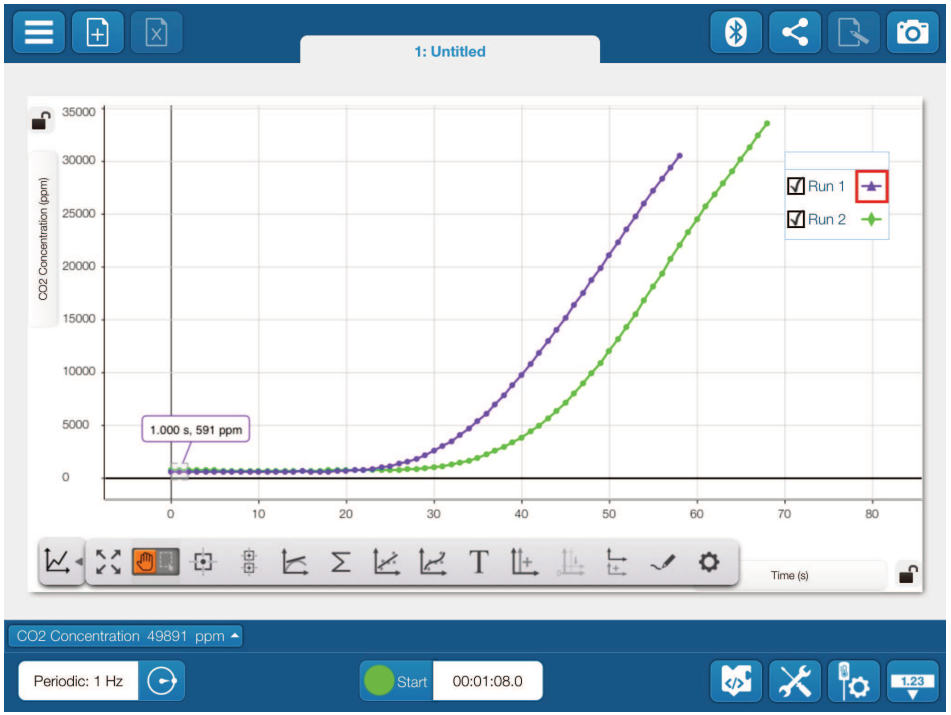


You will do this demonstration similar to the previous demonstration by replacing the butane lighter with the fuel gel. Rest the edge of the bowl on the neck of the lighter or another object to give a space between the glass bowl and the table. This will allow air to enter the system and keep the fuel gel ignited. Results with the fuel gel should give similar results to the butane lighter.

Additional Evidence

If students are not convinced that carbon dioxide and water are products of all fossil fuel combustion reactions after the two demonstrations and the molecular model activity, you may want to assign those students a fossil fuel and have them research the products of the combustion of the fuel. Use the fossil fuel examples on the handout, *Fuel Molecule Cards*. This can be a home learning assignment.

Additional Resources:

This is a set up using a butane lighter and a Pasco CO_2 sensor	This graph shows results of burning a butane lighter with a Pasco CO_2 sensor
	

Extension Opportunity: Uneven Distribution of Fossil Fuel Resources

About This Extension Opportunity

This extension is designed to explore the uneven distribution of fossil fuel resources that result from past geologic processes (MS-ESS3-1). The extension is designed to (1) allow students to connect to prior knowledge and experiences, (2) ask new questions which are added to the DQB, (3) investigate using illustrations and readings to make sense, and (4) broaden to related phenomena of uneven distribution of other resources.

If students have completed the *Everest Unit*, leverage their prior knowledge of tectonic forces throughout this lesson. This is a great opportunity to apply plate tectonic concepts in a new context. If students have not yet completed the unit, you may need to spend additional time eliciting initial ideas about tectonic forces, but use this lesson to generate curiosity about them for future learning. In this situation, students do not need to leave this lesson with all the 'answers' about tectonic forces so a target goal would be to heighten their curiosity.

Activity 1: Elicit prior knowledge and experiences of fossil fuels

Time

10 min

Materials per student

slides U-V
sticky notes and markers
Driving Question Board

Procedures

Elicit prior knowledge to expand on what we already know about fossil fuels. Display **slide U**. Elicit from students what they already know about how fossil fuels form, where they form, and their prior personal, family, or community experiences with them.

Suggested prompts	Sample student responses	Follow-up questions
What do we already know about how fossil fuels form?	They come from dead dinosaurs. They come from dead plants and animals. They are made from buried plant and animal matter that got turned into fuels.	*We know they have carbon in them, how do we think that carbon originally got into the fossil fuels?*

Suggested prompts	Sample student responses	Follow-up questions
What prior experiences do we have with fossil fuel industries in our communities or families?	My grandfather worked for an oil company. My uncle works on a ship that supplies oil rigs in the ocean. I've seen ships going in and out of the river carrying oil. Our town has a lot of natural gas wells in the area.	*Where did your grandfather work? Was it nearby us now or in another place?* *Why do we think there are so many oil rigs offshore in some places?* *Why does our town seem to have a lot of natural gas, but not coal?*

Pose the question, *Why do some places have these resources for mining or drilling, but not other places?* Listen for ideas like:

- *I'm not sure why some places have mining and others don't.*
- *I think it has to do where all the animals and plants died long ago.*

Add new questions to the DQB. Display **slide V**. Give students time to talk with a partner or group of 3 to add at least 1 new question to the DQB. When ready, have students share their question aloud as they post it to the DQB.

Say, *Let's dig into these questions further today and see if we can figure out _____ and _____ about fossil fuels.* (e.g., based on students' questions this could be how they form, where they form, why they don't form everywhere)

✱ ATTENDING TO EQUITY

Avoid villainizing or allowing students to villainize the fossil fuel industries. The fossil fuels industries have contributed to major societal advancements in the US and around the world. They employ over a million workers in the US (e.g., 600,000+ in the oil industry, close to 300,000 in the natural gas industry, and 75,000 in the coal industry). That's over a million people and their families whose livelihoods depend upon these industries. Countless families before them have worked in the industries too, many at great sacrifice. If this comes up in your classroom, refocus the conversation on the non-renewable nature of fossil fuels. They take millions of years to form and will not be available to us forever. Thus, motivating a need for innovation in our energy industry. People have always been innovative and will do so again for future energy needs, similar to the innovative people from the Industrial Revolution, who laid the groundwork for an energy system that each of us relies on today.

Activity 2: Examine and Discuss Illustrations

Time

15 min

Materials per student

slides W-X
1 copy of *Fossil Fuel Formation Illustrations* per student, printed double-sided to allow for student choice
dry erase board and markers to record class noticings

Procedures

Introduce students to illustrations of fossil fuel formation. Say, *I have some illustrations that show us more details about how fossil fuels form. We're going to examine these more closely. Based on your questions, what things might you look for in the illustrations to answer your questions?* Listen for:

- *How long they take to form.*
- *What they were before they were fossil fuels.*
- *How it happened over a long time.*
- *How they got buried and changed.*

Agree on how to annotate them. Display **slide W**. Elicit from students suggestions for how to annotate the illustrations (or preview with them how you want them to annotate the illustrations). Example strategies may include highlighting or circling key parts of the illustration that helps answer their question, putting a question mark near something they don't understand, putting a star by something they want to share aloud with the class, and underlining a key idea from the text.

Examine the illustrations. Pass out 1 copy of *Fossil Fuel Formation Illustrations*, which is a double-sided print of the illustrations. Allow students to choose the illustration they want to focus on most, either coal or oil and natural gas. There will not be enough time to do both. Give students about 5 minutes to individually, or in partners, examine the illustration and make annotations.

Facilitate a sharing of noticings to start answering our questions. Display **slide X.** Elicit from students things they noticed that help them answer the bigger question, *Why are fossil fuels in some places, but not other places?,* or things they noticed to answer their other questions posted to the DQB. Record noticings on the front dry erase board. If students answer a question, they can record the answer on their DQB sticky note question, too.

Suggested prompt	Sample student response
What did we notice about why some places may have fossil fuels resources and other places may not?	There had to be a swamp or ocean in the place long ago for there to be fossil fuels there now.
What other things did you notice that help to answer your question or other questions we posted?	Coal is mostly made from dead plant matter, but oil and natural gas seems to come from plants and tiny organisms. We really didn't see dinosaurs in the illustrations. These fossil fuels are 60 million years old. They got buried under stuff. Heat and pressure turned them from plants to fossil fuels.

Elicit new questions to motivate needing more information. Ask students what new questions came up for them as they looked at the illustrations. Listen for students to share:

- confusion about the layers and how so many layers got there and where they went.
- why the climate was different long ago.

Say, *I have some readings that may help us. Keep these new questions in mind, and the ones we already posted to the DQB, as we read to help us focus on the information we need when we read.*

Activity 3: Read and Discuss Fossil Fuel Formation

Time
20-25 min

Materials per student
slides Y-Z
1 copy of 1 of the readings from *Fossil Fuels Long Ago and Today* per student. There are 3 readings in the same document. Print double-sided. Have enough copies of each of the 3 readings to allow for student choice. Each student needs 1 of the 3 readings. Students can choose to read about coal, natural gas, or oil.
highlighter (optional)

Procedures

Preview the purpose of the activity to obtain more information. Introduce the readings and discuss reading strategies that they know about and elicit from students which strategies they want to use now. Agree on the strategies that could be helpful and how to annotate the text.

Allow students to choose the text they want to read. Then arrange students into groups of 2–3 where there is a mix of readings across the group members.

Display **slide Y** as a reminder of the activity. The guiding questions should be, *Why are fossil fuels in some places, but not other places?* and other questions posted to the DQB.

Read individually. Give students about 5–7 minutes to read the text on their own.

Share in small groups. With the remaining time, prompt students to share what they read about and compare the different fuels to see if they have more information now to answer the questions they are investigating. Remind students to reference the text to support their answers.

Convene as a whole group to discuss what we can answer about questions now. Display **slide Z.**

Suggested prompt	Sample student response
Why are fossil fuels in some places, but not other places?	The readings confirmed that there had to be swamps, marshes, or shallow seas in the place long ago in order to have fossil fuels there now. And that over time the plants were buried in layers and sometimes lifted up by tectonic forces.
What information did we find out to help us answer our other questions?	Some coal was formed 300 million years ago, some is younger at 60 million years. But all of them take millions of years to form. Heat and pressure helped the fuels turn from plant and animal matter into fuels. Some fuels form together, like natural gas and oil. Some fuels are near the surface and some we have to drill deep for the fuel.

Activity 4: Broaden to related phenomena

Time
10 min

Materials per student
slides AA-AB

Procedures

Elicit students' ideas about other Earth resources that may be special to some locations and not others. Display **slide AA**. Give students time to turn and talk about the questions on the slide. Then bring students back together to share their initial ideas. Listen for students to share ideas about:

- Freshwater resources
- Other mineral resources, like gold, copper, turquoise, diamonds and other precious stones, special rocks, like granite, sandstone, etc.
- Timber resources

Make a plan for additional investigation. Display slide **AB**. Elicit ideas from students about further investigation and provide guidance on how to complete independent research products and what students can bring back to share with the whole class on their projects. If students choose to complete independent research, make sure the class agrees on a question or set of questions they are trying to figure out, therefore providing helpful focus for student investigations.

Lesson 11 Teacher Reference

Carbon Dice Game Instructions and Station Cards

Guidance

Prior to the lesson:

- Decide where each "location" of carbon will be located in the classroom. These are the stations that students will rotate to. Assuming that the fossil fuel reservoir will be the largest reservoir, consider having students remain at their desk if they are in the fossil fuel reservoir to start.
- Tape the station cards in the appropriate location or have tape on hand to tape the station cards when you give instructions to students.

During the lesson:

- Provide each student with their own dice. In addition to the dice, provide each student with a Quick Reference Card as needed, which is included at the end of this document.
- Give students instructions about how they will roll their own dice and move within the carbon system according to the number rolled. Each station will have guidance on where to move next based on the roll of their dice.
- This version of the dice game is designed to be a quick, whole-group activity with no recording of data or information, but rather focusing students on observations of where carbon atoms are flowing in and out of the system components (or carbon reservoirs). If you choose to add a more structured activity for students to record their experience, consider having students record:
    - tally marks on a sheet of paper at each location and/or
    - their movement through the reservoirs (e.g., starting location, next location, next location, and so on).
- Arrange students in their starting location following the breakdown below. Have students in the fossil fuel reservoir remain in their seats.

Starting Location	Amount of carbon in gigatons	Percent of students starting in this location	Number of students for class size of 30	Number of students for class size of 20
Atmosphere	750-800	15%	5	4
Land plants and animals	600-650	10-15%	4	3
Soil and decomposers	1500-1600	30%	9	5-6
Fossil fuels	2,000* (lowest possible recoverable estimates)	40%	12	8
Totals	~5000	~100%	30	20-21

Start the game

- Begin the first round. Roughly about ⅔ of the class will be actively moving through the system, while the other third will be "locked" in the fossil fuel location.
- Have students complete roughly 10-15 rolls and pause to facilitate discussion throughout.

Modify the game to include combustion of fossil fuels

- Begin the second round. Introduce the change to the system: combustion of fossil fuels. Now the students who began in the fossil fuel location are "unlocked" and can roll their way into the system.
- Allow students 5-6 minutes to roll their dice and move through the system. Pause as needed when you start to notice a buildup in any of the locations or a depletion in a location, such as fossil fuels.
- If you need to adjust the game, "reset" the students to the starting locations and make adjustments. If you do this, take a minute to share how this simulation of the system is based on "chance" with the roll of the dice. In the real world, the system is much more predictable.

ALTERNATE ACTIVITY

If you want to include oceans: This activity is inspired by other versions of the activity developed and used by Project Wet. The original activity includes surface and deep ocean reservoirs, so if your model includes these reservoirs, consult the original activity and modify the stations and dice roll directions as needed. You can locate the original activity at the following website: *The Carbon Cycle Game*: https://tinyurl.com/CCgame.

If you are in social distancing: The CarbonTIME project from Michigan State University offers a Tiny World activity that is done individually with "counters" and a follow-up simulation.

- Website: CarbonTIME Fossil Fuels and Carbon Pools: https://carbontime.create4stem.msu.edu/human-energy-systems/lesson-4
  - Tiny World Modeling Activity 4.3 is an individual counter activity that simulates the flow of carbon atoms. Modify this activity to exclude the seasonal variation. Complete Scenarios #1 and #3.
  - Global Computer Model Activity 4.4 is a computer model based on the Tiny World counter activity. Consider using this after the counter activity to facilitate a discussion of the flow of carbon through components and processes before and after combustion is added to the system.

If you are in remote learning: The Digital Dice Game is provided as an option with an interactive dice and gameboard using Google Sheets.

Atmosphere

Number on Dice	What to do
1	**Stay in the atmosphere**. Carbon dioxide can stay in the atmosphere for as little as 30 years or up to thousands of years.
2	**Stay in the atmosphere**. Carbon dioxide can stay in the atmosphere for as little as 30 years or up to thousands of years.
3	**Stay in the atmosphere**. Carbon dioxide can stay in the atmosphere for as little as 30 years or up to thousands of years.
4	**Stay in the atmosphere**. Carbon dioxide can stay in the atmosphere for as little as 30 years or up to thousands of years.
5	**Go to the plant and animal reservoir.** You are used by a plant in photosynthesis and may be eaten by an animal.
6	**Go to the plant and animal reservoir.** You are used by a plant in photosynthesis and may be eaten by an animal.

Plants & Animals

Number on Dice	What to do
1	**Stay in the plant and animal reservoir**. You become part of a plant as it grows.
2	**Stay in the plant and animal reservoir**. You become part of a plant as it grows.
3	**Stay in the plant and animal reservoir.** You are eaten by an animal and become part of an animal.
4	**Stay in the plant and animal reservoir.** You are eaten by an animal and become part of an animal.
5	**Go to the atmosphere**. A plant or animal reacts you with oxygen for energy and gives you off as a CO_2 molecule back to the atmosphere.
6	**Go to the soil reservoir.** You are a dead plant or animal that has started to decompose.

Soil & Decomposers

Number on Dice	What to do
1	**Stay in the soil reservoir**. You are decomposed and become carbon in the soil.
2	**Stay in the soil reservoir**. You are decomposed and become carbon in the soil.
3	**Stay in the soil reservoir**. You are decomposed and become carbon in the soil.
4	**Stay in the soil reservoir**. You are decomposed and become carbon in the soil.
5	**Go to the atmosphere**. A decomposer reacts you with oxygen for energy and gives you off as a CO_2 molecule back to the atmosphere.
6	**Go to the atmosphere**. A decomposer reacts you with oxygen for energy and gives you off as a CO_2 molecule back to the atmosphere.

Fossil Fuels

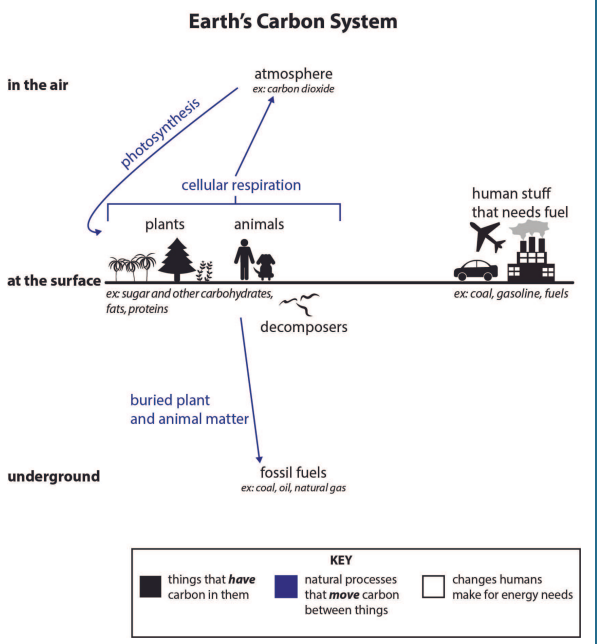
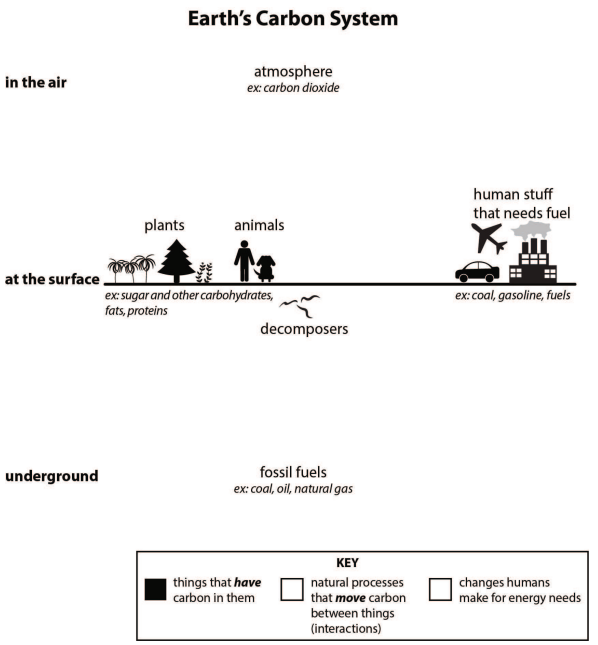
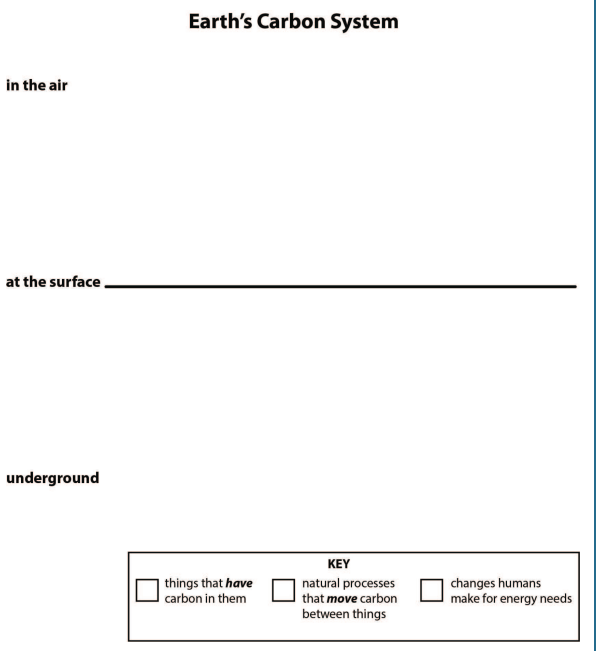
Number on Dice	What to do
1	**Stay in the fossil fuels reservoir**. You are ancient plant and animal matter trapped underground.
2	**Stay in the fossil fuels reservoir**. You are ancient plant and animal matter trapped underground.
3	**Stay in the fossil fuels reservoir**. You are ancient plant and animal matter trapped underground.
4	**Stay in the fossil fuels reservoir**. You are ancient plant and animal matter trapped underground.
5	**Go to the atmosphere**. A person reacts you with oxygen for energy and gives you off as a CO_2 molecule back to the atmosphere.
6	**Go to the atmosphere**. A person reacts you with oxygen for energy and gives you off as a CO_2 molecule back to the atmosphere.

Quick Reference Cards

Atmosphere	Plants and Animals
1. **Stay in the atmosphere**. Carbon dioxide can stay in the atmosphere for as little as 30 years or up to thousands of years. 2. **Stay in the atmosphere**. 3. **Stay in the atmosphere**. 4. **Stay in the atmosphere**. 5. **Go to the plant and animal reservoir.** You are used by a plant in photosynthesis and may be eaten by an animal. 6. **Go to the plant and animal reservoir.**	1. **Stay in the plant and animal reservoir**. You become part of a plant as it grows. 2. **Stay in the plant and animal reservoir**. You become part of a plant as it grows. 3. **Stay in the plant and animal reservoir.** You are eaten by an animal and become part of an animal. 4. **Stay in the plant and animal reservoir.** You are eaten by an animal and become part of an animal. 5. **Go to the atmosphere**. A plant or animal reacts you with oxygen for energy and gives you off as a CO_2 molecule back to the atmosphere. 6. **Go to the soil reservoir.** You are a dead plant or animal that has started to decompose.
Fossil Fuels	**Soil and Decomposers**
1. **Stay in the fossil fuels reservoir**. You are ancient plant and animal matter trapped underground. 2. **Stay in the fossil fuels reservoir**. 3. **Stay in the fossil fuels reservoir**. 4. **Stay in the fossil fuels reservoir**. 5. **Go to the atmosphere**. A person reacts you with oxygen for energy and gives you off as a CO_2 molecule back to the atmosphere. 6. **Go to the atmosphere**.	1. **Stay in the soil reservoir**. You are decomposed and become carbon in the soil. 2. **Stay in the soil reservoir**. 3. **Stay in the soil reservoir**. 4. **Stay in the soil reservoir**. 5. **Go to the atmosphere**. A decomposer reacts you with oxygen for energy and gives you off as a CO_2 molecule back to the atmosphere. 6. **Go to the atmosphere**.

Guidance on Carbon System Model Templates

Earth's Carbon System Model handout: The goal in this lesson is for students to *use* the carbon system model to make sense of CO_2 increasing, or building up, in the atmosphere. Depending on your students' prior experiences with the OpenSciEd 7th grade scope and sequence, they may be better positioned to develop the model first and then use their model, or to modify the model using a template that is already populated with parts of the system. You will need to determine where to start the modeling work and how much scaffolding your students need with developing and/or using the model.

Option 1: My students have prior knowledge of carbon cycle processes, but we will need to spend time orienting ourselves to a large-scale model.	Option 2: My students know a lot about carbon cycle processes but I want to give them a scaffold to start their model.	Option 3: My students know a lot about carbon cycle processes, and I want them to develop the model using a mostly blank template.
		

Print the carbon system model handout option that is right for your students. We recommend Option 1 for time efficiency and Option 2 or 3 for a more complete modeling activity. Make a class size version of the carbon system model you choose on chart paper. This model will be used again in later lessons.

Lesson 12 Teacher Reference

Model Ideas List

The combined lists of model ideas can be found below. Each model idea has been numbered so that it can be easily referenced.

Idea #	Combined Model Ideas List
1	
2	
3	
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Lesson 12: Answer Key

Tweet Claims Assessment Key

Allow your students to choose the modality for communicating their thinking. Offer oral administration to those students who would benefit from this modality. Guidance is provided depending on tweet options provided to students.

This assessment can be used to assess student progress on the LLPE. This LLPE is an integration of elements from the three dimensions.

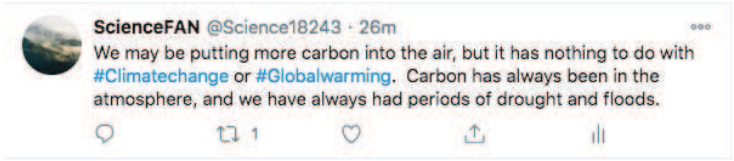
12.B Construct an argument supported by science ideas to refute and clarify claims through an explanation of the causal chain of events between the changing climate and water resources.

SEPs	DCIs	CCCs
7.3 Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. Students work individually, in small groups, and as a class to construct a diagrammatic representation of how fossil fuels lead to changes in water resources. This knowledge is used to dissect a tweet as a class and determine claims being made by the author. The class works to create an oral and written argument (written down by the teacher) to refute inaccurate claims and provide clarifying explanations. During this assessment task, students use their knowledge of identifying claims to dissect a tweet and identify claims that are supported and refuted by the science ideas they have figured out. Students work to craft an argument to refute the claims by crafting an explanation of the inaccuracies made within the claim. Students also have the option of completing this assessment orally. Look for how students use evidence and science ideas to refute the claims that are not supported. Students should be able to clearly trace their argument to the science ideas from our Model Ideas list. Students may also bring in ideas from the first lesson set or other units to expand upon their reasoning that may or may not be included in the Model Ideas list. These ideas have been identified by a double plus sign below.	**ESS2.D** ~~Weather and~~ climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ~~ice, landforms, and living things.~~ These interactions vary with ~~latitude, altitude, and~~ local and regional geography, all of which can affect oceanic and atmospheric flow patterns. **ESS3.D** Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). ~~Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding human behavior and applying that knowledge wisely in decisions and activities~~. (MS-ESS3-5) **ESS3.C** Typically, as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth, ~~unless the activities and technologies involved are engineered otherwise~~. (MS-ESS3-3), (MS-ESS3-4) Students should use their understanding of Earth's carbon system and its effects on the water system to complete this assessment. Students should identify that the release of carbon dioxide (greenhouse gas) from human activities, such as the burning of fossil fuels (combustion), leads to increases in temperatures in the atmosphere by increasing greenhouse gases that absorb and re-emit energy in the atmosphere. This increase in temperature has ripple effects on the processes of evaporation, atmospheric flow patterns, and precipitation over various land forms and types. Students should identify that this trend has emerged with the use of fossil fuels and that the carbon dioxide imbalance will increase with consumption. Students should use these ideas to identify claims that need refuting and to explain the needed clarifications to each claim.	**2.1** Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. In this assessment, students use their science ideas to refute claims that do not scientifically explain the causal relationship between human activities, the increase in carbon dioxide, the increase in temperatures, and changing climate. Students should make clear in their clarifications and explanations that human activities that release greenhouse gases are causing changes in our climate, and these changes are negatively affecting communities. Students should communicate these ideas specifically on the last question of this assessment, in writing explanations to clarify the inaccurate claims.

The scoring guidance provided below uses a + and ++ notation that can help you identify different ideas that students should (or could) include in their responses.

- If several of the ideas marked with a + are missing from a student's response, this may indicate that the student has not mastered the science ideas or that the student may be struggling to bring those ideas together in a written explanation or model. Additional probing of their thinking can provide insight about whether the student is struggling with a science practice or science idea or both.
- If all or almost all of the ideas marked with a + are present in a student's response, this may indicate that the student has mastered the science ideas and is able to use them in a written explanation or explanatory model.
- If the ideas marked with a ++ are present in a student's response, this indicates that the student is bringing a deeper understanding of the science ideas or a deeper engagement with the practice to their response. Students should not be marked off if ideas marked with a ++ are not present in their response.

Version 1: Social Media Post Assessment Key



Read the tweet above. Identify the claims in the tweet and record them in the space below.
+ We are putting more carbon dioxide into the air.
+ Carbon dioxide has nothing to do with climate change.
+ Carbon dioxide has nothing to do with global warming (this may be combined with the statement above).
+ Carbon dioxide has always been in our atmosphere.
+ We have always had periods of droughts and floods.

Read the claims you have identified. What claims match our science ideas?
+ We are putting more carbon dioxide into the air.
+ We have always had periods of droughts and floods. (Note that this is true but is misleading as written. Do not count off if this claim is not listed in this section. While this claim could fall under this section of claims that match our science ideas, it should be identified by students in the next section of the assessment that asks for additional explanation or clarification.)

What claims **do not** match our science ideas and/or need to be explained or clarified?
+ Carbon dioxide has nothing to do with climate change.
+ Carbon dioxide has nothing to do with global warming (this may be combined with the statement above).
+ Carbon dioxide has always been in our atmosphere.
+ We have always had periods of droughts and floods.

Start by picking 2 claims from the list you created that **do not** match our science ideas and/or need to be explained or clarified. Rewrite the ones you pick below.
+ Students should identify 2 claims from the above section.

Rewrite each claim that you have chosen so that they are scientifically accurate.
Each original claim identified above has been rewritten to reflect a version of the claim that is scientifically accurate. Students may phrase these ideas in different ways and should be counted correct if they contain the same general ideas.

+ Carbon dioxide has nothing to do with climate change.
    + *Should be changed to:* Carbon dioxide is causing climate change *OR* Carbon dioxide is causing global warming, which causes climate change.

+ Carbon dioxide has nothing to do with global warming.
    + *Should be changed to:* Carbon dioxide is causing global warming.

+ Carbon dioxide has always been in our atmosphere.
    + *Should be changed to:* Carbon dioxide has always been in our atmosphere, and we have caused it to increase at a rate that is causing climate change.

+ We have always had periods of droughts and floods.
    + *Should be changed to:* We have always had periods of droughts and floods, but the frequency, intensity, and severity of the droughts and floods are being worsened by climate change.

Look at your rewritten scientifically accurate claims. What evidence or model ideas do we have to support why these newly rewritten claims are more accurate than the original claim?

Each original claim has been broken down individually to show matching supporting evidence and science ideas below.

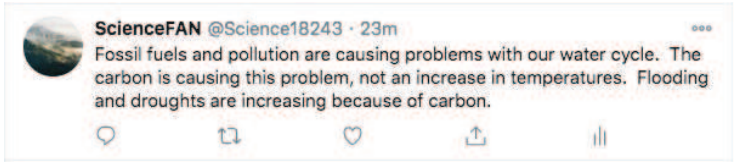
+ Carbon dioxide has nothing to do with climate change.
    + Carbon dioxide traps energy and causes an increase in temperatures on average known as global warming.
    + Weather changes daily, while climate is a measure of average conditions over time. Climate change is the change in climate we are seeing due to the increase in temperatures.
    + The increase in temperatures causes evaporation rates to increase.
    + The extra evaporation dries some areas out more and causes droughts.
    + The dry areas get drier because they experience a decrease in precipitation due to increased temperatures.
    + The extra water moves to places that normally receive this water, and they get more precipitation than normal causing floods.
    + Because of the increase in temperatures, we are getting more frequent and intense floods and more droughts than before we added extra carbon dioxide to the atmosphere.
    + Climate has had minor changes over time, which we see from our ice core data, but the changes in climate we are experiencing now are occurring at much faster and more dramatic rates than what has happened in the past.

+ Carbon dioxide has nothing to do with global warming.
    + Carbon dioxide traps energy and causes an increase in temperatures on average known as global warming.

+ Carbon dioxide has always been in our atmosphere.
    + Carbon dioxide has had minor changes over time, which we see from our ice core data, but what we are experiencing now is a much faster and dramatic change than what has happened in the past.

+ We have always had periods of droughts and floods.
    + The increase in temperatures causes evaporation rates to increase.
    + The extra evaporation dries some areas out more and causes droughts.
    + The dry areas get drier because they experience a decrease in precipitation due to increased temperatures.
    + The extra water moves to places that normally receive this water, and they get more precipitation than normal causing floods.
    + Because of the increase in temperatures, we are getting more frequent and intense floods and more droughts than before we added extra carbon dioxide to the atmosphere.

Version 2: Social Media Post Assessment Key



Read the tweet above. Identify the claims in the tweet and record them in the space below.
+ Fossil fuels and pollution are causing water cycle problems.
+ Carbon dioxide is the problem.
+ The increase in temperatures is not a problem.
+ Flooding and droughts are increasing because of carbon dioxide.

Read the claims you have identified. What claims match our science ideas?
+ Carbon dioxide is the problem.
+ Flooding and droughts are increasing because of carbon dioxide.

What claims **do not** match our science ideas and/or need to be explained or clarified?
+ Fossil fuels and pollution are causing water cycle problems.
+ The increase in temperatures is not a problem.
++ Flooding and droughts are increasing because of carbon dioxide. (This claim is only accepted for this clarification box if students claim that the carbon dioxide is increasing in the argument below. Recognizing that carbon dioxide has always been in the atmosphere may be a higher level connection than just stating carbon dioxide is a problem.)

Start by picking 2 claims from the list you created that **do not** match our science ideas and/or need to be explained or clarified. Rewrite the ones you pick below.
+ Students should identify 2 claims from the above section.

Rewrite each claim you have chosen so that they are scientifically accurate.
Each original claim identified above has been rewritten to reflect a version of the claim that is scientifically accurate. Students may phrase these ideas in different ways and should be counted correct if they contain the same general ideas.
+ Fossil fuels and pollution are causing water cycle problems.
    + *Should be changed to:* The pollution of the atmosphere from carbon dioxide caused by the burning of fossil fuels causes water cycle problems.

+ The increase in temperatures is not a problem.
    + *Should be changed to:* The increase in temperatures is a problem for our carbon system and our water system.

+ Flooding and droughts are increasing because of carbon dioxide.
    + *Should be changed to:* Flooding and droughts are increasing because of global warming due to the increased carbon dioxide in the atmosphere.

Look at your rewritten scientifically accurate claims. What evidence or model ideas do we have to support why these newly rewritten claims are more accurate than the original claim?
Each original claim has been broken down individually to show matching supporting evidence and science ideas below.
+ Fossil fuels and pollution are causing water cycle problems.
    + Fossil fuels emit carbon dioxide during combustion. The pollution is the carbon dioxide that is being added to the atmosphere.
    + The water cycle problems are caused by an increase in temperatures.
    + Carbon dioxide traps energy and causes an increase in temperatures on average known as global warming.
    + The increase in temperatures causes evaporation rates to increase.
    + The extra evaporation dries some areas out more and causes more frequent and intense droughts.

+ The dry areas get drier because they experience a decrease in precipitation due to increased temperatures.
+ The extra water moves to places that normally receive this water, and they get more frequent and intense precipitation than normal, causing floods.

+ The increase in temperatures is not a problem.
+ The increase in temperatures causes evaporation rates to increase.
+ The extra evaporation dries some areas out more and causes more frequent and intense droughts.
+ The dry areas get drier because they experience a decrease in precipitation due to increased temperatures.
+ The extra water moves to places that normally receive this water, and they get more frequent and intense precipitation than normal, causing floods.
+ Increases in temperatures cause problematic changes to the water system.

+ Flooding and droughts are increasing because of carbon dioxide.
+ Carbon dioxide existed in the atmosphere long before humans started to add extra amounts of carbon dioxide to the atmosphere. Floods and droughts are increasing because there is an increase in the carbon dioxide in the atmosphere.
+ Carbon dioxide traps energy and causes an increase in temperatures on average known as global warming.
+ The increase in temperatures causes evaporation rates to increase.
+ The extra evaporation dries some areas out more and causes more frequent and intense droughts.
+ The dry areas get drier because they experience a decrease in precipitation due to increased temperatures.
+ The extra water moves to places that normally receive this water, and they get more frequent and intense precipitation than normal, causing floods.

Alternate Tweet Key

This tweet is an alternate tweet that could be used if a third option is needed. This tweet could be used for future reassessment or as an alternate to the *Version 1: Social Media Post Assessment* tweet if it is preferred by students. Note that, if this tweet is used, the tweet will need to be added to an assessment handout for student use.

Read the tweet above. Identify the claims in the tweet and record them in the space below.
+ Climate change is not a big deal.
+ Climate will eventually balance out.
+ The trees will pull the carbon dioxide out of the atmosphere.
+ The frequency and severity of droughts is starting to decrease.
+ Carbon dioxide helps to stabilize temperatures.

Read the claims you have identified. What claims match our science ideas?
+ None

What claims **do not** match our science ideas and/or need to be explained or clarified?
+ Climate change is not a big deal.
+ Climate will eventually balance out.
+ The trees will pull the carbon dioxide out of the atmosphere.
+ The frequency and severity of droughts is starting to decrease.
+ Carbon dioxide helps to stabilize temperatures.

Start by picking 2 claims from the list you created that **do not** match our science ideas and/or need to be explained or clarified. Rewrite the ones you pick below.
+ Students should identify 2 claims from the above section.

Rewrite each claim that you have chosen so that they are scientifically accurate.
Each original claim identified above has been rewritten to reflect a version of the claim that is scientifically accurate. Students may phrase these ideas in different ways and should be counted correct if they contain the same general ideas.
+ Climate change is not a big deal.
    + *Should be changed to:* Climate change is causing large problems with our water cycle.

+ Climate will eventually balance out.
    + *Should be changed to:* Climate change will continue to get worse unless we change our combustion habits.

+ The trees will pull the carbon dioxide out of the atmosphere.
    + *Should be changed to:* Trees pull carbon dioxide out of the atmosphere, but the photosynthesis rate is much lower than the rate of respiration and combustion.

+ The frequency and severity of droughts is starting to decrease.
    + *Should be changed to:* Droughts and floods are increasing in intensity, frequency, and severity.

+ Carbon dioxide helps to stabilize temperatures.
    + *Should be changed to:* Carbon dioxide is causing an increase in global temperature.

Look at your rewritten scientifically accurate claims. What evidence or model ideas do we have to support why these newly rewritten claims are more accurate than the original claim?

Each original claim has been broken down individually to show matching supporting evidence and science ideas below.

+ Climate change is not a big deal.
    + Climate change is a big deal because it is affecting many lives negatively.
    + Data from our past lessons show that there is an increase in droughts and floods frequency, intensity, and severity that is affecting cities everywhere.
    + The increase in temperatures causes evaporation rates to increase.
    + The extra evaporation dries some areas out more and causes more frequent and intense droughts.
    + The dry areas get drier because they experience a decrease in precipitation due to increased temperatures.
    + The extra water moves to places that normally receive this water, and they get more frequent and intense precipitation than normal, causing floods.

+ Climate will eventually balance out.
    + The climate will not eventually balance out.
    + According to our Carbon System Model, the trees cannot pull that much carbon dioxide out of the atmosphere. We are adding carbon dioxide at a much higher rate than the trees are absorbing it.
    + Our combustion of carbon dioxide is adding more than the natural system can balance out.

+ The trees will pull the carbon dioxide out of the atmosphere.
    + According to our carbon system model, the trees cannot pull that much carbon dioxide out of the atmosphere. We are adding carbon dioxide at a much higher rate than the trees are absorbing it.

+ The frequency and severity of droughts is starting to decrease.
    + The increase in temperatures causes evaporation rates to increase.
    + The extra evaporation dries some areas out more and causes more frequent and intense droughts.
    + The dry areas get drier because they experience a decrease in precipitation due to increased temperatures.
    + The extra water moves to places that normally receive this water, and they get more frequent and intense precipitation than normal, causing floods.

+ Carbon dioxide helps to stabilize temperatures.
    + Carbon dioxide traps energy and causes an increase in temperatures on average known as global warming.

Information for Carbon Solution Cards

In this lesson students are presented with information regarding different atmospheric carbon solutions. Each solution lists a percentage of carbon that the solution would potentially impact each year when the solution is put into practice.

The information on many solutions were found on Project Drawdown Table of Solutions located at https://www.drawdown.org/solutions/table-of-solutions. The results were pulled from the estimate of impact of the solution over the next 30 years (years 2020-2050), or Scenario 1, in the Table of Solutions. Scenario 1 was utilized because this scenario is based off of a 2-degree Celsius change in temperatures by 2100, the same amount used by the UCAR simulation's recommended temperature limit earlier in Lesson 12.

It is important to remember that students have an initial goal of reaching the equilibrium point, which is reducing the carbon emissions or increasing carbon uptake by 9 gigatons of carbon per year at the 2015 levels. To develop the level of impact of each solution per year in gigatons, this impact number had to be divided by 30, then divided by the 9 gigatons each year that we are emitting (based on the 2015 data) to determine the percentage of change each year for that solution.

How solution percentages are calculated

This solution percentage was calculated for each solution by using the following formula:

If using numbers found on a website that lists amount of carbon the solution can decrease per year:

(# of gigatons of carbon the solution would reduce per year) ÷ 9 gigatons = answer × 100 = Percent of carbon the solution would mitigate in gigatons per year.

If using data from project drawdown Table of Solutions Scenario 1:

((# of gigatons listed in scenario 1 ÷ 30) ÷ 9 gigatons) = answer × 100 = Percent of carbon the solution would mitigate in gigatons per year.

Many other carbon solutions are available from Project Drawdown that might be of interest to students. When a solution is clicked on, this will go to a page with a larger description. Make sure to read the impact section on the left-hand side of the screen, as this gives clarification on the actions that society would need to take to reach that level of reduction in atmospheric carbon dioxide. The technical summary also goes more in depth and provides detailed information about that lifestyle change.

How to create your own solution cards

Students may show interest in other solutions that are not in this solution card set. If you choose to add a solution to the card deck from either Project Drawdown or another source, the following information would need to be added to the solution card, along with a descriptive photo:

- *What is this solution?*
    - 1-2 sentences explaining what the solution is and how it works.
    - If it is in use or experimental at this point, along with availability to the broader audience (if it is not available, when it could be available).
- *What would we have to do?*
    - 2-3 bulleted points about how the solution could be implemented.
- *How would this affect people?*
    - Cost of the solution
    - Ease of use
    - Impact on jobs (if any)
    - Aesthetic concerns (if any)
- *How would this affect the environment?*
    - Environmental Information
    - Where the solution can be used and implemented
    - If the solution hurts, harms, or helps environment and how
    - Impact of the solution on wildlife, etc.
- Amount of CO_2 the solution would offset
    - A bar graph illustrating the amount of carbon the solution would reduce if everyone engaged in the solution, along with a verbal description
    - Time it will take to implement the solution

Lesson 17 Teacher Reference

Project Choice and Platform Information

Project Choice Considerations

Below is a list of considerations for each type of project. Think about these options when allowing your students to select their project choice. Consider your devices available, space in your room, and other factors, such as how students are expected to turn in work. Remove any options from the student handout if they do not fall in line with your student expectations. Student privacy policies vary widely by school and district. Remember to check with your student privacy school policies before approving the use of any specific projects, sites, or apps.

Project type	Considerations
Meetings	• Consider who the targeted audience is • Communicate about the meeting to parents/caregivers, especially if the meeting involves community members • Craft an agenda and talking points for the meeting and a list of action items • Handouts with information and graphics can help meeting attendees and provide information
Posters, Brochures, Flyers,	• This more traditional option can be done without any digital tools • Paper can easily be lost by students without a paper management system • Can be done on a variety of digital platforms as well • Different digital tools have different sharing settings and capabilities
Commercials, Podcasts, Newscasts, Mock Social Media	• Some recording options are easier than others—help students find an appropriate tool based upon their individual strengths • Make sure all students have permission to be recorded if their voices or bodies end up on the project • Recorded items could be shared—check student privacy policies
Infographic, Newspaper Article	• Are more susceptible to copying and pasting • Might require additional sources of data
Website	• Can be done on a variety of platforms • Check sharing settings of any blogs or sites • Check student privacy policies before students register for a site and before any sites go live
App	• Could be a draft on paper or an actual app • If students create an actual app, monitor student privacy • Creating an actual app could take more time than a more traditional project format

Potential Project Platforms

Below is an alphabetical list of some widely-used project creation platforms, along with their pros and cons. This list is not all-inclusive, but will give an idea of different ways students can demonstrate their learning. Each platform is linked to the Commonsense.org review when available, if you would like further information regarding the digital tool.

Platform	Use	Pros	Cons
Adobe Spark	Adobe Suite has many different applications and uses. Can be used to create: • Billboards • Flyers • Posters • Charts • Websites • Children's books • Comic strips • Mock apps and social media pages	• Very versatile • Many different presentation options • Looks professional • Web-based platform	• Meant for ages 13 and up, if no school login is available • Check sharing settings against school policies • Choices could be overwhelming to some students • Steeper learning curve than Google platforms
Animaker	Versatile creation tool Can be used to create: • Posters • Billboards • Pages in children's books • Flyers • Social media pages • Commercials • YouTube videos • Instagram stories • Whatsapp stories	• Web-based platform • Easy to navigate • Create a variety of projects	• Check sharing settings against school policies • Only lite version is free with limited features • Need to create login or use Google credentials
Anchor	Simplistic platform used to make podcasts	• Record an actual podcast • Has basic editing functions • Up to 10 can work together on the same podcast • Can import music	• Available on Androids, iPhones, and web-based applications • Must be 13 years old • Can only share publicly
Auxy studio	Music creation app Can be used to create: • Songs • Jingles • Podcasts	• A variety of tools to create sounds, beats, and loop tracks • Can create current-age sounding music	• Only available as an iOS app • Has features to upload content to social media

Book Creator	Digital storybook creation website	• Free to register for the site • Large selection of graphics to choose from • Easy to use • Sharing options available	• Some features require a subscription upgrade • Compatible only with iPad and Google Chrome
Clips	Video recording and sharing platform Can be used to create: • Commercials • YouTube videos • Newscasts • Children's books read aloud • Mock TikTok	• Captions are available in many different languages • Can be easier to use than GarageBand • Can upload any videos or pictures on your iOS device for use	• Requires an Apple ID login • Very easy for students to share work—check with student privacy policies • Only available with iOS apps • No classroom-specific templates
Flipgrid	Video recording and sharing platform Can be used to create: • Commercials • YouTube videos • Newscasts	• Teacher can create an account and control accessibility, sharing features • Single videos can be recorded • Web-based platform	• Not a lot of editing is available with Flipgrid • Teacher has to create a class site and distribute codes to students
GarageBand	Video recording and sharing platform Can be used to create: • Podcasts • Songs	• Various audio editing options • Easy to trim music and audio files	• Can be too complex for some students • Learning curve involved • Some background music has to be purchased • Only available on iOS
Google Docs	More traditional word processing application Can be used to create: • Articles • Create comic strip layout to print and draw • Write lyrics to a song • Write up a script • Brochures	• Easy to use • Familiar to most students • Web-based platform • Different layouts exist on the Google suite for a variety of purposes • Can be shared with select stakeholders	• Limited ability to reformat pages • Charts can be hard to layout or organize in different ways • Text direction cannot be changed
Google Drawings	Online drawing tool similar to Microsoft Paint application Can be used to create: • Billboards • Posters • Charts • Flyers • Any other simplistic visual product	• Easy to use • Integrates with other Google applications • Can import images from search features • Can be shared with select stakeholders	• Has limited tools to utilize • No pre-made templates or layouts • Simplistic look vs. a more sophisticated look achieved with Adobe tools

Google Slides	Tool traditionally used to create presentations Can be used to create: • Posters • Billboards • Pages in children's books • Flyers • Social media pages	• Easy to use • Familiar to most students • Web-based platform • Multiple premade layouts and color schemes • Can be shared with select stakeholders	• Hard to create detailed drawings • Harder to export as a JPG if needed
iMovie	Tool traditionally used for creating and editing videos Can be used to create: • Commercials • YouTube videos • Newscasts • Children's books read aloud • Mock TikTok	• Easy to use • Templates and layouts available • Allows for voice-overs • Would need a webcam or camera to create mock TikTok	• Available only on iOS platforms • Limited video editing available
Keynote	Tool traditionally used to create presentations Can be used to create: • Posters • Billboards • Pages in children's books • Flyers • Social media pages	• Similar to Google Slides • Has more features than Google Slides • Basic graphics and layouts available • Voice-overs can be added but are more difficult to integrate	• Available only on iOS platforms • Harder to share with classmates and stakeholders
Microsoft Powerpoint	Tool traditionally used to create presentations Can be used to create: • Posters • Billboards • Pages in children's books • Flyers • Social media pages	• Similar to Google Slides • Has more features than Google Slides • Basic graphics and layouts available • Easy to record and play audio over slides	• Harder to share with classmates and stakeholders • School needs Microsoft Office license to utilize • Doesn't function as well on iOS devices
Piktochart	Application typically used to create infographics Can be used to create: • Infographics • Posters • Flyers • Billboards	• Students can create professional-looking graphs and charts • Templates available • Controlled sharing settings available	• Basic features are limited • Does require a free login
Pixton	Comic creation tool	• Easy to use • Has a lot of graphics to choose from • Can create multiple frames • Many options to share work • Available for Android and iOS	• Mostly human figures—upgrade is needed for additional characters • Teacher has to create a class site and distribute codes to students

Powtoon	Tool traditionally used to create presentations Can be used to create: • Posters • Pages in children's books • Flyers • Commercials • YouTube videos • Newscasts	• Many different presentation formats • Premade templates • Many different ways to share the product • A multitude of images and videos are available to use • Easy to use • May need recording device if doing a newscast • Can upload and use your own videos • Web-based platform	• Students can add pictures and videos from a variety of sources, including Flickr, which may not be supported by some schools • Check with student privacy policies if students use images or likenesses due to the shareability of Powtoon
QuickTime	Traditional recording, video editing, and playback software included on Mac devices Can be used to create: • Commercials • YouTube videos • Newscasts • Children's books read aloud • Mock TikTok • Podcasts • Songs	• Easy to use • Can upload or modify any videos • Can be used to record audio	• Microsoft version is no longer supported by Apple • Comes with macOS • Does not have a lot of standard templates or music to utilize
Scratch or Scratch Jr.	Coding application designed to introduce K-8 students to basic coding language Can be used to create: • Animated commercials • Interactive children's stories	• Unique way to create a children's book or commercial • Interesting for students who like to code • Can easily be shared with others via email • Scratch Jr is very simplistic—easy to use	• Involves a coding learning curve for some students • Can take more time than other options • All text—no voice-over option • Only available on Google Chrome, iOS, and Amazon

Lesson 17 Teacher Reference

Potential Accompanying Standards

Different projects will lend themselves to different potential standards for ELA, Mathematics, and Technology based upon their modality and presentation style. Use the tables below to help develop any accompanying rubrics or materials for students in your classroom. Consider sharing these standards with teammates who may also teach these content areas to develop a cross-curricular connection. The list below is not exhaustive and are only suggestions, not recommendations. Many states that do not use Common Core standards have similar areas, such as reading, writing, speaking, and listening, that can be cross-referenced. Ultimately, consult your own state adopted standards when deciding on any potential additional standards.

ELA Common Core College and Career Readiness Standards Connections

Consider the following Common Core ELA standards for student use. Many standards are applicable to more than one project. Depending on the state, this alignment may vary. Consult your state standards documents for further guidance.

Standard	Indicator	Statement
Reading		
Integration of Knowledge and Ideas	CCSS.ELA-LITERACY.CCRA.R.7	Integrate and evaluate content presented in diverse media and formats, including visually and quantitatively, as well as in words.
Writing		
Text Types and Purposes	CCSS.ELA-LITERACY.CCRA.W.2	Write informative/explanatory texts to examine and convey complex ideas and information clearly and accurately through the effective selection, organization, and analysis of content.
Production and Distribution of Writing	CCSS.ELA-LITERACY.CCRA.W.4	Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
Production and Distribution of Writing	CCSS.ELA-LITERACY.CCRA.W.6	Use technology, including the Internet, to produce and publish writing and to interact and collaborate with others.
Research to Build and Present Knowledge	CCSS.ELA-LITERACY.CCRA.W.8	Gather relevant information from multiple print and digital sources, assess the credibility and accuracy of each source, and integrate the information while avoiding plagiarism.
Speaking and Listening		
Comprehension and Collaboration	CCSS.ELA-LITERACY.CCRA.SL.2	Integrate and evaluate information presented in diverse media and formats, including visually, quantitatively, and orally.
Presentation of Knowledge and Ideas	CCSS.ELA-LITERACY.CCRA.SL.4	Present information, findings, and supporting evidence such that listeners can follow the line of reasoning, and the organization, development, and style are appropriate to task, purpose, and audience.
Presentation of Knowledge and Ideas	CCSS.ELA-LITERACY.CCRA.SL.5	Make strategic use of digital media and visual displays of data to express information and enhance understanding of presentations.

Common Core Mathematics Standard Connection

Consider the following Common Core math standard for student use. These math standards tend to correlate to projects that are more data-driven, such as a quantitative infographic, and are pulled from the 6th and 7th grade standard set. While measurement standards seem applicable for this project, note that they are developed in elementary grades, utilized in relational and expressive domains in middle school, and revisited in high school to develop an understanding of probability. Depending on the state, this alignment may vary. Consult your state standards documents for further guidance. Be mindful to draw from grade-level or just below grade-level appropriate math so that the mathematics component does not inhibit student learning.

Standard	Indicator	Statement
Grade 6 - Ratios and Proportional Relationships	CCSS.MATH.CONTENT.6.RP.A.1 CCSS.MATH.CONTENT.6.RP.A.2	Understand ratio concepts and use ratio reasoning to solve problems.
Grade 7 - Ratios and Proportional Relationships	CCSS.MATH.CONTENT.7.RP.A.2	Recognize and represent proportional relationships between quantities.

ISTE Standard Connection

Consider the following technology standards for student use. Many ISTE standards are applicable to more than one project. Depending on the state, this alignment may vary. Consult your state standards documents for further guidance.

Standard	Indicator	Statement
Knowledge Constructor	3b	Students plan and employ effective research strategies to locate information and other resources for their intellectual or creative pursuits.
Computational Thinker	5b	Students collect data or identify relevant data sets, use digital tools to analyze them, and represent data in various ways to facilitate problem-solving and decision-making.
Creative Communicator	6a	Students choose the appropriate platforms and tools for meeting the desired objectives of their creation or communication.
Creative Communicator	6c	Students communicate complex ideas clearly and effectively by creating or using a variety of digital objects, such as visualizations, models, or simulations.
Creative Communicator	6d	Students publish or present content that customizes the message and medium for their intended audiences.
Global Collaborator	7a	Students use digital tools to connect with learners from a variety of backgrounds and cultures, engaging with them in ways that broaden mutual understanding and learning.
Global Collaborator	7c	Students contribute constructively to project teams, assuming various roles and responsibilities to work effectively toward a common goal.

Reference: Peer Feedback Guidelines

Teacher Instructions

There will be times when helping students to give each other feedback will be very valuable for their three-dimensional learning and for learning to give and receive feedback. We suggest that peer review happen at least once, but preferably two times, per unit. This document provides options on how to support this in your classroom. It also includes student materials to support giving and receiving feedback, along with self-assessment rubrics with which students can reflect on their experience with the process.

When is a good time to facilitate peer review?
Peer feedback is most useful when complex and diverse ideas are visible in student work and not all work is the same. Student models or explanations are good opportunities for which to use a peer feedback protocol. They do not need to be final pieces of student work; rather, peer feedback will be more valuable to students if they have time to revise their work after receiving the feedback. It should be a formative, not summative, type of assessment. It is also necessary for students to have experience with past investigations, observations, and activities so that they can use these experiences as evidence for their feedback.

What classroom structures can I use for peer review?
Below are three examples of ways to organize peer review in your classroom. You may choose to use all of them as your time or material constraints allow, or you may choose to always use the same structure so that your students get familiar with it and become better at it over time.

Sticky Note Peer Review: In this protocol—shared on *Tools for Ambitious Science Teaching*—students use sticky notes to leave questions and comments on posted student work. Time is built in for students to respond to the feedback. Use the self-assessment rubrics in this document at the end of the class period to have students reflect on their experience in this feedback session.

Peer Review with Unit Rubrics: Each unit—and the OpenSciEd curriculum overall—has Science and Engineering Practice (SEP)-specific rubrics for teachers to assess student work. You can also use these as a way for students to assess each other's work and give feedback on how to improve. For example, in the first lesson set of OpenSciEd Unit 8.2: *How can a sound make something move?* (Sound Waves Unit), students develop models of how objects vibrate to produce sound. We suggest having students use the rubric to give each other specific feedback. You can use this in a gallery walk context or have students exchange models.

Group Review: Ask students to form groups of four and bring their individual models or explanations (or other work) to their group. Review the peer feedback guidelines as a class, giving examples of productive and nonproductive feedback. Then, in pairs, have students provide feedback on the other two pieces of student work. They can use sticky notes or write directly on the work. Make sure to allow time, after feedback is exchanged, for students to individually revise their models and complete the self-assessment rubrics.

Giving Feedback to Peers

This tool was inspired by the Sticky Note Feedback resource originally developed by Ambitious Science Teaching at: https://ambitiousscienceteaching.org/sticky-note-student-feedback/.

Feedback needs to be specific and actionable.
For feedback to be productive, it needs to be related to science ideas and provide suggestions for improvement.
Here are some examples of productive feedback:

- "Your model shows that the sound source changes position when it is hit. I think you should add detail about how the sound source moves back and forth after it is hit."
- "You said that the drum moves when it makes a sound, but the table doesn't move when it makes a sound. We disagree and suggest reviewing the observation data from the laser investigation."

Here are some examples of nonproductive feedback that does not help other students improve:

- "I like your drawing."
- "Your poster is really pretty."
- "I agree with everything you said."

How to Give Feedback
Your feedback should give ideas for specific changes or additions the person or group can make. Use the sentence starters below if you need help writing feedback.

- "The poster said _____. We disagree because _____. We think you should change _____."
- "I like how you _____. It would be more complete if you added _____."
- "We agree that _____. We think you should add more evidence from the _____ investigation."
- "We agree/disagree with your claim that _____. However, we do not think the _____ (evidence) you used matches your claim."

Receiving Feedback from Peers

The purpose of receiving feedback is to get ideas from your peers about things you might improve or change to make your work more clear, more accurate, or better supported by evidence. It can also help you to communicate your ideas more effectively to others.
When you receive feedback, you should take these steps:

- Read it (or listen to it) carefully. Ask someone else to help you understand it, if necessary.
- Decide if you agree or disagree with the feedback, and say why you agree or disagree.
- Revise your work to address the feedback as needed.

Self-Assessment: Giving Feedback

How well did you give feedback today?

Today, I...	YES	NO
Gave feedback that was **specific and about science ideas**.		
Shared a suggestion to help improve my peer's work.		
Used evidence from investigations, observations, activities, or readings to support the feedback or suggestions I gave.		

One thing I can do better the next time I give feedback is:

Self-Assessment: Receiving Feedback

How well did you receive feedback today?

Today, I...	YES	NO
Read the feedback I received carefully.		
Asked follow-up questions to better understand the feedback I received.		
Said or wrote why I agreed or disagreed with the feedback.		
Revised my work based on the feedback.		

What is one piece of feedback you received?

What did you add or change to address this feedback?

Lesson 17: Rubric 1

Rubric: Designing a Community Resilience Plan

Allow your students to choose the modality for communicating their thinking by selecting different products from the *Project Options*. Offer oral administration to those students who would benefit from this modality.

This rubric can be used to assess group progress on the LLPE. The LLPE is an integration of elements from the three dimensions.

The rubric is based on a sample class Criteria Checklist. Modify the rubric to match your class' Criteria Checklist. Add criteria your class agreed was important even if not shown in the example below.

17.A Apply scientific principles to design a process/system that the school can undertake to reduce the vulnerability to climate change impacts (e.g., high heat, changing water resources) in the short-term and contribute to rebalancing carbon in the long-term.

SEPs	DCIs	CCCs
6.6 Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process or system. Students work in groups to design a system (mix of solutions) that is relevant given the projected impacts their community is facing or will face in the future. Students support their plans with science ideas figured out during the unit.	**ESS3.C** Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth, unless the activities and technologies involved are engineered otherwise. (MS-ESS3-3), (MS-ESS3-4) **ESS3.D** Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depends on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding human behavior and applying that knowledge wisely in decisions and activities. (MS-ESS3-5) **ETS1.B** There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (MS-ETS1-2), (MS-ETS1-3) The focus of the climate resilience project is on changing human behaviors and/or communicating about new technologies through designing a community plan. Students use knowledge about carbon imbalance, temperature rise, and precipitation change (either/or changes to the amount, frequency, type, or duration) to suggest a mix of solutions. As part of this work, they consider their community stakeholders to try to understand their behavior and why or why not they will adopt a solution. Through understanding the science and projected changes in their community, considering stakeholders and their concerns, and learning about solutions and new technologies that are available, students design plans to meet the agreed upon criteria.	7.1 Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale. One criteria is to include a wisely selected mix of solutions for the community resilience plan that helps the community contribute to the long-term rebalancing of carbon, while also preparing for changes happening in the community right now. This is a key portion of the class Criteria Checklist and planning sheet.

Rubric: Designing a Community Resilience Plan

Group Members: _____

Category	Developing	Mostly demonstrated	Fully demonstrated
Tells people about the problems Criteria Checklist Planning sheet Part 1	Identifies at least 1 problem that will affect our community (e.g., flooding).	Identifies the complete list of problems and describes them generally.	Identifies the complete list of problems and explains specifically when and/or how the community members (stakeholders) could be affected. Fully meets Criteria Checklist.
Identifies key stakeholders impacted by the problems Planning sheet Part 2	Identifies a general group of school or community stakeholders.	Identifies different stakeholder groups and possible needs of each group.	Identifies different stakeholder groups and specifically references how the stakeholders will be more or less directly impacted by the problems caused by the carbon imbalance.
Teaches people about what's causing the problem Criteria Checklist Planning sheet Part 3	Identifies at least 2 relevant science ideas for explaining the problem(s). Missing an important idea.	Identifies the most relevant science ideas for explaining the problem(s).	Identifies the most relevant science ideas for explaining the problem(s). Provides evidence to support those ideas. Fully meets Criteria Checklist.
Directs people to solutions Criteria Checklist Planning sheet Part 4	Includes at least 1 solution for rebalancing the carbon cycle and 1 solution to prepare the community for changes happening now.	Includes a mix of solutions for rebalancing the carbon cycle and preparing the community for changes happening now that are closely aligned to the problem(s) and stakeholders identified.	Includes a mix of solutions for rebalancing the carbon cycle and preparing the community for changes happening now that are closely aligned to the problem(s) and stakeholders identified and gives people different actions they can take to enact different solutions.
Other:			
Other:			

Lesson 17: Rubric 2

Rubric: Argue for the Best Solution to Solve a Problem in Your Community

This assessment is designed for students to write their ideas. Alternatives include offering oral administration to those students who would benefit from this modality. Allow your students to choose the modality for communicating their thinking.

This assessment can be used to assess student progress on the LLPE. The LLPE is an integration of elements from the three dimensions.

17.C Construct an argument grounded in evidence and scientific reasoning to recommend a design solution that will prepare a community for predicted changes to temperature and/or precipitation (effect).		
SEPs	**DCIs**	**CCCs**
7.3 Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. Students are given the authentic task of thinking about which solutions to argue for given that a community cannot implement them all. They construct an argument (written or orally) that claims which solution is most promising for the community, and they support the claim with evidence collected through investigations and scientific reasoning.	**ESS3.C** Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth, unless the activities and technologies involved are engineered otherwise. (MS-ESS3-3), (MS-ESS3-4) **ESS3.D** Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depends on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding human behavior and applying that knowledge wisely in decisions and activities. (MS-ESS3-5) The focus of the climate resilience plan project is on changing human behaviors and/or communicating about new technologies to one's own community and taking into account the problems the community will face. Students use knowledge about carbon imbalance, temperature rise, and precipitation change to suggest a mix of solutions. As part of this work, they consider stakeholders and try to understand their behavior and why or why not they will adopt a solution. Through this project students come to understand the problems their community faces and possible solutions based on what they understand about the community in which they live.	2.2 Cause and effect relationships may be used to predict phenomena in natural or designed systems. Students identify a solution they believe is promising to solve the problem (temperature or precipitation change) in their community. As they argue for the solution they use cause and effect to explain how the solutions prepare the community for the change that is occuring or may occur in the future as a result of the carbon imbalance.

Rubric: Argue for the Best Solution to Solve a Problem in Your Community

Name: _____

Explanation (Question 1)	Category			Feedback
	Missing	Developing	Mastered	
• A problem, or change, is identified. • The problem is explained using science ideas figured out in the unit. • The problem is supported by historical data or projections about temperature and/or precipitation.				
Claim (Question 2)	Missing	Developing	Mastered	**Feedback**
• There is a claim that answers the question, *What solution is most important for our community given the changes we face?*				
Justification (Questions 3 & 4)	Missing	Developing	Mastered	**Feedback**
Evidence or empirical data that supports the claim is presented. • Data or relevant information may come from carbon solution cards or water and heat solution cards. • Data interactives and other data sets examined in the unit. • Earth's carbon system model with the flow numbers for different processes.				
Scientific principles or ideas that explain how each piece of evidence supports the claim (*reasoning*). • Draws upon science ideas figured out during the unit. • Is connected to the problem identified on Question 1. • Draws upon trade-offs and social constraints that limit designs (which strategies work for which kinds of people and situations, realistic given the economic needs of people and their everyday behavior).				

Lesson 17: Rubric 3

Rubric: Evaluating Solutions by Asking Questions

This rubric can be used to assess progress on the LLPE. The LLPE is an integration of elements from the three dimensions.

<table>
<tr><td colspan="3">17.B Ask questions to challenge the proposed resilience plan to evaluate whether the solutions meet the class' agreed criteria checklist and will reduce vulnerabilities to climate impacts in the short-term and rebalance carbon in the long-term.</td></tr>
<tr>
<td>1.7 Ask questions that challenge the premise(s) of an argument or the interpretation of a data set.

7.5 Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.

When students provide feedback to a peer, they are focused on sharing this feedback in two forms. First, they take on the role of a skeptical community member who is not immediately convinced about the plan. In this role, they ask questions to challenge the premise of parts of the plan. In particular, they can look at the student's arguments for different solutions in Part 4 and ask questions to help the student refine either the solutions, or the arguments to support them.

By asking these questions and providing feedback to a peer, they are evaluating a classmate's design plans based on the class Criteria Checklist.</td>
<td>ETS1.B There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (MS-ETS1-2), (MS-ETS1-3)

ESS3.D ~~Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming).~~ Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depends on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding human behavior and applying that knowledge wisely in decisions and activities. (MS-ESS3-5)

Students engage in a feedback process to evaluate another group's plan against the class' agreed upon Criteria Checklist. They examine the group's plan to provide feedback about identifying the problems and vulnerabilities of community members, teaching people about the cause of the problem and wisely selecting a mix of solutions based on their community members' needs, concerns, and accessibility for the solutions in the community (such as engineering capabilities).</td>
<td>7.1 Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale.

A focus of the plan is to include a mix of solutions so that the community can contribute to the long-term stabilizing or rebalancing of the carbon cycle while also preparing for changes happening now. This crosscutting concept is a critical lens students apply in Part 4 as they determine the mix of solutions to include in their resilience plans.</td>
</tr>
</table>

Rubric: Evaluating Solutions by Asking Questions

Name: _____

Agreed upon criteria	Example demonstrations of (1) asking questions to challenge the plan, and (2) evaluating the plan against criteria	Category			Feedback
		Missing	Developing	Mastered	
Tells people about the problem(s) Evaluating Parts 1 & 2	• There are questions related to Parts 1 &2 of the planning sheet. • The questions reflect ones that may come from a community member skeptical about the problem and/or who may be affected. • Feedback provided is specific and helps the person make improvements to better answer the questions. • Feedback provided helps the person better meet the criteria. • Feedback provided helps the person consider vulnerabilities of community members.				
Teaches people about what's causing the problem. Evaluating Part 3	• There are questions related to Part 3 of the planning sheet. • The questions reflect ones that may come from a community member skeptical about what's causing the problem. • Feedback provided is specific and helps the person make improvements to better answer the questions. • Feedback provided helps the person better meet the criteria.				
Directs people to solutions Evaluating Part 4	• There are questions related to Part 4 of the planning sheet. • The questions reflect ones that may come from a community member skeptical about the solutions that are chosen and whether they will fix the problem. • The questions asked and/or the feedback provided guides the person to an improved mix of solutions for long-term and short-term changes. • Feedback provided is specific and helps the person make improvements to better answer the questions.				

Lesson 17: Rubric 4

Rubric: Communicating Our Community Resilience Plans

Allow your students to choose the modality for communicating their plans by selecting different formats for sharing the plans.

This assessment can be used to assess student progress on the LLPE. The LLPEs is an integration of elements from the three dimensions.

17.D Communicate information in writing and/or oral presentation about how adopting individual, family, or school solutions (subsystems) to reduce vulnerabilities to climate change and/or rebalance carbon can contribute to broader community resilience (larger system).

SEPs	DCIs	CCCs
8.5 Communicate scientific and/or technical information (e.g., about a proposed object, tool, process, system) in writing and/or through oral presentations. Students work with many elements of Obtaining, Evaluating, and Communicating information as they gather, evaluate, and choose information to communicate in their community resilience plan and how to communicate it to others. In this culminating presentation, students should share the integrated science ideas and community stakeholder perspectives, as well as a mix of solutions. This can be in written form (hard copy or digital) or in an oral presentation. Students might also opt for oral meetings with others, which could include a combination of written and oral work.	**ESS3.D** Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depends on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding human behavior and applying that knowledge wisely in decisions and activities. (MS-ESS3-5) **ESS3.C** Typically, as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth, unless the activities and technologies involved are engineered otherwise. (MS-ESS3-3), (MS-ESS3-4) **ETS1.B** There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (MS-ETS1-2), (MS-ETS1-3) The focus of the climate resilience project is on changing human behaviors and/or communicating about new technologies through designing a community plan. Students use knowledge about carbon imbalance, temperature rise, and precipitation change to suggest a mix of solutions. As part of this work, they consider stakeholders and try to understand their behavior and why or why not they will adopt a solution. Through understanding the science and projected changes in their community, considering stakeholders and their concerns, learning about solutions and new technologies that are available, students design plans to meet the agreed upon criteria.	4.1 Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. When students communicate their plans to others, they should focus on how to convince others that actions taken at the individual or school level (subsystem) can impact change at the large scale.

Rubric: Communicating Our Community Resilience Plans

Name: _____

Category	1	2	3
Communicate information to stakeholders about the mix of solutions and how they work together to rebalance carbon and prepare the community, and why it is important to implement.	Shares information about the solution and some information about how to implement it.	Shares detailed information about the solution and some information about how to implement it.	Shares detailed information about the solution and tailors information about how to implement it for a specific stakeholder group(s).
Communicate about why these solutions are important to implement given the problems or changes in temperature and precipitation the community will face.	Shares information about the generic problems the community may face with generic solutions connected to the problems.	Shares some community specific information about problems but selects generic solutions connected to the problems.	Shares detailed information about the specific problems the community may face and specific solutions that target those problems.
Communicate information to stakeholders about how individual, family, or school level changes in behaviors contribute to the community's efforts toward resilience.	Shares some information about solutions in different subsystems that are connected to generic needs and goals for resilience.	Shares information about how solutions in different subsystems contribute to the specific community's needs and goals for resilience.	Shares detailed information about how solutions in different subsystems contribute to the specific community's needs and goals for resilience.
Information is presented in a way that is informative and positive and is not meant to cause fear, sadness, or anxiety.	Final product raises fear, sadness, or anxiety.	Final product attempts to be informative and not raise fear, sadness, or anxiety.	Final product was thoughtfully designed and explained in a way to be informative and to not raise fear, sadness, or anxiety.
Information is accessible to a targeted group of stakeholders.	Final product communicates basic information to stakeholders.	Final product uses everyday language, along with symbols and images, to communicate information.	Final product thoughtfully pairs symbols, images, and text in a way that communicates important ideas to the target stakeholder group(s) in everyday language commonly used by the stakeholder group(s).