WHAT MAKES THE WEATHER CHANGE?

Atmospheric Processes in Weather and Climate
IQWST LEADERSHIP AND DEVELOPMENT TEAM

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Atmospheric Processes in Weather and Climate

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Art

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Lesson 1

Atlanta Surface Area Map – Courtesy WSI Corporation, The Weather Channel
Belem Surface Area Map – Courtesy WSI Corporation, The Weather Channel
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Oslo Surface Area Map – Courtesy WSI Corporation, The Weather Channel
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10-Day Forecast: Buenos Aires, Argentina – Courtesy WSI Corporation, The Weather Channel
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Belem, Brazil Weather Report – Courtesy WSI Corporation, The Weather Channel
Atlanta, Georgia Weather Report – Courtesy WSI Corporation, The Weather Channel

Lesson 5

Cloud Cover Map – Courtesy National Oceanic and Atmospheric Administration, U.S. Department of Commerce
U.S. Surface Area Map – Courtesy National Oceanic and Atmospheric Administration, U.S. Department of Commerce
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Lesson 6

Midwest Surface Map – Courtesy WSI Corporation, The Weather Channel

Lesson 7

January Global Map Temperatures – Courtesy University of Oregon Department of Geography
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Lesson 1 – Climate Change 279
What Makes the Weather Change? is an Earth Science unit that focuses on what causes variation in local weather events and global climate patterns. Students figure out what makes the weather change by developing a model of the flow of matter and energy through the atmosphere.

Driving Question
What Makes the Weather Change? is the Driving Question that organizes and motivates various activities throughout the unit. The scientific principles students learn and the inquiry practices in which they engage are instrumental to understanding and answering this Driving Question. Students complete a number of investigations and create models to explain weather concepts. There are two learning sets in the unit’s instructional sequence, providing a total of eight lessons.

Learning Set 1: What Causes a Storm?
Students begin by drawing on their everyday experiences with weather to identify the conditions they need to investigate that contribute to weather events like a storm. Students first consider how air at the surface of Earth is heated. Students draw on their understanding of energy from the IQWST PS2 unit to analyze what happens to matter and energy to cause surface air to be heated. Students create a model that explains how the air at the surface is heated through a sequence of energy transfers from the sun to the Earth’s surface, energy conversion from solar to thermal energy, and energy transfer (through conduction) from the ground to the air. Students then investigate what happens to the air after it is heated. Students investigate the movement of air masses at different temperatures and attempt to explain why hot air rises. They develop a model of convective currents and revise their models to show the movement of matter and energy in a storm.

After investigating additional weather conditions, including pressure, humidity, and lift, students develop and revise a model of a storm that shows what happens to matter and energy before, during, and after a storm. They then use their model to explain patterns in the weather condition data from a real storm in the Midwest. At the end of this learning set, students can explain the changes that occur in local weather patterns from day to day. They are left with the question of explaining why the weather varies from one location to another on Earth.
Learning Set 2: Why Is Weather Different from Place to Place?

Students begin Learning Set 2 with a question about how location affects weather. Students have constructed and tested a model that explains a storm and how the different conditions affect daily weather, but students have also determined that their models cannot explain the patterns in the data that show that weather conditions vary by location on Earth. Students determine how temperature varies by latitude. To investigate this finding, students analyze the number of hours of daylight a city receives as well as its temperature. Students consider differences in hours of daylight, which their model says would lead to temperature differences, but then reject that factor as a possible explanation for the relationship between latitude and temperature. Students then collect data to analyze whether the shape of Earth affects temperature. This activity raises the question about the angle at which light hits Earth and whether that affects temperature. After discovering that the angle at which light hits an object affects the intensity, students construct an explanation about why temperature varies at different latitudes. Students use visualizations of surface temperature at two different times of the year (January/July) and observe that the warmer areas shift north in the summer and south in the winter. Their previous explanation cannot account for this, and they engage in a series of simulations to explore the idea of a tilted Earth. Students construct a model that explains seasonal variations in temperature. In the culminating activity, students use all of the evidence they have collected, as well as the scientific principles they have developed, to explain why two cities in opposite hemispheres vary in their weather patterns.

Appendix

This lesson very briefly engages students with concepts related to climate change, including global warming and the impact of greenhouse gases. It builds upon other lessons related to human impacts on Earth’s systems, particularly in 6th grade units about ecosystems and about natural resources (including energy resources). This lesson could be further expanded upon with projects in which students investigate their own questions specific to climate change, using internet resources to find information, to analyze additional data, and to analyze the credibility of internet sources. Such exploration would provide an authentic application of the practice of obtaining, evaluating, and communicating information (among others) and would address many middle school literacy standards as well.

IQWST Overview

Both Interactive Digital Edition (IDE) users and print users of IQWST can access PDFs of the Teacher Edition and of an IQWST Overview booklet digitally. Teachers who received a print Teacher Edition also received a print copy of the overview. The IQWST Overview is referenced throughout the Teacher Edition, as it contains a great deal of information useful for teaching IQWST, such as reading strategies, writing strategies (including claim-evidence-reasoning formatted explanations) and supports for 3D teaching and learning. The same book contains information and strategies applicable to all IQWST units.
At the beginning of each IQWST Lesson, the NGSS Performance Expectations (PEs) addressed in that lesson are listed. The more deeply you understand NGSS, the more the descriptions of PEs and their components (the Disciplinary Core Ideas/DCIs, Science and Engineering Practices/SEPs, and Crosscutting Concepts/CCC) will make sense to you.

However, if you are newer to NGSS, several key aspects of the standards are extremely important to note:

1. Remember that a PE addressed in a lesson does not mean that the PE will be met in a lesson. Performance Expectations, as described in NGSS, are designed to be the end products of instruction. They name the expectation of students after a series of activities, lessons, units, or even at the end of middle school. PEs name the ideas on which students, in most states, will be assessed on a state-wide test that is designed in a 3-dimensional manner.

2. Therefore, students should not be assessed on the PE, as written, during the course of instruction. During the course of instruction, they should be assessed on their developing understanding of the content addressed in the PE, the crosscutting concept addressed in the PE, and their facility with the practice named in the PE. But, the specific combination named in the PE is designed to be the final assessment on a state-wide test, not on a classroom test.

3. IQWST uses the language of *Building Toward* to support teachers in thinking about the PEs in this manner. That is, prior to each investigation or activity (not sure if other is needed) one or more of the PEs will be named in this manner: *Building Toward PE MS-PS1-3*. That language is meant to communicate that students will be experiencing a phenomenon or engaging in activities that address some aspect of the PE. It may be that an activity addresses what seems like a very small part of what is needed to “meet” the PE, and may not even be named in the PE itself, but that aspect is always necessary for students to construct a deep understanding so that they can “meet” that PE when it is formally and finally tested.

4. Also important to understand is that a PE might state that students will be able to “Analyze and interpret data . . .” when they are ultimately tested, but that does not mean the practice of analyzing and interpreting data is the only practice students need to engage in to learn the components of that PE along the way. So, a PE for a lesson might indicate that the
practice is to analyze and interpret data, but in the lesson that names this as a PE the lesson is building toward, students might be planning an investigation, and not doing any analysis or interpretation of data. Or, they might primarily be asking questions, but not doing any analysis or interpretation of data. This is the intention of the NGSS, but it may seem odd when the actual experience of a phenomenon, or investigation, or other activity in the lesson that indicates it is Building Toward a particular PE, doesn’t seem to relate to that PE at all. It always will, but it is sometimes to address a part of the PE that is not immediately obvious, and may not be named in the PE at all.

Here is an example from Physical Science:

**Building Toward Performance Expectation MS-PS1-2**

*Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.*

*Clarification Statement: Examples of reactions would include burning sugar or steel wool, fat reacting with sodium hydroxide, and mixing zinc with hydrogen chloride. Assessment is limited to analysis of the following properties: density, melting point, boiling point, solubility, flammability, and odor.*

**Disciplinary Core Idea PS1.A:** Structure and Properties of Matter

- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.

**Disciplinary Core Idea 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.

Students would be Building Toward PE MS-PS1-2 in a lesson that addresses any one of the following: atoms, molecules, substances/matter, physical processes, what makes something a property, an individual property, qualitative data/measurements, burning, elements, the periodic table of elements, close observation, description of substances (quantitative data), molecular structure, reactants vs products, or others. To address the content named here, students could be engaged in any one of the 8 practices, in combination with crosscutting concepts.

Therefore, know that students really are building toward a PE, even when the activity names a different practice or different crosscutting concept other than the one named in the PE itself. Students will get there eventually, but the expectation in the NGSS is that students’ experiences along the way prepare them to be able to address the standard, not to “meet” the standard in individual lessons.
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What Makes the Weather Change?

Scientific Principles
The principles below are suggested wordings of key ideas as they occur across the course of this unit. (See the IQWST Overview for detailed discussion of Scientific Principles.) Most important are that these statements 1) are developed with students as new ideas are learned and that each 2) uses students’ words as much as possible. That is, rather than provide students with a list of principles they must learn, these ideas are the natural conclusion of investigations in which students have engaged. As IQWST students record their developing understandings, based on evidence, they engage in a behavior similar to that of real scientists. When scientists figure out something important, they record their ideas so that they can keep track of them and can communicate them to others.

As you introduce the idea of Scientific Principles, support students in understanding that these are considered principles because although they represent “what we’ve figured out so far” as a class, they more broadly represent enduring ideas or theories, laws, or other ideas about the natural world that not only operate today but operated in the past and will continue to operate in the future. The Science and Engineering Practice, Constructing Explanations and Designing Solutions, includes this as an element of the practice:

- 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.

Therefore, use the statements below as a guideline. You may find principles worded somewhat differently within the unit in order to illustrate that it is the core idea, not the precise wording, that matters most.
<table>
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<th>Lesson</th>
<th>Scientific Principle</th>
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| 2      | 1. Light energy from the sun is mostly transmitted through the air before reaching the ground, and the ground absorbs some of the light energy that reaches it.  
2. Molecules transfer thermal energy from one end of an object to another and to other objects by collision between molecules that transfer the kinetic energy of one molecule to another (conduction).  
3. The air at the Earth's surface is primarily heated by the transfer of thermal energy from the ground below it. |
| 3      | 4. When thermal energy is transferred from the heat source (Earth) to the air, it increases the kinetic energy of the air molecules and the air becomes less dense and rises.  
5. When warmer, less dense air rises, cooler, more dense air moves in to take its place (convection). |
| 4      | 6. Low-density air columns have low pressure and high-density air columns have high pressure. Air masses move when high-pressure air pushes into the space of low-pressure air.  
7. When warmer less dense air is lifted by cooler more dense air, the less dense air is said to be unstable as it transfers energy to the surrounding air.  
8. A front is the boundary between two large air masses. When two air masses of different temperatures blend so that their temperature and water vapor content are the same, we say it has reached equilibrium. If it happens quickly, the atmosphere is said to be stable and if it happens slowly, the atmosphere is said to be unstable.  
9. The greater the difference of temperature and pressure of two colliding air masses, the more unstable the atmosphere and more likely a storm will develop.  
10. Water vapor in the atmosphere condenses around particles of dust to form clouds. Humidity is a measure of the amount of water vapor in the atmosphere.  
11. As water vapor condenses, it changes to a liquid and releases energy to the surrounding air.  
12. Since condensation is transferring energy to the air around it, the air has more thermal energy and will continue to rise. As it rises, it will continue to condense and form higher clouds until there is no more water vapor in the air and no energy to be transferred. |
| 7      | 13. Intensity of light varies depending how far north or south of the equator you are and how long the light shines on a place.  
14. Temperatures vary in a predictable pattern depending on latitude.  
15. Intensity differences explain why temperatures vary in the same pattern. |
| 8      | 16. Earth's tilt on its axis causes light to hit the Earth more intensely and for longer periods of time in different parts of the Earth during the year. This causes seasons. |
STANDARDS ADDRESSED IN THIS LESSON

Building toward Performance Expectation MS-ESS2-5
Earth’s Systems
Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.
Clarification Statement: Emphasis is on how air masses flow from regions of high pressure to low pressure, causing weather (defined by temperature, pressure, humidity, precipitation, and wind) at a fixed location to change over time, and how sudden changes in weather can result when different air masses collide. Emphasis is on how weather can be predicted within probabilistic ranges. Examples of data can be provided to students (such as weather maps, diagrams, and visualizations) or obtained through laboratory experiments (such as with condensation). [Assessment Boundary: Assessment does not include recalling the names of cloud types or weather symbols used on weather maps or the reported diagrams from weather stations.]

Building toward Performance Expectation MS-ESS2-6
Earth’s Systems
Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.
Clarification Statement: Emphasis is on how patterns vary by latitude, altitude, and geographic land distribution. Emphasis of atmospheric circulation is on the sunlight-driven latitudinal banding, the Coriolis effect, and resulting prevailing winds; emphasis of ocean circulation is on the transfer of heat by the global ocean convection cycle, which is constrained by the Coriolis effect and the outlines of continents. Examples of models can be diagrams, maps and globes, or digital representations. [Assessment Boundary: Assessment does not include the dynamics of the Coriolis effect.]
Background Knowledge

Weather Conditions and Weather Events

- Weather conditions refer to the atmospheric conditions that compose the state of the atmosphere: temperature, wind, clouds, and precipitation.
- Weather events are combinations and interactions of weather conditions that occur at a specific place and time. Tornadoes, hurricanes, and other storms are weather events. They are specific combinations of temperature, wind, precipitation, and clouds occurring at a specific time.

Setup

Specific instructions for activity setup are embedded within the lesson.

For Activity 1.1, weather sounds (rainstorm, thunder, blizzard, tornado, hurricane, etc.) can help students think about the various conditions that make up weather. Search the internet for audio clips of sounds that you can play for students during the opening discussion. Otherwise, have students think about these weather events without listening to the sounds that accompany them.

SAFETY GUIDELINES

This lesson presents no unusual safety concerns; however, see IQWST Overview for general laboratory safety.

Differentiation and Other Strategies

World Map

1. Use a world map in the classroom to identify the location of the example cities. Groups can mark the location of their city with a colored sticker or pin.
2. This map will help students begin to see the global nature of weather conditions and events. Students return to this map in Lesson 2 in order to investigate the second part of the Driving Question: Why Is Weather Different from Place to Place?
Local Weather Data
3. How you handle this project depends on the amount of available space in the classroom.
   - A chart can be kept in the classroom for recording the weather each day. Groups can be responsible for one day each or for a week at a time.
   - For homework each night, students can individually record the daily data. They could watch a weather report on television, use the internet, or read a newspaper.
Teaching Lesson 1

Overview

Activity 1.1
Analyze data from world cities to determine that weather conditions appear everywhere and are the same.

Activity 1.2
• Introduce the Driving Question and Driving Question Board.
• Post questions on the Driving Question Board to be used throughout the unit.

Learning Performances
Students will

• analyze patterns in data to determine the conditions involved in defining weather events.
• generate questions about the cause of weather phenomena in terms of transfer of energy and flow of air and water.

Building Coherence

This unit focuses on what happens to the matter and energy during a storm and other weather events. There are strong connections to units IC1 and IC2. This unit also connects to students’ everyday experiences with weather. In this lesson, students are introduced to the conditions that interact to produce various weather events.

Timeframe
One to two 50-minute class periods
Activity 1.1: Identifying Weather Conditions around the World

Building Toward Performance Expectation MS-ESS2-6
Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.

Disciplinary Core Idea ESS2.D: Weather and Climate
- 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.

Science and Engineering Practices: Analyzing and Interpreting Data
Crosscutting Concept: Patterns

Materials

For Each Group
- Data for selected cities (located in the student edition)
- Buenos Aires, Argentina
- Atlanta, Georgia
- Oslo, Norway
- Belem, Brazil
- Singapore, Singapore
- Ushuaia, Argentina

For Each Student
- SE Activity 1.1

For the Class
- World Map
**Introducing the Activity**

As students enter the classroom, have the weather sounds playing. After about five minutes, make a list on the board of the sounds students heard. Ask students to categorize these sounds (weather).

- What is weather?
- What makes up the weather?
- What exactly did you hear? What kinds of weather were represented? (Possible student responses might include the following: storms, snow, rain, wind, clouds, tornado, and so on. Record all reasonable responses about the weather.)

Be sure that the list includes weather events such as snowstorms, hurricanes, tornadoes, and so on, as well as conditions such as rain, snow, temperature, clouds, and wind.

Explain to students that in this unit they are going to try to predict and explain something that happens all around them—weather. In order to do that, they need to figure out what weather is.

- What conditions make up the weather?
- Do you think these conditions and events are the same everywhere in the world?
- How could we find out?

In the next activity, students will look at weather reports (data) from cities throughout the world in order to compare conditions and events and establish a common list of conditions to investigate.

**Introducing the Activity**

Brainstorm what weather is and what conditions make up weather events. In this discussion, students will identify conditions that change and interact to produce weather events. The goal of this learning set is to make predictions about a weather event (storm). To do this, the variables that contribute to the event need to be identified.

Guide students about weather variables by discussing what they recall from a local weather report.

- Who has listened to a weather report? What are some details you remember the person reporting? Project the weather report for the current conditions for your city (not the forecast).
• **What details were included in the report?** *(Students should list temperature, wind, clouds, and precipitation. In addition, they may add humidity, dew point, or wind chill, depending on the season and your location.)* List these conditions on the board. Students will return to this list and use it to help create the Driving Question Board later in the lesson.

• **Are these conditions the same every day and throughout the year where you live?** *(It is important to identify that while the conditions are the same, they vary throughout the year.)*

• **Do you think these conditions can help predict the weather?**

In this activity, groups will be given weather data for five consecutive days for one city, along with the forecast for those five days. These cities are located in various parts of the world. The sample cities are the following: Buenos Aires, Argentina; Atlanta, Georgia; Oslo, Norway; Belem, Brazil; Singapore, Singapore; and Ushuaia, Argentina. Students will use data from these same cities again in Lessons 6 and 7.

In addition to analyzing the weather conditions in the sample cities, the class should track conditions locally as well. It is important throughout this unit to make connections between what students are studying in the lesson and local events and conditions. That connection to their everyday lives makes the science more relevant.

**Guiding the Activity: Analyzing Weather Conditions**

Assign students to six groups and distribute weather data for one of the cities to each of the groups. Each packet of data contains a brief description of the location of the city and weather reports for five days, as well as the forecast. The weather reports for each city are from the same five days in May 2017. Using a week of data allows students to see that weather is not the same everywhere, as well as how weather can change in a specific place. Students should examine the data in order to determine the weather conditions used to help predict the weather.

Have each group plot the location of their city on the classroom map. Also indicate the location of your home city, since the class will be tracking local weather data as well. Have students share the weather conditions they saw in each of the cities. Use the list of conditions on the board and add any new ones that students found. Discuss what they found.
WHAT MAKES THE WEATHER CHANGE?

With this definition of weather, ask students if they have any ideas about why these conditions and events vary from day to day (at a given place) and from place to place. Students are not expected to know the answer. This question is meant to prompt them to create the Driving Question for the unit: What Makes the Weather Change? Write this question on the Driving Question Board. This is the question students will try to answer in this unit. In the next activity, students will brainstorm questions they have about weather conditions and events, and set up the Driving Question Board.

- Do the same conditions appear on all of the reports? (These should be the conditions already listed on the board, with possibly the addition of dew point and/or wind chill, depending on the time of year. Make sure the following conditions are listed: temperature, wind, clouds, precipitation, and humidity.)
- Do they have the same values everywhere? (It might be hotter in Atlanta, Georgia, than in Oslo, Norway.)
- Do the same weather events occur everywhere? Is it raining in all cities? Do some cities have rain and others snow?
- Were the conditions in your group’s city the same every day, or did they change? (Since these conditions do not remain the same in all weather events, they should be identified as variables.)
- Do these conditions always produce the same event? Do they always create a storm?
- Do you think changes in these conditions help us predict the weather? Why?

When concluding this activity, students should understand the following points.

- The same weather conditions appear everywhere but do not necessarily have the same values. These are identified as variables.
- Weather events are different in different places, even at the same time of the year.
- Weather conditions at the same location vary from day to day.
- Students have identified conditions that make up weather. “Weather event” is a phrase used to describe what’s happening with these conditions at a particular time and place.
Activity 1.2: Setting Up the Driving Question Board (DQB)

Building Toward Performance Expectation MS-ESS2-5
Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.

**Disciplinary Core Idea ESS2.C: The Roles of Water in Earth's Surface and Processes**
- 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.

**Disciplinary Core Idea ESS2.D: Weather and Climate**
- Because these patterns are so complex, weather can only be predicted probabilistically.

**Science and Engineering Practices:** Asking Questions and Defining Problems; Obtaining, Evaluating, and Communicating Information

**Crosscutting Concepts:** Cause and Effect; Energy and Matter

**Materials**

**For Each Student**
- SE Activity 1.2
- Lesson 1 Reading One

**Introducing the Activity**

- In several places there were storms, but why weren’t storms everywhere if the same conditions are everywhere?
- Why does this happen?
- Are these conditions causes of the weather, effects of the weather, or both?
- Do you think these conditions interact in some way to create weather events?

Students saw that the weather was not the same every day. This is a good point to link to local conditions.
WHAT MAKES THE WEATHER CHANGE?

Discussion: Brainstorming

Purpose: To develop questions about why weather varies and what causes weather.

- Why do you think weather varies?
- What causes weather?
- What was happening in each of these storms we observed at the beginning of class? What conditions were present? *(There was wind, precipitation—either snow or rain—and clouds.)*
- Do you think these conditions can help predict what will happen with the weather?
- What do you know about wind? *(It is moving air.)*
- What is temperature? *(Temperature is a measure of the thermal energy of matter. Thermal energy is the kinetic energy of the random motion of particles in an object.)*

Students may have the (previous) understanding of temperature (IQWST IC1 and PS1). Review or establish that understanding. Ask what material students are talking about when they give the temperature in a weather report *(air)*.

- What is precipitation? *(Precipitation is water that has evaporated and moved into the atmosphere and then falls as rain or snow, for example.)* Students should be familiar with the hydrologic cycle if they studied the IQWST ES1 unit.

Have students think about the questions they have about what happens with these conditions to cause a storm. Have them write their questions on sticky notes. Students will post the notes on the DQB when they are finished. Some possible questions include:
• What causes the wind in a storm?
• Why is the wind stronger in a storm?
• Why does it stop after a storm?
• Why is it windy in some places but calm in others?
• What causes the temperature to change?
• Where does the energy come from to cause the temperature to rise?
• Why is it hotter in some places and cooler in others?
• Where does all the water (or snow) come from in a storm?
• Why is it sometimes rain and sometimes snow?
• Is rain just increased condensation?
• Why does it rain more in some places than in others?
• What is air pressure? Why is it part of the weather report?
• Why is elevation on the weather report?

Students have seen that all of these conditions change, and they are trying to figure out how those changes affect weather. Refer to the definition of temperature that students gave earlier (a measure of the thermal energy in matter).

• What matter are we talking about when we refer to temperature when we talk about the weather? (The matter is air.)
• Is there matter in any of the other conditions? (Students should suggest that the wind is moving air—that is, matter. Also, precipitation is matter, in the form of water.)
• If both air and water are moving, what is happening to each of these materials (matter)? (Air moving is wind, and water moving in and out of the atmosphere is precipitation/evaporation.)
• What is necessary to make these conditions occur? (Energy makes these conditions occur. Students may have learned that energy can be transferred [IQWST PS2].)

If you can figure out what is occurring with both the matter and energy in each of these conditions, then you can figure out what is happening in a storm. Return to the DQB and remind students of the Driving Question: What Makes the Weather Change? Turn to the DQB, and have students post their questions under the appropriate condition.
Students have identified two key elements that they need to consider in order to figure out what occurs with weather and storms—in particular, matter and energy. One of the conditions students identified was temperature. They identified that temperature was the measure of the thermal energy in the air. Ask students if they have any ideas about why temperature changes. In the next lesson, students will investigate this question.

**Wrapping Up**

**WW**
Candidate words include matter, variables, thermal energy, local/regional, and the list of weather conditions and weather events, which could be on the DQB only and not the Word Wall (e.g., wind, temperature, precipitation).

**DQB**
Set up the Driving Question Board. (See DQB sample in the Teacher Edition, and see IQWST Overview for more on use of the DQB.) Post the list of weather conditions.

**Assessing Learning**
As groups present their data in Activity 1.1, have them articulate the patterns they observed in the weather conditions as a way to assess their developing understanding of what it means to analyze data to determine patterns.
Introducing Lesson 1 Reading One: What Can Clouds Tell Us about Weather?

Students may be familiar with weather patterns in the location where they live, but often students think that the weather patterns they experience are the same patterns that everyone experiences all over the world. Ask students why they think it might be helpful to know about weather patterns for a region. Who might want this information, and how would they use it? This will get students thinking about patterns in general and the reasons that scientists, and many people all over the world, care about patterns—specifically weather patterns. You can also use the Getting Ready question in the reading to help students to think about how they use patterns in their lives.

Reading Follow Up

Review students’ ideas about why they think weather forecasts are sometimes right and sometimes wrong, simply to identify their thinking at this point in time. You will begin looking more closely at weather by investigating patterns in weather conditions, such as temperature, humidity, pressure, and wind as ways that makes weather change.
Activity 1.1: Identifying Weather Conditions around the World

What Will We Do?
We will analyze data to determine if the same weather conditions are present everywhere.

Prediction
Do you think all weather reports contain information on the same conditions, such as temperature, wind, humidity, precipitation, and clouds? Explain your prediction.
Answers will vary.

Procedure
□ a. Name of your group’s city: ______________________________________________________________

□ b. Find your city on the world map. All groups will share their city’s location when you go over this activity.
c. Check the weather conditions that are listed on all five days of the reports. List them here. (All cities have data on the following conditions: temperature, wind, precipitation, humidity, and air pressure.)

Answers will vary depending on city, and may include ideas like dressing for the weather or planning activities. Look for students to consider why establishing patterns in one location—over time—might be important (as indicated by “keep track of”). You might ask if they have ever looked to see what average temperature or precipitation are for a city at a particular time of year, for example, and when/why that information could be useful.

d. Was there a weather event that occurred in your city during the five days that you analyzed (for example, a storm)? If there was, describe what it was.

Answers will vary depending on city.

e. Did any of the conditions change during the five days? Describe any changes you noticed.

Answers will vary depending on city.
Making Sense

1. Why do you think it would be important to keep track of the weather conditions in a particular location?

   Answers will vary and may include ideas like dressing for the weather or planning activities. Look for students to consider why establishing patterns in one location—over time—might be important (as indicated by “keep track of”). You might ask if they have ever looked to see what average temperature or precipitation are for a city at a particular time of year, for example, and when/why that information could be useful.
Data

**Atlanta, Georgia**

Data were collected between May 3, 2017, and May 7, 2017.
Data

Belem, Brazil
Data were collected between May 3, 2017, and May 7, 2017.

### 10-Day Weather Forecast

<table>
<thead>
<tr>
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<th>Table</th>
<th>Descriptive</th>
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<td><img src="image" alt="Thunderstorm" /></td>
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<td>75°F</td>
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<td>40% / 0.06 in</td>
<td>100% / 0.58 in</td>
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Data

**Buenos Aires, Argentina**

Data were collected between May 3, 2017, and May 7, 2017.
Data
Oslo, Norway
Data were collected between May 3, 2017, and May 7, 2017.
Data

Singapore, Singapore

Data were collected between May 3, 2017, and May 7, 2017.
**Data**

**Ushuaia, Argentina**

Data were collected between May 3, 2017, and May 7, 2017.

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**Weather Report**

Ushuaia, Argentina

**Current Conditions - °F | °C**

Local Reporting Station

Showers in the Vicinity

- **45°F**
  - Feels Like: 35°
- Wind Chill: 35°
- Heat Index: 45°
- Dew Point: 37°
- Visibility: 6.21 mi
- Wind: 30 mph
- Humidity: 76%
- Pressure: 29.24"
- Gusts: 41 mph

---

**Weather Report**

Ushuaia, Argentina

**Current Conditions - °F | °C**

Local Reporting Station

- **43°F**
  - Feels Like: 33°
- Wind Chill: 33°
- Heat Index: 43°
- Dew Point: 37°
- Visibility: 6 mi
- Wind: 24 mph
- Humidity: 81%
- Pressure: 30.12"
- Gusts: NA

---

**Weather Report**

Ushuaia, Argentina

**Current Conditions - °F | °C**

Local Reporting Station

- **39°F**
  - Feels Like: 30°
- Wind Chill: 39°
- Heat Index: 39°
- Dew Point: 36°
- Visibility: 6 mi
- Wind: 0 mph
- Humidity: 87%
- Pressure: 30"
- Gusts: NA

---

**Weather Report**

Ushuaia, Argentina

**Current Conditions - °F | °C**

Local Reporting Station

- **39°F**
  - Feels Like: 39°
- Wind Chill: 39°
- Heat Index: 39°
- Dew Point: 36°
- Visibility: 6 mi
- Wind: 0 mph
- Humidity: 87%
- Pressure: 30"
- Gusts: NA

---

**10-Day Weather Forecast**

<table>
<thead>
<tr>
<th>Days</th>
<th>Graph</th>
<th>Table</th>
<th>Descriptive</th>
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<td><img src="45%C2%B0" alt="45°F" /></td>
<td><img src="36%C2%B0" alt="36°" /></td>
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<td>Wednesday 05/04</td>
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<td><img src="36%C2%B0" alt="36°" /></td>
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<td><img src="31%C2%B0" alt="31°" /></td>
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<td>Friday 05/06</td>
<td><img src="40%C2%B0" alt="40°F" /></td>
<td><img src="33%C2%B0" alt="33°" /></td>
<td>Clear</td>
</tr>
<tr>
<td>Saturday 05/07</td>
<td><img src="41%C2%B0" alt="41°F" /></td>
<td><img src="37%C2%B0" alt="37°" /></td>
<td>Partly Cloudy</td>
</tr>
</tbody>
</table>
Activity 1.2: Setting Up the Driving Question Board (DQB)

You teacher will provide instructions for this space.

This space is provided for note-taking, if desired.
Getting Ready
Think about the heat of summer. You and your friends decide that it would be fun to go to the beach tomorrow, so you turn on the television to listen to the weather forecast. The weatherperson says it will be hot and sunny, so you decide to make plans to go to the beach. The next day, you all arrive at the beach, but soon the clouds move in and it begins to rain. Your day at the beach is ruined. What happened to the weather forecast of hot and sunny?

Think about what you know about weather forecasting. How far in advance do you think accurate weather forecasts can be made?

Answers will vary.

In class, you looked at data about the weather for a specific city. The data provided information on the current conditions and then it predicted the weather for the next five days. You learned that the conditions that make up the weather are temperature, humidity, air pressure, wind, clouds, and precipitation. If they interact in a particular way, they can produce storms. Scientists look for these patterns of interaction to help them predict the weather.

Most people have listened to a weather forecast that turned out to be wrong. Meteorologists are people who study and forecast the weather. They use technology to study the clouds, winds, and temperature in order to look for patterns to help them forecast the weather. In other IQWST units, you used patterns to help you figure out the answers to questions. In the IQWST IC1 unit, you saw that different gases created different color patterns on the light spectrum. You could use this pattern to tell one gas from another. In the IQWST LS1 unit, you looked for patterns in the data in NetLogo to help identify predator/prey relationships.

In this unit, you will look for patterns in the weather conditions you identified. This will help you figure out how conditions like temperature, humidity, pressure, and wind interact to produce storms. Once you figure out the patterns, you will be able to answer the Driving Question: What Makes the Weather Change?
Can Cloud Patterns Predict Weather?

One pattern that meteorologists use is clouds. Cloud patterns have been used to predict weather for centuries. From the time of the ancient Greeks until today, clouds have been used as signs of the weather to come. Most of the changes in the weather that clouds can predict happen within two or three days. They are useful for predicting day-to-day changes in weather. People have studied clouds over long periods of time and identified three main patterns in clouds that are very good indicators of weather to come. These three main cloud types or patterns are called *cumulus*, *stratus*, and *cirrus*.

The big, white, puffy clouds that are spread across the blue sky in the top picture promise a dry afternoon. These clouds are called *cumulus* clouds, and this pattern in the clouds indicates that the weather will be fair and dry.

The term *stratus* is used to describe flat, hazy clouds that are low above the Earth’s surface. They vary in color from dark gray to nearly white. Stratus clouds mean rain or, if it is cold, snow. Stratus clouds do not bring heavy rain and snowstorms the way some other types of clouds do. Stratus clouds usually bring drizzle or very light precipitation. If you are talking about a cloudy day, you are usually talking about a sky filled with stratus clouds that hide the sun. They look like a huge gray blanket that hangs low in the sky.

Have you ever gotten up in the morning and not been able to see across the street because the fog was so thick? What do you think fog is? Would you be surprised to learn that fog is really a cloud? Sometimes stratus clouds are on the ground or very near the ground, and then we call them fog.

High, see-through, wispy clouds are called *cirrus* clouds. If there are only a few in the sky, the weather will not change, but when you see a lot of these clouds, it can be a sign that the weather will change tomorrow or the next day. This type of cloud pattern lets meteorologists know that stormy weather is on the way.

The last type of cloud is one that you probably have seen on a stormy day. You may call them *thunderheads*. These
Lessons 1: What is Weather?

You are going to read an article about a group of people who do not use any technology but are able to make a very accurate prediction about the weather six months in advance. As you read, pay attention to what these farmers use to predict the weather and how clouds play an important part in their prediction.

Can Stars Help People Predict the Weather?

What if people did not have technology for forecasting the weather? Could they predict storms or major weather events correctly? Some farmers in South America predict the weather six months in advance by looking at the stars. In the predawn early morning, bright, clear stars lead farmers to predict plenty of rain and a successful growing season for their crops. If those stars appear less bright, farmers plant their crops later, because they are expecting less rain, and they expect it to come later in the season. Both the amount and the timing of the rain affect the growing season. Looking to the stars is important to these farmers to help determine when they should plant their crops.

Can Clouds Help with the Weather Forecast Months from Now?

You have been reading about cloud patterns that help meteorologists predict weather in the near future. Scientists who study and forecast the weather a week or more into the future also use technology to study weather conditions, including clouds.

Do you think the clouds you see today could help you predict what would happen six months from now? Why?

Responses will vary—but look for students to answer why.

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Responses will vary—but look for students to answer why.
A group of scientists studied what the South American farmers do to see if their ideas make sense scientifically. It may surprise you to learn that farmers who look to the stars have correctly predicted El Niño for hundreds of years, but scientists only have had the technology for predicting El Niño for about 20 years. Watching the stars is a successful way for farmers in the Andes Mountains to forecast the weather.

**How Accurate Is This Prediction Technique?**

El Niño is a weather pattern that brings heavy rains to South America. It does not occur every year, but because it affects crops and fishing, it is important to be able to predict when it will occur. The farmers did not know they were forecasting what is now called El Niño. They understood what the difference in the stars indicated. Each village has its own specific way of making these observations. Some watched the sky for 10 nights, while others only focused on June 24, which is the Festival of San Juan. In every case, the results are used to plan when they will plant their crops. They do this by looking at the following three things about the constellation Pleiades:

1. How bright the constellation appears
2. The date when the constellation is first visible in the sky (because sometimes it is too cloudy to see the constellation when it should first be visible in the Southern Hemisphere)
3. The position of the brightest star in the constellation

All three of these things depend on the clarity of the atmosphere. In El Niño years, clouds high in the atmosphere block the constellation. Farmers know that this means there will not be much rain during the growing season. The following diagram indicates where the clouds appear in an El Niño year. They block the Pleiades from clear view. Clouds play a big part in helping these farmers make predictions about the weather.

The scientists who wrote this article wanted to know how accurate the farmers were in their predictions. They decided to review climate data from the Andes Mountains. They reviewed cloud data from the month of June and precipitation data from October through February. They also reviewed data that showed how good the potato harvest was. They discovered that the farmers were right about 65% of the time. That is pretty amazing when you consider the farmers were using what they could see in the sky to predict what would happen with the weather six months later.
STANDARDS ADDRESSED IN THIS LESSON

Building toward Performance Expectation MS-ESS2-5
Earth’s Systems
Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.
Clarification Statement: Emphasis is on how air masses flow from regions of high pressure to low pressure, causing weather (defined by temperature, pressure, humidity, precipitation, and wind) at a fixed location to change over time, and how sudden changes in weather can result when different air masses collide. Emphasis is on how weather can be predicted within probabilistic ranges. Examples of data can be provided to students (such as weather maps, diagrams, and visualizations) or obtained through laboratory experiments (such as with condensation). [Assessment Boundary: Assessment does not include recalling the names of cloud types or weather symbols used on weather maps or the reported diagrams from weather stations.]

Building toward Performance Expectation MS-PS1-4
Matter and Its Interactions
Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.
Clarification Statement: Emphasis is on qualitative molecular-level models of solids, liquids, and gases to show that adding or removing thermal energy increases or decreases kinetic energy of the particles until a change of state occurs. Examples of models could include drawings and diagrams. Examples of particles could include molecules or inert atoms. Examples of pure substances could include water, carbon dioxide, and helium.
Background Knowledge

Systems
- In the IQWST LS2 unit, students will revisit the concept of systems. At this point, they need to know that a system is a unit of interacting parts.
- In this unit, they will be exploring the flow of matter and the flow of energy through weather systems.

Earth’s Surface
Encourage students to use the term *Earth’s surface* rather than ground. Earth’s surface is inclusive of ground, bodies of water, and objects on Earth. All of this matter absorbs solar energy. This is important for students to understand when talking about solar energy heating the Earth. If the term *ground* is used, students can think that the only thing that heats up is the dirt and soil.

Energy Transfer from the Sun
This unit focuses on students’ understanding of the basic flow of matter and energy that affects weather/temperature. Students may have seen very complex illustrations that show radiation being reflected and absorbed by the clouds and air. This unit only focuses on the absorption of energy by objects (matter) on Earth’s surface. This accounts for over 51% of the radiation from the sun. The more complex ideas around solar radiation will be handled in high school.

For your information, the approximate distribution of solar radiation is as follows:

- 4% is reflected back to space by the Earth’s surface.
- 20% is reflected back to space and scattered by clouds.
- 6% is scattered by the Earth’s atmosphere.
- 19% is absorbed by clouds and the atmosphere.
- Approximately 51% is absorbed and converted to thermal energy by the Earth’s surface.

Light Transmission
Although the first Scientific Principle for the unit is stated in Activity 2.2: “Most of the light energy from the sun is transmitted through the air to the Earth’s surface,” a more nuanced statement would be, “Once light energy reaches Earth’s atmosphere, most light energy is transmitted through the air to Earth’s surface.” Light passes not just through the “air,” as we use the term to identify the atmosphere most immediately surrounding us, but it also travels through space (where there is no air) and through the many layers of Earth’s own atmosphere, such as the exosphere, thermosphere, mesosphere, stratosphere, and troposphere. Even given the many layers through which light travels, most of the sun’s energy still reaches all the way to the Earth’s surface. Middle school standards do not address this content, which is why the suggested wording for the Scientific Principle is less detailed.
Setup

Activity 2.2
This activity uses pea-sized solid vegetable shortening balls. You may make these ahead of class or have students make them during the setup time.

SAFETY GUIDELINES

• A heat source is used in Activity 2.2. Review lab safety procedures when using hot objects.

Differentiation and Other Strategies

1. You may do the second activity as a teacher demonstration or as a group activity. Depending on the amount of time in the class period, you may choose to set up part or all of the apparatus prior to class.
2. You might encourage students to go beyond the curriculum to learn more about layers of the atmosphere (exosphere, thermosphere, mesosphere, stratosphere, troposphere) or what is meant by space or outer space.
3. As the reading in this lesson deals with cooking by conduction, students might ask about cooking by convection or about cooking in a microwave oven. Students might also wonder whether cooking directly over a fire (e.g., toasting a marshmallow over a campfire, cooking on a grill) is also conduction. These topics would tie in-class learning to out-of-class experiences, and would make good topics for individual pursuit. Even if no student raises these questions, you might choose to raise any of ideas as questions for further exploration.
Overview

Activity 2.1
Create a model of how the air is heated.

Activity 2.2
- Use an apparatus to determine how the air is heated.
- Construct a consensus model of how the atmosphere is heated.

Learning Performances

Students will
- construct and defend an explanation for the spread of heat through a material, or between materials, in terms of transfer of kinetic energy.
- construct and defend a model of how air is heated by the sun that includes conversion of solar energy to thermal energy in Earth’s surface and the transfer of thermal energy via conduction from Earth’s surface to air.

Building Coherence

The purpose of this lesson is to explore the concept of air temperature and to develop an understanding of how the atmosphere is heated. In the previous lesson, students determined that temperature, when referring to weather, is the measure of thermal energy in the air. They will draw on concepts of energy transfer (developed in the IQWST PS2 unit) to explain two ways the atmosphere is heated.

Timeframe

Two to three 50-minute class periods
Activity 2.1: It Is Heating Up

Building toward Performance Expectation MS-ESS2-5
Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.

Disciplinary Core Idea ESS2.C: The Roles of Water in Earth’s Surface and Processes
- 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.

Disciplinary Core Idea ESS2.D: Weather and Climate
- Because these patterns are so complex, weather can only be predicted probabilistically.

Science and Engineering Practices: Asking Questions and Defining Problems; Developing and Using Models; Constructing Explanations and Designing Solutions; Engaging in Argument From Evidence

Crosscutting Concepts: Energy and Matter; Systems and System Models

Materials

For Each Student
- SE Activity 2.1

Introducing the Activity
Establish the idea that weather is a system and will be studied as a system. Discuss with students what they have learned about interactions.

- What does it mean when objects interact? (When two or more objects have an effect on one another, it is called an interaction.)
If students did the IQWST LS1 unit, they learned that an ecosystem is the interactions between biotic and abiotic factors in an area. Other examples of systems could include the human body system, an electrical system, and the solar system. In this unit, weather and storms are called a system because the conditions of which they are made interact.

In Lesson 1, students identified matter and energy as two key elements of weather. Students will be tracing matter within the system and also tracing the flow of energy through the system by looking at the conditions that interact to create the system.

Review the DQB, which should now contain these items:

- Wind—Moving air.
- Temperature—A measure of the thermal energy in matter. Thermal energy is the kinetic energy of the random motion of the particles in an object.
- Precipitation/clouds—The movement of evaporated water, moisture in the air (water vapor).

In Lesson 1, students agreed that when talking about weather, temperature refers to the measure of the thermal energy of air—the relative warmness or coolness of the air. In this activity, they will focus on the condition of temperature. Where does the thermal energy come from?

**Introducing the Activity**

Students should refer to the idea that all energy is being transferred.

By tracing the matter and energy, students decided in Lesson 1 to try to figure out how storms are created. Discuss with students what they know about energy.

Students should refer to the idea that all energy is being transferred.

- **Where does the energy come from?**
- **When you talked about temperature, what was heating up and cooling off? (air)**

Discuss with students what they have learned about what happens when an object (matter, like air) gets hotter.

- **What makes up all matter? (All matter is made up of particles called molecules.)**
- **What happens to the molecules when an object gets hotter? (The molecules in an object are constantly moving and bouncing into each other. When they are heated, they move around faster and bounce off each other more. This movement is called kinetic energy.)**
The kinetic energy due to molecular motion is called thermal energy. Temperature is an indication of this energy.

Discuss the following ideas with students. If they have done the IQWST PS2 unit, examples from that unit are in parentheses following the idea. Otherwise, use whatever examples are familiar to students.

- **Where does the energy come from to heat the Earth?** *(from the sun as solar or light energy)*

- **How do we know that light energy can heat things? What examples can you think of?** *(Solar energy can be used to heat water. Students observed this when they heated beakers with dark and clear water and observed the temperature increases. They read about solar energy being used to heat water.)*

- **What else can happen when light interacts with matter such as water?** *(Heating the beakers with dark and clear water showed reflection, transmission, and absorption, but at different proportions.)*

- **What is the relationship between light energy and thermal energy?** *(Temperature of the water increased when it absorbs the light energy. An increase in the temperature of an object—in this case, the water—is an indication of an increase in the object’s thermal energy.)*

Review temperature-related questions on the DQB, and probe student understanding with questions such as:

- **If temperature is the measure of thermal energy of air (atmosphere), how does air get heated? In what ways could the atmosphere be heated?** *(Students will most likely think that the solar energy emitted from the sun is responsible for heating the atmosphere. They may think that the air absorbs the solar energy.)*

- **Do you have any idea why temperature changes in one location or from one day to another?** *(Students may demonstrate some understanding that air masses can move or some variables that affect the amount of thermal energy in an air mass can change. If not, prompt them to this understanding. Make it clear that the variables that affect air mass do not include day/night.)*

- **What may happen to molecules in an air mass if the temperature changes?** *(They can become more or less energetic.)*
WHAT MAKES THE WEATHER CHANGE?

Make sure that students understand the difference between the movement of the object (air mass) and the movement of its particles. Ask students to explain the difference between the object getting hotter and the object moving. Both involve energy, but how are they different? Students should refer to the difference between the object moving and its particles moving. The particles in an object are always moving, and they move faster when the object is heated. This increases the kinetic energy of the particles. The more kinetic energy the particles have, the more thermal energy the object has.

If students have worked in the IQWST PS2 unit, ask them about the example of children on a bus. They can refer to the children moving around, bumping into each other when they are on the bus. This is the kinetic energy of the particles (children) and the thermal energy of the bus. If the bus starts to move, all of the individual particles (children) that are moving now move together as one unit. Therefore, the kinetic energy of the moving bus also increases.

At the beginning of this discussion, students were asked to think about how air is heated. They agreed on the following ideas:

- The sun emits solar energy.
- Light is the source of energy in objects (matter).
- Light can be reflected, transmitted, or absorbed.
- Solar energy can be converted to thermal energy when absorbed.
- Light can heat things up.

Do these ideas help explain how air is heated? Ask students what tool(s) they have used previously to understand what is happening with something they can observe directly. If students have done the IQWST PS1 unit, they constructed a model of how they see. In the IQWST IC1 unit, they constructed a model of the particulate nature of matter. In this activity, students will construct a model of how the Earth’s air is heated.
Guiding the Activity

Creating a Model of How Air Is Heated

Using SE Activity 2.1, students will engage in an activity to construct the model. Explain to students that, based on what they understand about matter and energy and how matter can be heated, they are to work in a group to construct a model showing how air is heated. Their model needs to show the following:

- energy source
- matter that is being heated
- processes that are occurring (e.g., absorption, conversion)
- arrows showing the transfer of energy

After the models are completed, groups will share them. Possible models that may emerge are the following:

1. Air—The air absorbs the solar energy and converts it to thermal energy.
2. Ground—Objects on the Earth’s surface absorb most of the solar energy and convert it to thermal energy. This does not explain how the air is heated.
3. Both—The objects on the Earth’s surface and the air absorb the solar energy and convert it to thermal energy.

Use several models from the students’ groups to begin to develop a consensus model of how air is heated.

Developing a Consensus Model

Review concepts from group models. The symbols < . . . > indicate possible concepts from students’ models.

<The sun emits solar energy.> If students completed the IQWST PS2 unit, they learned that light energy coming from the sun is called solar energy. This is a concept that they should understand.

<Solar energy heats the surfaces it hits.> Students should give examples from personal experience that solar energy can heat things.

- If I am out in the sun, my skin sometimes begins to feel warm.
- When I go barefoot in the summer, the sand (or cement) is warm.
- If I leave my bike in the sun, the handlebars get hot.

Students should be able to state that the sun heats all matter on the Earth’s surface, because it is absorbed and converted into thermal energy.
Discussion: Synthesizing

Purpose: To explain that their model shows how air is heated.

Help students understand that the solid and liquid objects on the Earth’s surface absorb most of the solar energy. Discuss with students what they know about light being transmitted. If they completed the IQWST PS1 unit, remind them that when they heated the dark water, it got hotter than the clear water.

- What happened to the light in the clear water? *(Most of it was transmitted because the water was clear.)*
- What happened to the light in the dark water? *(Most of it was absorbed and the temperature went up.)*
- Is the air more like the clear water or the dark water? Do you think the solar energy is absorbed or transmitted by the air? *(The air is clear like the clear water, so it seems that most of the solar energy would be transmitted.)*

Have students copy the class model on SE Activity 2.1 and answer the Making Sense questions.

- Does our model answer the question, “How is the Earth’s air heated?”
- Is there anything missing from our model?
- If the air transmits most of the solar energy it receives, how does the air get heated? Prompt students to think about how the thermal energy is transferred to the air.
- Where is most of the thermal energy absorbed? *(It is absorbed by the surface of the Earth.)*
- Does our model explain how the thermal energy from the surface gets into the air? What do you think happens? *(Students may know from IQWST PS2 that energy can be transferred, but they have not learned yet about the kind of transfer [conduction] that happens here.)*

In the next activity, students will try to answer the question of how the thermal energy from the Earth’s surface gets into the air.
Activity 2.2: A Little Heat from Me to You

Building toward Performance Expectation MS-PS1-4
Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.

- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.
- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations.

**Disciplinary Core Idea PS3.A: Definitions of Energy**
- The term "heat" as used in everyday language refers to both thermal motion (the motion of atoms or molecules within a substance) and radiation (particularly infrared and light). In science, heat is used only for this second meaning; it refers to energy transferred when two objects or systems are at different temperatures.

**Science and Engineering Practices:** Developing and Using Models; Planning and Carrying Out Investigations; Constructing Explanations and Designing Solutions; Obtaining, Evaluating, and Communicating Information; Analyzing and Interpreting Data; Engaging in Argumentation From Evidence; Asking Questions and Defining Problems

**Crosscutting Concepts:** Patterns; Energy and Matter

**Materials**

**For Each Group (Either Class Demonstration or Group Activity)**
- (1) ring stand
- (1) metal bar
- (1) burette clamp
- (1) hot plate
- (4) pea-sized solid vegetable shortening balls
- paper towels*
- (1) paper plate

**For Each Student**
- SE Activity 2.1
- SE Activity 2.2
- Lesson 2 Reading One

*This item is not included in the kit. Equipment included in the kit.
Introducing the Activity: Investigating Heat Transfer

Students left Activity 2.1 with a question about how thermal energy is transferred from the Earth’s surface to the air. Ask: “What examples can you think of in which thermal energy is transferred between objects?” Prompt students with an example to begin, if needed.

- a spoon that gets hot when you put it into a cup of hot chocolate
- your hand touching the outside of a cup that had hot water inside
- your finger touching a hot iron that burns your finger

Students should set up the activity according to the directions on SE Activity 2.2. The setup should be similar to the following diagram.

Guiding the Activity: Setting Up the Apparatus

- A metal rod is placed perpendicular to the ring stand bar so that it is touching the heat source. (Do not turn on the heat source until the setup is complete.) The heat source can be either a hot plate or a short, stubby candle. Be sure that the crossbar is touching the heat source.
- Place a paper towel under the shortening balls, but away from the heat source.
- Soften and shape the solid shortening into four pea-sized balls.
- Press the balls on the crossbar at equal intervals beginning at the end opposite the heat source.

After students record and explain predictions, they should complete the investigation using SE Activity 2.2.
Discussion: Pressing for Understanding

Purpose: To define the process of conduction.

Have students share the results of the activity and gauge how it compared to their predictions. Engage students in a Pressing for Understanding discussion in order to answer the question from Activity 2.1: How does the thermal energy get from the surface to the air?

- What were the results of this experiment?
- What happened to the balls of shortening? (They fell off the rod but at different times.)
- Was there any pattern to the way they fell off? (The ones that were closest to the heat source fell off first.)
- Where did the heat come from? (The hot plate/candle)
- Were the shortening balls over the heat source? (No, they were away from the heat source.)
- Why do you think the shortening melted? (The rod got hot and melted the shortening.)
- Why didn’t all of the shortening melt at the same time? (The rod got hot nearest the heat source first and then the thermal energy was transferred down the rod.)
- What does this tell you about what was happening to the rod? (Students should be able to say that the entire rod did not get hot at the same time.)
- Do you think the thermal energy from the hot plate was being converted or transferred along the rod?
- What makes the rod warmer?

Press students to arrive at the molecular explanation of what is happening. (The molecules in the rod are moving faster over the heat source and have more kinetic energy. They have more thermal energy.)

- How was the thermal energy transferred along the rod? (Help students to understand that the faster-moving molecules in the rod bumped into the slower-moving molecules. Some energy was transferred to the slower-moving molecules, causing them to move faster and increase the thermal energy along the rod.)
WHAT MAKES THE WEATHER CHANGE?

1. Most of the light energy from the sun is transmitted through the air to the Earth’s surface. The Earth’s surface absorbs some of the thermal energy that reaches it. (Principle #1)

2. Particles transfer thermal energy from one place to another by collision between particles. Collisions transfer the energy of one particle to another (conduction). (Principle #2)

3. The air at Earth’s surface is primarily heated by the transfer of thermal energy from the ground below it. (Principle #3)

Return to the DQB and the Matter and Energy chart. What can we add to our chart?

Discuss the idea of a scientific principle. If students have done previous IQWST units, they are familiar with this idea. When scientists come to a common understanding about things, they call those ideas scientific principles. Students have just developed three principles about how air at the Earth’s surface is heated.

Say something like “From our discussion, it seems like we have come to a few conclusions. Let me check these with everyone to see if we all agree.” Propose each statement one at a time and ask the following questions:

- Does everyone agree (with this statement)?
- What evidence do we have to support this principle?
- Is there anything you want to add or change?
- Does this seem like an important scientific understanding that we will be able to use to answer our DQ?

1. Most of the light energy from the sun is transmitted through the air to the Earth’s surface. The Earth’s surface absorbs some of the thermal energy that reaches it. (Principle #1)

2. Particles transfer thermal energy from one place to other by collision between particles. Collisions transfer the energy of one particle to another (conduction). (Principle #2)

3. The air at Earth’s surface is primarily heated by the transfer of thermal energy from the ground below it. (Principle #3)

These questions do not need to be asked with these words or in this order, but they should be asked in some form to help the class reach consensus.
In the Temperature row of the Matter column, add the information from this lesson.
Remind students to add these ideas to their Driving Question Notes.

**Wrapping Up**

- **What do we still need to learn?**
- **How is thermal energy transferred in the air?**

Return to the class model of how the air is heated, and ask if there is anything that can be added to the model. Students should now be able to label the transfer of thermal energy from the surface to the air as conduction. The class model should include the following points:

  - the sun
  - the Earth's atmosphere (molecules)
  - labeled energy transfers and conversions

Post a copy of the consensus model of how air is heated on the DQB. We still do not know how the heated air at the surface rises to higher levels in the atmosphere or how this might contribute to a storm forming. In the next lesson, students will explore how thermal energy is transferred in the air.

**Sample Consensus Model**

![Sample Consensus Model Image]
Candidate words include system, air mass, energy transfer, conduction.

Place Principles #1, #2, and #3 on the DQB. Add a copy of the consensus model of conduction.

**Assessing Learning**

For Activity 2.1, use students’ *individual* models to assess their developing understanding of how air surrounding them is heated by the ground’s thermal energy. The class consensus model reflects the class’ understanding at this point, but the Making Sense questions may be used to elicit how students make sense of the consensus model. At the end of the lesson, after Activity 2.2, Making Sense question #4 may be used to assess students’ understanding of conduction applied to the atmosphere. Students’ individual models could be assessed before developing a whole-class consensus model to check students’ developing understanding of how air gets heated. In every instance of developing scientific principles, the class discussion enables you to assess students’ ability to generalize using evidence from their activities. You may wish to have students write independently and then share ideas, or share ideas orally with a partner first and then write before conducting small-group or whole-class discussion so that students have multiple and varied opportunities to construct understanding of the in-class investigations.

Introducing Lesson 2 Reading One: Why Does Conduction Matter?

This reading connects students’ everyday experiences to what they have learned about the phenomenon of conduction. Use the Getting Ready question to have students begin to think about how food gets hot. Prompt them to think about what is happening with the energy when food heats.

Reading Follow Up

Discuss students’ understanding of how what they have learned so far applies to how food cooks. Their responses to the “Making Sense” question at the end of the reading can serve as an assessment of their understanding of conduction. You might also bring out the pan again and revisit the scenario of putting it on a hot stove, this time adding a metal spoon to the pan and asking students to explain what happens to the spoon. Or add the metal lid and ask why the lid has a handle that is not made of metal. This extends students’ understanding of conduction, requiring them to make sense of the idea that some materials are better conductors than others—the metal conducts heat better than the material that the pot lid handle must be made of. This could be done as a discussion or as a written assessment task. In this discussion, focus as well on the energy transfers taking place. Although these examples move away from weather, they support students in developing a deeper conceptual understanding of energy transfer.
Activity 2.1: It Is Heating Up

What Will We Do?
We will construct a model of how the Earth’s air is heated.

Procedure
☐ a. With your group, use the following space to construct a model of the way the air above the Earth is heated. Use arrows to show the transfer of energy. Your model should include the energy source, what is being heated, and any process that is taking place.
Making Sense

1. Does the class model make sense to you? YES  NO

2. Explain your ideas. 
   Answers will vary.
Activity 2.2: A Little Heat from Me to You

What Will We Do?
We will determine if thermal energy can be transferred from one object to another.

SAFETY

- Be careful with the heat source as well as the objects that are heated.
- Follow lab safety procedures for working with heated objects.

Prediction

Which shortening ball will fall from the rod first, or will they all fall at the same time? (Circle one)

1 2 3 4 all at the same time

Why do you think that?
Answers will vary.
Procedure

Your teacher will show you how to set up the apparatus. You will be observing a setup similar to the following illustration.

- **a.** Record your start time at the top of the data table.
- **b.** Light or turn on the heat source. Have one person use a stopwatch to record the time when each object falls from the rod.
- **c.** Record the time on the data table.
- **d.** Calculate the difference in fall time by subtracting the start time from each fall time.
Data
Start Time: _________

<table>
<thead>
<tr>
<th>Object Number</th>
<th>Fall Time</th>
<th>Time Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Making Sense

1. What pattern did you observe with the fall time of the objects?
   Students should observe that the objects closer to the heat source fell sooner than the ones farther away. The ones farther away had a longer fall time.

2. Why did the objects fall like that?
   The thermal energy from the heat source was being conducted through the metal rod and took longer to reach the objects farther away.
3. Did the thermal energy from the heat source transfer directly to the objects?
   No, it was conducted through the metal rod and transferred to the object.

4. At the beginning of this activity you asked, How does thermal energy get into the atmosphere? How would you answer that question after doing this activity? Be sure to include energy transfers.
   Some light energy is absorbed by the atmosphere directly. The rest is absorbed by the Earth’s surface. The Earth’s surface transfers the solar energy to the air by conduction.

5. Your class will return to the class model from Activity 2.1 and add or delete elements. Be sure to adjust the copy of the model you have on SE Activity 2.1.
Lesson 2 Reading One: Why Does Conduction Matter?

Getting Ready

Have you ever hard-boiled an egg? When you start, the egg is not solid on the inside. When you crack and peel the egg and eat it, the center is cooked and firm. How do you think that happens?

Answers will vary.

In class today, you heated the end of a metal rod and saw evidence that the heat was transferred from one end to the other. You learned that this is called conduction. If you put a metal pan on the stove, even though the heat is under the pan, the metal handle on the pan can become very hot. This is just like the rod from the investigation you did in class. By conduction, the heat is transferred from the bottom of the pan to the end of the handle. In this reading, you will find out how conduction cooks food, like your hard-boiled egg.

Conduction and Your Food

Have you ever thought about how food gets hot? One way for food to cook is for the food to come into contact with a hotter object such as a pan on a stove. Think about what you do to cook hard-boiled eggs. You start with a pan of water and put it on the stove. Turn on the stove and the burner transfers energy to the pan. That is conduction. The thermal energy from the pan is transferred to the water. Because the eggs are in contact with the water, thermal energy is transferred to them by conduction. But what cooks the inside of the egg?

Have you ever helped crack an egg, or watched someone else do it? If so, then you have seen that what is inside the egg is gooey and soupy—an egg white (which is usually clear) and a squishy round yellow yolk in the middle. Why does an egg that was boiled in hot water form into something solid that you can hold in your hand? The reason why eggs transform shape when they are heated (boiled in their shell or even just fried or scrambled in a pan) has to do with what
they are made up of—a lot of proteins. Proteins are molecules that make up a large part of most living things, and it is important for us to eat proteins as part of our diet.

When the proteins of a raw, liquid egg come into contact with heat, it causes them to change form. When you increase the temperature of the food, you increase the speed of the molecules in a food. The greater their speed, the more they collide. These collisions between the molecules can lead to changes in molecular structures by creating new molecules. These collisions break apart the protein molecules and create new molecules. These new molecules have different characteristic colors, flavors, and textures from the original molecules. The formation of new molecules is called a chemical reaction. A chemical reaction is necessary to break down the proteins that are in the uncooked egg.

Remember what you learned about conduction. It is all about the motion of the molecules inside of objects. As the molecules move faster, the object has more thermal energy. Those fast-moving molecules bump into others and make them move faster. So that is what happens inside the egg. As the molecules in the egg white start to move faster, some of their energy gets transferred to the yolk. As they all move faster, the thermal energy inside of the egg increases and cooks the egg all the way to the yolk.

Describe another example of how conduction cooks a food that you like to eat.

Answers will vary. Look for students to describe conduction accurately in their example, likely drawing directly from the paragraphs above. You might choose to use this item as an assessment.

Look at the picture of the hand holding an ice cube. The ice cube that this person is holding is melting. Use what you know about conduction to draw a diagram that explains what is happening in this image. If you remembered that the energy moves from where it is warmer to where it is cooler, then your diagram should show the heat being transferred from the hand to the ice cube by conduction. As more thermal energy is transferred from the hand to the ice cube, it melts. So what does all of that have to do with weather? In this lesson, you learned that air at the surface of the Earth is heated from below by conduction. The energy is transferred to the air and the thermal energy of the air increases. Temperature measures the thermal energy of an object. You identified temperature as a condition of weather. On the DQB, the class is keeping track of what happens to matter and energy during a storm. In this lesson, you added the idea of conduction as a way that energy is transferred and moved.
What Happens to the Hot Air?

STANDARDS ADDRESSED IN THIS LESSON

Building toward Performance Expectation MS-ESS2-6
Earth’s Systems
Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.
[Clarification Statement: Emphasis is on how patterns vary by latitude, altitude, and geographic land distribution. Emphasis of atmospheric circulation is on the sunlight-driven latitudinal banding, the Coriolis effect, and resulting prevailing winds; emphasis of ocean circulation is on the transfer of heat by the global ocean convection cycle, which is constrained by the Coriolis effect and the outlines of continents. Examples of models can be diagrams, maps and globes, or digital representations.] [Assessment Boundary: Assessment does not include the dynamics of the Coriolis effect.]

Building toward Performance Expectation MS-PS1-4
Matter and Its Interactions
Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.
Clarification Statement: Emphasis is on qualitative molecular-level models of solids, liquids, and gases to show that adding or removing thermal energy increases or decreases kinetic energy of the particles until a change of state occurs. Examples of models could include drawings and diagrams. Examples of particles could include molecules or inert atoms. Examples of pure substances could include water, carbon dioxide, and helium.

Building toward Performance Expectation MS-PS3-5
Energy
Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.
Clarification Statement: Examples of empirical evidence used in arguments could include an inventory or other representation of the energy before and after the transfer in the form of temperature changes or motion of object. [Assessment Boundary: Assessment does not include calculations of energy.]
Preparation

Background Knowledge
See Unit Overview for general background knowledge for this unit.

Setup

Activity 3.1
Heating water before class is recommended. Use a tea-kettle-type container so that you can distribute the hot water to each of the groups. Small pieces of gravel help hold the heat, especially if immersed in very hot water first. Pour more hot water over the hot gravel. The activity also works with a candle rather than hot water/gravel, but be careful that the chimneys are not burned by the flame.

Activity 3.2
Students need ice water for this experiment. It is fine if the ice melts before the students use the water, as long as the water remains very cold.

SAFETY GUIDELINES
- Use safety goggles during Activities 3.1 and 3.2.
- In Activity 3.1, handle matches and the lit incense carefully. Do not walk around with them lit.
- The teacher should prepare and distribute the hot water, cautioning students not to move near it.
- Activity 3.2: Balloons are used in this activity. Be sure to learn the severity of any latex allergies and make appropriate accommodations (e.g., Can the student observe an activity with a balloon, as long as they do not handle the balloon?).
- You will burn incense in this activity. Students with asthma or other breathing difficulties may need to sit closer to a window or other ventilation, or you may need to make other accommodations such as performing a demo so that less incense is burning in the classroom.
Differentiation and Other Strategies

1. If students are not able to complete both trials in one class period, a second day may be needed. Be sure to have the hot soil and ice water ready before class.
2. The introduction to the lesson along with the introduction to the activity could be completed on Day 1, and then the actual experiment could be completed on Day 2.
Teaching Lesson 3

Overview

Activity 3.1
Investigate changes in density due to the heating and cooling of gases. Use a convection box to observe what happens to the air (smoke) when part of the box is heated and there is cooler air on the other side.

Activity 3.2
Use a physical model to determine why the warmer air rises.

Activity 3.3
- Create a consensus model of convection using the principles of convection and density.
- Create a model of how the air moves in the atmosphere.

Learning Performances
Students will

- analyze results from a physical model to explain why hot air rises and cold air sinks.
- construct and defend a model of convection that explains why hot air rises and cold air sinks in terms of movement of air masses due to density differences.
- analyze the differences between conduction and convection in terms of energy transfer and flow of matter.
- apply a model of convection to explain one cause of wind.

Building Coherence

The purpose of this lesson is to figure out what happens to the hot air once it is heated at the surface. Students will be introduced to the concept of convection as a mechanism for the movement of both matter and energy. This lesson builds on concepts from other IQWST units (IC1, IC2, and PS2) including the particle model of matter, density, and energy transfer.

Timeframe
Three 50-minute class periods
Activity

Activity 3.1: How Do Differences in Temperature Affect Air Masses?

Building toward Performance Expectation MS-PS1-4

Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.

- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations.
- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.

Disciplinary Core Idea PS3.A: Definitions of Energy
- The temperature of a system is proportional to the average internal kinetic energy and potential energy per atom or molecule (whichever is the appropriate building block for the system's material). The details of that relationship depend on the type of atom or molecule and the interactions among the atoms in the material. Temperature is not a direct measure of a system's total thermal energy. The total thermal energy (sometimes called the total internal energy) of a system depends jointly on the temperature, the total number of atoms in the system, and the state of the material.
- The term “heat” as used in everyday language refers to both thermal motion (the motion of atoms or molecules within a substance) and radiation (particularly infrared and light). In science, heat is used only for this second meaning; it refers to energy transferred when two objects or systems are at different temperatures.

Science and Engineering Practices: Developing and Using Models; Planning and Carrying Out Investigations; Analyzing and Interpreting Data; Constructing Explanations and Designing Solutions

Crosscutting Concepts: Systems and System Models; Energy and Matter
In the next activity, students will use a physical model in order to see what happens when colder air comes in contact with warmer air. This model will allow them to control the temperature of the air and observe the effects of temperature differences.
Using the Convection Box

In this activity, students will use a convection box (see picture) in order to investigate what happens when cooler and warmer air come together.

Since air is not visible, students will create smoke using incense in order to observe what happens. The smoke moves as part of the air and allows students to see how the air is moving.

If students have done either the IQWST IC1 unit or the IQWST LS1 unit, they may suggest that the incense is like the indicators that they used in those units. In Chemistry, they used an indicator paper to show the presence of ammonia in the air, and in Life Science, they used an indicator (iodine) to show when starch was present. Both of these indicators allowed students to see something that they could not see directly.

Without actually using the hot soil and smoking incense, demonstrate for them how the experiment is to be done. On SE Activity 3.1, have students predict what they think will happen during the experiment. They should predict what will happen if the incense is held over the tube above the cold water and then what will happen if it is held over the tube above the hot soil. Once they have made their predictions, have them conduct the experiment in their groups.

Students should follow the instructions on SE Activity 3.1 for completing Trial 1. They should complete their diagram and description of what happened. Be sure to check that students have set up the apparatus correctly before they begin. When Trial 1 is complete, groups should proceed to do Trial 2. Before they begin Trial 2, the teacher should check to be sure that the soil is hot enough. When Trial 2 is finished, they should complete SE Activity 3.1.
Discussion: Synthesizing
Probe: To analyze what happens when warm and cold air come together.

- Ask one group to describe what happened to the smoke in the box in Trial 1. (The smoke went down the chimney over the cold water and moved across the box and up the chimney over the hot soil. The warmer air rose.)
- Did everyone get the same results? If not, what was different?
- How does what happened compare with your prediction?
- Did you get the same results in Trial 2? (Students should indicate that in Trial 2, the smoke from the incense was not pulled into the box. If all groups did not get the same results, you may want to repeat the experiment as a demonstration. Students should all see the same thing happening to the smoke in the box.)
- What do you think happened? Why did the smoke move the way it did? (Students should reach the conclusion that the hotter air and colder air behaved differently. The hotter air rose, but the cooler air did not.)
- Why do you think the hotter air rises? (At this point, this remains an open question and should be posted on the DQB.)

In this activity, they observed what happened when air masses of different temperature came in contact. In the next activity, students will investigate what happens to a single air mass when it is heated and cooled.

Homework or Assessment
Using what students understand about convection and the model of the experiment they created, they could be asked to show how convection happens in a room by explaining what is happening to the matter and energy. They should use arrows to show the movement of air and then use energy transfer and conversion to explain what is happening.

Homework Follow Up
Have students share their diagrams and explanations of convection.
Activity 3.2: What Happens When Air Is Heated or Cooled?

Building toward Performance Expectation MS-PS1-4
Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.

- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations.
- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.

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- The term “heat” as used in everyday language refers to both thermal motion (the motion of atoms or molecules within a substance) and radiation (particularly infrared and light). In science, heat is used only for this second meaning; it refers to energy transferred when two objects or systems are at different temperatures.

Science and Engineering Practices: Developing and Using Models; Planning and Carrying Out Investigations; Analyzing and Interpreting Data; Constructing Explanations and Designing Solutions

Crosscutting Concepts: Systems and System Models; Energy and Matter
**Introducing the Activity**

In the last experiment, what happened to the heated air? It rose up and out of the box. If you want to figure out why heated air rises, what would you need to change about the last experiment? Guide students to the following ideas:

- Only hot air is needed in order to figure out what is happening to it.
- In the last experiment, the hot air left the convection box. We would need some way to trap the air. We want to trap the hot air to see what happens and then cool it to see if there are any changes.

Ask: "What do you know about air?" Students should come up with the following ideas:

- Matter is anything that has both volume and mass.
- Matter is made of molecules. (In IQWST IC1, students created a particle model of matter.)
- Molecules are always in motion.
- Air has mass and volume and is matter.

Show students the materials (bottle, balloon, and rubber band) that they will use in this experiment. Use the following prompts to get students to think about what they need to use and observe.

### Materials

<table>
<thead>
<tr>
<th>For Each Group</th>
<th>For Each Student</th>
</tr>
</thead>
<tbody>
<tr>
<td>- (1) empty, dry plastic drink bottle*</td>
<td>- (1) pair of safety goggles*</td>
</tr>
<tr>
<td>- (1) small balloon that can be stretched over the mouth of the bottle</td>
<td>- SE Activity 3.2</td>
</tr>
<tr>
<td>- (2) containers deep enough to submerge the bottle in water halfway up</td>
<td></td>
</tr>
</tbody>
</table>

(1) electronic scale

- tongs

*This item is not included in the kit.

Equipment included in the kit.
Guiding the Activity
Using SE Activity 3.2, students should read the purpose of the activity, in addition to the paragraph at the top of the page that further explains what they are going to do. Explain that the word system, in this experiment, refers to the bottle, balloon, rubber band, and air in the bottle.

Have students make predictions and complete the activity. Remind students that they are trying to figure out what happens to the matter and energy in a storm. Understanding how air behaves when heated and cooled will help them answer that question.

Discussion: Synthesizing
Purpose: To construct an explanation about why air behaves the way it does.

When students have finished, have them share their models of what they observed. Their models should show the following observations:

- When the system is heated, the warmer air in the bottle expands into the balloon. The model should show molecules farther apart, and arrows should indicate upward movement.
- When the system is cooled, the molecules should be close together, and arrows should indicate downward movement.
Use the following prompts with students for creating a consensus model of what they observed.

<table>
<thead>
<tr>
<th>Prompt</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>What happened to mass in this investigation?</strong></td>
<td>(Mass should not have changed from before heating to after heating.)</td>
</tr>
<tr>
<td><strong>What happened to volume?</strong></td>
<td>(No air was added to the bottle, but the balloon inflated. This showed that the air was taking up more space—increasing the volume.)</td>
</tr>
</tbody>
</table>

Ask: “What do you know about density?” If students worked with the IQWST IC1 unit, they learned that density is the relationship between mass and volume.

<table>
<thead>
<tr>
<th>Prompt</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>When matter is heated, it becomes less dense. The volume increases and there are fewer molecules in the same amount of space.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>When matter is cooled, it becomes denser. The molecules are closer together and take up less space.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>There are more molecules in the same amount of space.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Is hot air more or less dense than cold air? Why?</strong></td>
<td>(It is less dense because the molecules are moving faster [transfer of thermal energy] and are farther apart.)</td>
</tr>
<tr>
<td><strong>Does the experiment show that the hotter, less dense air is expanding?</strong></td>
<td>(The balloon on top of the bottle inflated. This means that the heated air in the bottle is expanding.)</td>
</tr>
<tr>
<td><strong>What happens to the air molecules in the bottle when they are cooled? How do you know?</strong></td>
<td>(They become denser because the molecules move less and are closer together. They collapse back into the bottle.)</td>
</tr>
</tbody>
</table>

Students have created models of the movement of matter and energy in two situations. In the next activity, they will combine these models to explain why heated air rises.

**Sample Convection Model**

![Sample Convection Model](image)
Activity 3.3: Why Heat Rises

Building toward Performance Expectation MS-ESS2-6
Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.

Disciplinary Core Idea ESS2.D: Weather and Climate
- 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.

Building toward Performance Expectation MS-PS3-5
Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

Disciplinary Core Idea PS3.B: Conservation of Energy and Energy Transfer
- When the motion energy of an object changes, there is inevitably some other change in energy at the same time.

Science and Engineering Practices: Asking Questions and Defining Problems; Developing and Using Models; Constructing Explanations and Designing Solutions; Obtaining, Evaluating, and Communicating Information; Engaging in Argumentation from Evidence

Crosscutting Concepts: Patterns; Systems and System Models; Energy and Matter

Materials

For Each Student
- SE Activity 3.3
- Lesson 3 Reading One

Introducing the Activity: Creating Group Models
In the first activity in this lesson, students saw smoke (air) rising in the convection box over the heat source. Then, they created a model of what happened. Next, they observed that temperature can cause differences in density and cause air to rise or sink. Then, they created a second model. In this activity, students will combine their models in order to develop a consensus model of why hot air rises.

Refer to the DQB and remind students that they are trying to figure out what happens to matter and energy as they relate to weather conditions, particularly in a storm.
Use the following prompts to help students develop a list of things to include in their model.

- What were the important elements in the experiments you just did?
- What was the effect of temperature differences?

Emphasize that it was the air that was moving in both experiments. In the convection box, the smoke helped them to see the moving air. In the second activity, they saw the air expand in the bottle into the balloon.

- Where did the matter go?
- What was happening to the molecules in the air?
- Where did the energy go? How was the energy transferred? (In the convection box, energy was transferred by conduction from the heat source to the air. Matter and energy were moved by convection because the heated air became less dense and rose. In the bottle and balloon, energy was transferred by conduction from the heated water to the bottle. The bottle transferred energy to the air. The air became less dense and expanded and rose into the balloon.)

Using SE Activity 3.3, review with students the items that need to be included in their model:

- location of the heat source
- a label to show how the air is heated (energy transfer by conduction)
- location of hotter and cooler air masses
- arrangement of molecules in each of the air masses
- small arrows showing the movement of molecules within each air mass (representing the kinetic energy of the air mass)
- large arrows showing how each mass of air is moving

Allow groups time to complete their models and write a description of what is happening.

Discussion: Synthesizing

Purpose: To reach a consensus on why hot air rises (conduction and convection model).

Bring the class together and have one group share their model with the class using the board. Compare the model to the previous bullet points. During the discussion, the class may suggest changes to the model the group has shared. The change should be made to the class model if most students agree.
In Lesson 2, students learned that energy is transferred from the Earth’s surface to the air by conduction. In the model, the energy is transferred from the heat source to the air in the same way. If conduction is not part of the model, add it now.

- **What does this model show?**
- **Does it include all of the parts?**
- **Do you agree with how the molecules are represented? What would you change?** (Students should know that during heating, molecules move faster and spread out if they can. This concept is covered in the IQWST PS2 unit.)
- **Does the model show how the air is heated?**
- **Do you agree with how the air masses are moving?**
- **What do you know about the molecules in a cooler air mass?** *(They are closer together than in a warmer air mass.)*
- **Does this model show a difference in the arrangement of molecules in the hotter and cooler air masses? If not, how should the model be changed to show this?**
- **Does the model show how the air masses moved? If so, how?** *(The model should show the hotter mass rising and the cooler one moving in to take its place.)*
- **How should the model be changed to show this?**
- **Did the heated air move the same way in the bottle?** *(The hotter air moved up and into the balloon, but once all the air was heated, there was no cooler air to move in to take its place. It was also different from the convection box, because there was not a constant heat source.)*
- **Is there a heat source in the diagram?**
- **Why is the heat source important?** *(If there was no heat source, there would not be a temperature difference. The temperature difference occurs because energy is transferred from the heat source to the air. That causes the molecules in the air above it to move faster and increase its thermal energy.)*
- **How is energy transferred from the heat source to the air?**

The idea that “Differences in temperature can cause air to move” should be added to the DQB in the Matter column of the Temperature row. In the Energy column, add the following information: “Energy is being transferred from the heat source to the air, increasing the kinetic energy of the molecules. This is conduction. The hotter air becomes less dense and rises and transfers energy to the air above. As it rises, cooler air moves in to take its place. Energy is transferred by the movement of the air mass. This is convection.”
Both of these words *conduction* and *convection* should be added to the consensus model. The class model should be similar to the following one but should reflect students’ suggestions and ideas. Allow students a few minutes to copy the class consensus model onto SE Activity 3.3.

If students have completed the IQWST PS2 unit, ask them about the example of kids on a bus. They can refer to the kids moving around and bumping into each other when they are on the bus. This is the kinetic energy of the particles (kids) and the thermal energy of the bus. If the bus starts to move, all the individual particles (kids) that are moving move together as one unit. Then the kinetic energy of the moving bus is also increasing.
Discussion: Synthesizing

Purpose: To synthesize ideas about conduction and convection and apply the consensus model to what happens in the atmosphere.

- Do you think that this model of convection can help us explain what happens in the atmosphere?
- How do you think what happens in the atmosphere would be similar? Different?

Remind students that they are trying to figure out what happens to weather conditions to create a storm.

- How would understanding how air moves in the atmosphere help explain a storm?
- Since you already have a model of convection, do you think you can take that model and create a model of what happens in the atmosphere?

On the board or on paper to project with a document camera, create a model of how air in the atmosphere moves using the principles of conduction and convection. Remind students that in this model, they are talking about large air masses.

In Lesson 2, they learned that a large parcel of air that has similar properties throughout is called an air mass.

- What do you need to make convection happen? (You need a heat source.)
- How is air above the Earth heated? (It is heated from below by conduction.)
- What is the heat source in your model? (The Earth is the heat source.)
- How is this heat source different from the convection box? (This heat source is not constant; it changes.)
- What happens to the air as it is heated according to your model of convection? (The thermal energy from the Earth is transferred to the air. The air molecules move faster and farther apart. They become less dense than the air around them and rise.)
- What label on the model should show transfer of thermal energy from Earth to air? (The label should be conduction.)
- How would you arrange the molecules of air? (They should be farther apart than the surrounding air [less dense].)
- What label on the model should show the molecules of heated air rising? (The label should be convection.)
- What happens to the air as it cools? (The air has less thermal energy. Molecules of the air are closer together—denser. More molecules are closer to Earth.)
- What happens in the space left by the rising, less dense air? (Cooler, more dense air moves in to fill in the space left by the rising air.)
- What do you call moving air? (Moving air is called wind.)
- What created the wind in your model? (The temperature/density differences between cooler and warmer air caused convection.)
- Does anyone want to add anything else to the model?
- If not, can we agree that this is how we think air moves in the atmosphere based on what we understand about convection?
- Are there questions about how air moves in the atmosphere that you still have? If so, add these to the DQB.

Once the class agrees on the model of how air moves in the atmosphere, post it on the DQB. See the following sample model.
Wrapping Up

Return to the list of Scientific Principles and add the following:

- When thermal energy is transferred from the heat source (Earth) to the air, it increases the kinetic energy of the air molecules and the air becomes less dense and rises. (Scientific Principle #4)
- When warmer, less dense air rises, cooler, more dense air moves in to take its place (convection). (Scientific Principle #5)

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What does this lesson have to do with weather? Both wind and temperature are on the DQB as weather conditions that are important in a storm. Is what we learned in this lesson enough information for us to explain what happens to cause a storm?

- What do we still need to learn?
- Do any of the other conditions we saw in the weather data contribute to a storm?

Add any new questions to the DQB.

In the next lesson, students will investigate other factors (pressure, humidity, and lift) in order to develop a storm model.

Candidate words include density, convection, open/closed systems.

Candidate items include students’ models from this lesson, objects from the investigations such as a bottle with a balloon attached, or a photo or drawing of the convection box. Post Scientific Principles #4 and #5 on the DQB. To the Energy column on the DQB, add an explanation of convection; to the Matter column add the scientific principle about convection; to the Matter column add that differences in temperature can cause air to move. By the end of Lesson 3, add the consensus model of why heat rises.

Assessing Learning

Models from SE Activity 3.1 can be used to assess students’ understanding of the process of convection. SE Activity 3.2 Making Sense questions can be used to assess students’ understanding of the movement of matter and energy when two air masses collide, as well as when one air mass is heated and cooled. The Making Sense question from Lesson 3 Reading One can be used to assess students’ understanding of the movement of matter and energy in thermal radiation and convection. Always, individual models, explanations, or questions in the SE may be assessed prior to pairs, small-group, or whole-group aim of consensus. The discussion in which students develop Scientific Principle #4 will help you to gauge how well students are able to generalize using evidence from their investigations.
Introducing Lesson 3 Reading One: Why Learn about Convection?
Ask students if they have ever roasted marshmallows over a fire or grill. Use the Getting Ready question to have them think about how the marshmallows cook if they are not in the fire. This reading focuses on common, everyday examples of convection.

Reading Follow Up
Review student understanding of how food cooks with convection. Their responses to the “Making Sense” question at the end of the reading can serve as an assessment of their understanding of convection. Focus your discussion on thermal energy transfer to the air, heated air rising, and cooler air moving into its place. Some students may have experience with convection ovens at home and will be able to discuss how food cooks more evenly and faster in all areas of the oven because the heated air is moving throughout the oven.
What Will We Do?
We will investigate what happens if cold air and warm air are next to each other.

SAFETY
- Wear goggles when handling hot water and hot soil.
- Be sure to clean up any water or soil that spills.
- Be careful when lighting the incense with the match, and make sure the match is no longer burning before throwing it away.
- Dispose of water and soil as directed by your teacher.

Prediction
One, what do you think will happen to the smoke from the incense if you hold it above the glass tube that is over the cold water?

Answers will vary.

Two, what do you think will happen if you put it above the tube that is over the hot soil?

Answers will vary.
Procedure
There are two trials in this activity. Record the results of each trial in the boxes on the chart. Your teacher will have an example of the setup for you to look at.

Trial 1: Smoke on the Cold Side
☐ a. Assemble the materials for the apparatus according to your teacher’s direction. It should look the same as the example that your teacher has set up.
☐ b. Your teacher will give you a dish with hot soil. Be sure to handle the dish carefully.
☐ c. Place the dish of hot soil under the chimney on the left side of the box. The dish of cold water should go under the chimney on the right side. Slide the glass over the front of the box.
☐ d. Use a match to carefully light the incense. Hold the incense with the smoking end at the opening of the chimney above the cold water.
☐ e. Do not move around or bump the table while you are watching the smoke, because it will disturb the air inside the box.
☐ f. Shine the flashlight at the window of the apparatus to help you see the smoke.
☐ g. Draw a picture of what you observe happening in the box labeled Trial 1. Be sure to include the water and soil in your diagram.

Answers will vary.
Trial 2: Smoke on the Hot Side
☐ h. Have your teacher check to make sure that the soil is still hot enough to do Trial 2. It may be necessary to replace the soil with new hot soil.
☐ i. When the apparatus is set up, hold the incense with the smoking end over the dish of hot soil.
☐ j. Shine the flashlight at the window of the apparatus in order to observe what is happening to the smoke.
☐ k. Draw a picture and write a description of what you observe in the Trial 2 box.
☐ l. After you complete both trials, return all equipment and clean your work area.
☐ m. Complete the Making Sense questions that follow.
   Answers will vary.
### Data

<table>
<thead>
<tr>
<th>Trial 1</th>
<th>Trial 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagram</td>
<td>Diagram</td>
</tr>
<tr>
<td>Description</td>
<td>Description</td>
</tr>
</tbody>
</table>
Making Sense

1. Based on what you saw in this activity, what do you think is happening to the matter and energy in this experiment?
   The energy is being transferred from the heat source to the air. The air is expanding (becoming less dense) and rising.

2. What do you still need to be able to explain?
   Answers will vary.
Activity 3.2: What Happens When Air Is Heated or Cooled?

What Will We Do?
We will create a model of what happens to air when it is heated and cooled.

Prediction
This is a picture of the equipment you will use to do this activity. First, you will heat the bottle by putting it in a dish of very hot water. Then, you will cool it by filling the bowl with ice.

Predict what you think will happen to each of the parts when they are heated and cooled.

- When heated, the bottle will __________ Answers will vary.
- When cooled, the bottle will __________ Answers will vary.
- When heated, the balloon will __________ Answers will vary.
- When cooled, the balloon will __________ Answers will vary.

Procedure
☐ a. Gather the materials necessary to perform the activity. Your teacher will specify these.
☐ b. Follow the steps and be sure to fill in the chart as you go along.
  ☐ 1. Place the balloon over the neck of the bottle, making sure there is a good seal and that no air can escape.
  ☐ 2. Weigh the bottle and the balloon. Record the weight.
  ☐ 3. In the chart, describe what the balloon and bottle look like before you begin.
  ☐ 4. Stand the bottle in the container and have your teacher add the hot water. Let the bottle sit in the hot water for two minutes. On the chart, record any changes in the balloon or bottle.
  ☐ 5. Remove the bottle from the hot water and immediately place it in the ice water bath for two minutes. Record any changes on the chart.
  ☐ 6. Remove the bottle from the ice-water bath. Allow the bottle to return to room temperature. While you wait for the bottle to return to room temperature, clean your work area and return everything except the scale/balance.
  ☐ 7. Weigh the bottle and balloon again and record the data. Be sure to describe what the room temperature bottle and balloon look like.
Data

Weight of Balloon and Bottle
At room temperature before heating and cooling: ______ Answers will vary.
At room temperature after heating and cooling: ______ Answers will vary.
Change in weight: ______ Answers will vary.

<table>
<thead>
<tr>
<th>At Room Temperature (Before)</th>
<th>After Heating</th>
<th>After Cooling</th>
<th>At Room Temperature (After)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description of Bottle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The bottle feels hot.</td>
<td></td>
<td>The bottle feels cold.</td>
<td></td>
</tr>
<tr>
<td>Description of Balloon</td>
<td>The balloon is not inflated and is hanging down.</td>
<td>The balloon inflates.</td>
<td>The balloon deflates. It looks like it did at the beginning.</td>
</tr>
</tbody>
</table>

Making Sense

1. Return to your prediction at the beginning of the activity. Compare your prediction to what actually happened. Record your comparison.
   Answers will vary.
2. Create a model to show what happened to the matter (air) and the energy in the activity you just completed. Your model should include what happened to the matter and energy when the bottle was heated and then when it was cooled.
   - location of heat source
   - label for how air is heated
   - the arrangement of molecules in the bottle and the balloon
   - arrows to show the movement of molecules

Answers will vary.

The models should show that thermal energy is being transferred by conduction from the hot water to the water bottle and then from the water bottle to the air inside. Arrows should indicate that the air molecules are moving faster and farther apart causing the balloon to expand.
Activity 3.3: Why Heat Rises

What Will We Do?
Develop a consensus model of why hot air rises.

Procedure
☐ a. Use your description of what happened in Activity 3.1 and your diagram from Activity 3.2 to start your model. Be sure to include the following items in your model:
☐ 1. location of heat source
☐ 2. label for how air is heated
☐ 3. location of hotter and cooler air masses
☐ 4. the arrangement of molecules in each air mass
☐ 5. small arrows showing the movement of molecules in each air mass
☐ 6. large arrows showing how each mass of material moves
☐ b. Add anything that you have learned about density to your model that will help explain why heat rises.
☐ c. After you have drawn your model, write a description of what is happening in your model. Be sure to include what is happening to both the matter and the energy.

Data
Group Model of Why Heat Rises
Use your model to explain why warmer air rises.

Answers will vary.

Models will vary but should include the following: location of heat source, label for how air is heated, location of warmer and cooler masses of air, arrangement of molecules in each air mass, small arrows to show movement of molecules in each air mass, and large arrows to show movement of air masses.
Use this space to record the consensus model of why hot air rises.

**Consensus Model of Why Heat Rises**
Diagram should be the same as the class consensus model.
Making Sense

1. If you hold your finger next to the flame on a candle like the one in the picture, you can feel heat, but you will not get burned; however, if you hold your finger above the candle, you will. Use what you know about the movement of matter and energy to help to explain why this happens.

Thermal energy is transferred to the air above the flame and the heated air rises. As the heated air rises, cooler air moves in to take its place. This causes convection and more hot air to rise. Some thermal energy is radiated from the flame to the side of the candle, and that is why you feel heat. It is hotter above the candle because of convection.
Lesson 3 Reading One: Why Learn about Convection?

Getting Ready

Have you ever sat by a fire and roasted marshmallows? If you hold the marshmallows above the fire or coals and slowly turn the stick, they will cook and become golden brown. Sometimes if you are not careful, they can burn or even catch fire. How do you think that can happen if they are not in the flames but are above the fire?

Have you ever watched a fire burn and seen the sparks from the fire rise and swirl above the fire? The sparks are following the movement of air away from the fire. What do you think is causing the air to rise? In class, you learned that convection is a process that moves both energy and matter.

How Does Convection Toast the Marshmallow?

In Lesson 2, you learned that air is heated from below, so the fire heats the air above it. When a fire burns, both matter and energy are being moved. As it heats, the space between the molecules in the air increases. This makes the air less dense, and it rises. As it moves upward, it carries the extra energy with it. As the hotter air rises, cooler air moves in to take its place. This air is then heated and rises. When it moves farther from the fire, it cools, becomes denser, and sinks.

This diagram is a model of convection taking place around a fire. Notice how the air above the fire is being heated and rising. The red arrow shows the air above the fire heating and rising, carrying more thermal energy. The cooler air near the fire is pulled in. It is then heated and rises. This is what causes the sparks to swirl above the flame. They are caught in the air that has been heated by the fire and is rising. As long as the fire continues to burn, this convection current will continue to move the air and energy.
What does that have to do with roasting marshmallows? You know that if you put your marshmallow directly in the fire it will burn, but there is enough thermal energy in the air above the fire to heat your marshmallow until it turns a golden brown like the one in the image. Even if only hot coals are left, they continue to heat the air above them by conduction. The air carries enough thermal energy to roast the marshmallows.

**Where Else Does Convection Occur?**

Have you ever helped bake cookies? If there are two trays of cookies baking at the same time, you often need to switch the trays around, because the one on the top rack bakes faster than the one on the bottom. Most ovens, gas or electric, have their heat source on the bottom of the oven.

If the heat source is on the bottom, why would the cookies on the top shelf bake more quickly?

The top shelf cooks faster because the air is heated from below and becomes less dense and rises. There is more hot air trapped at the top of the oven because it cannot get out.

If your answer included convection, you are right. The air in the oven is heated by the heat source on the bottom and rises. Because the oven is closed, there is no place for the hotter air to go, and it is trapped on the top of the oven. Even though some of the air cools and sinks, because of the trays of cookies, there is more hot air on the top of the oven than on the bottom, so the food at the top cooks faster. This natural convection occurs in all ovens because of temperature differences and the placement of the heat source.

If there is convection in a regular oven, what is a “convection oven”? You may even have a convection oven in your kitchen. Does it look any different from the regular oven? Why is it called a convection oven?

The difference between the two types of ovens is that in a convection oven, air is moved throughout the oven with the help of a fan. In natural convection, the movement is caused by a difference in temperature. Because the air in a convection oven is constantly moving, it does not get trapped at the top and food cooks more evenly. This moving air transfers thermal energy more quickly than if the air was still. The term convection oven may be a shortened version of forced convection oven, which is a more accurate description of what is occurring.
STANDARDS ADDRESSED IN THIS LESSON

Building toward Performance Expectation MS-ESS2-4
Earth’s Systems
Develop a model to describe the cycling of water through Earth’s systems driven by energy from the sun and the force of gravity.
Clarification Statement: Emphasis is on the ways water changes its state as it moves through the multiple pathways of the hydrologic cycle. Examples of models can be conceptual or physical. [Assessment Boundary: A quantitative understanding of the latent heats of vaporization and fusion is not assessed.]

Building toward Performance Expectation MS-ESS2-5
Earth’s Systems
Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.
Clarification Statement: Emphasis is on how air masses flow from regions of high pressure to low pressure, causing weather (defined by temperature, pressure, humidity, precipitation, and wind) at a fixed location to change over time, and how sudden changes in weather can result when different air masses collide. Emphasis is on how weather can be predicted within probabilistic ranges. Examples of data can be provided to students (such as weather maps, diagrams, and visualizations) or obtained through laboratory experiments (such as with condensation). [Assessment Boundary: Assessment does not include recalling the names of cloud types or weather symbols used on weather maps or the reported diagrams from weather stations.]
Background Knowledge

Barometers
- Changes in air pressure are indications of changes in weather. This change is measured using a device called a barometer. The first barometer was created in 1643 by Evangelista Torricelli using mercury in a tube that was inverted into a bowl of mercury. He observed that the top of the mercury in the tube fluctuated by a few percent, due mainly to what we know now to be changes in air pressure. This is because the column of air directly above the setup pushes on the dish containing the mercury. This forces the mercury up the tube. The higher the pressure, the higher the mercury rises. This is where the unit, inches of mercury, is derived. Air pressure in weather reports is often reported using this measurement.
- In this activity, students will construct a water barometer, also known as a storm glass. These types of barometers have been around since the 17th century. The actual change of pressure in this device occurs too slowly for direct observation. However, over a 24-hour period, the change will be noticeable.

Fronts
- In this unit, students primarily study cold fronts where cooler air is replacing warmer air because it is along cold fronts that storms most often occur. Fronts are the leading edges of air masses.
  - Warm front—This front occurs when a warmer air mass replaces a cooler air mass. Generally, a warm front moves from southwest to northeast. Weather behind the front becomes warmer and more humid.
  - Cold front—This front occurs when a cooler air mass replaces a warmer air mass. Clouds and precipitation often occur at a cold front because the warmer air rises, cools, and condenses. The weather behind a cold front is cooler and drier.
- Other front types include two types of occluded fronts (an occluded front is a formed boundary where frontal systems of large temperature differences collide):
  - Cold occlusion—The air mass overtaking a warm front is cooler than the cool air ahead of the warm front, causing the mass to plow under both air masses.
  - Warm occlusion—The air mass overtaking a warm front is not as cool as the cold air ahead of the warm front; therefore, it rides over the colder air mass while lifting the warm air.

Instability
- To understand stability/instability, you need to know that as air rises, it cools at a rate of 5.40°F for each 305 m it rises. It cools at this rate as long as the humidity in the air is not condensing.
- The 5.40°F cooling rate is the same no matter how warm or cool the surrounding air is.
- Rising air cools at this regular rate because it is moving into lower pressure air, aloft and expanding. Expansion cools the air. (Sinking air warms at the same rate because it is being compressed as it descends.)
• Even though warm air rising from the surface cools, if it remains warmer than the surrounding air, it continues to rise. This rising air is said to be unstable.

**Humidity**

• The term water vapor rather than water should be used when referring to humidity. Water vapor is a gas that is lighter than oxygen and nitrogen. As a gas, the molecules are free to move about. Students should understand that water has three phases: solid, liquid, and gas (IQWST IC1).

• Unlike other gases in the atmosphere (~78% nitrogen, ~21% oxygen, ~1% trace gases) that remain constant, the amount of water vapor does not. All water vapor will convert back into the liquid phase through condensation and eventually leave the atmosphere.

• Humidity is the amount of water vapor in the air.

**Setup**

**Activity 4.2**

The demonstration in this activity requires practice.

Activity 4.2 is done twice. The first trial requires room temperature water. In the second trial, you will need warm and cold water. If the tap water available does not get hot, you will need to heat some before doing the activity. The water does not need to be boiling, but there should be a significant temperature difference between the warm and cold water in the second trial.

**Procedure**

**Trial 1**

1. Fill one beaker with room temperature water and add a few drops of red food coloring so that the water is dark enough to clearly see the color. Do not make it so dark that students will not be able to see what is happening.
2. Fill a second container with room temperature water and use blue food coloring, stirring to distribute the color.
3. Make sure the cups you are using match up exactly in size. Place one on top of the other before filling to ensure that they match exactly.
4. Fill one cup with the red water until it is almost overflowing. Fill the second cup with blue water until it is almost overflowing.
5. Place the index card on top of the cup containing the red water. Press down on the top of the card to form a seal. Keeping your hand flat on the card, slowly turn the cup over above the container until it is upside down. Carefully take your hand away to make sure the seal is set. Then put your hand back on the index card.
6. Move the cup with the red water over the top of the cup with the blue water so that the edges match up and the card acts as a boundary between the two cups.
7. Once the two cards are stacked on top of each other, slowly remove the index card. Be sure to keep one hand on both cups, where the rims meet, in order to be sure they stay in place.
   • What happened when the index card was removed? (*The blue and the red water mixed together.*
What do you think will happen if we turn the cups on their sides and the two masses of water are forced into each other? (Student answers may vary. They may say the water will all mix together completely, the water will separate back to red and blue, or nothing will happen.)

8. Keeping one hand on each cup, slowly turn the cups to one side while holding the middle together.

Be careful to hold them together since they are not sealed.

Note: You may want to put a thin strip of duct tape on two sides of the cup where they come together. This will not hold the cups together as you turn them, but it will make it easier to keep them lined up.

While you are preparing for Trial 2 of the demonstration, have students complete questions a and b for Trial 1 on SE Activity 4.2. Then, have students predict what they think will happen in Trial 2 when one cup has cold water and the other has hot. Use the following procedure for Trial 2. Make sure there is a significant difference in temperature between the two cups of water, or you will not get the desired results.

**Trial 2**

1. Fill one beaker with hot water and add a few drops of red food coloring so that the water is dark enough to clearly see the color. Do not make it so dark that students will not be able to see what is happening.
2. Fill a second container with cold water and use blue food coloring, stirring to distribute the color. Be sure that there is a significant temperature difference between the red and blue water.
3. Make sure the cups you are using match up exactly in size. Place one on top of the other before filling to ensure that they match exactly.
4. Fill one cup with the red water until it is almost overflowing. Fill the second cup with blue water until it is almost overflowing.
5. Place the index card on top of the cup containing the red water. Press down on the top of the card to form a seal. Keeping your hand flat on the card, slowly turn the cup over above the container until it is upside down. Carefully take your hand away to make sure the seal is set. Then put your hand back on the index card.
6. Move the cup with the red water over the top of the cup with the blue water so that the edges match up and the card acts as a boundary between the two cups.
7. Once the two cards are stacked on top of each other, slowly remove the index card. Be sure to keep one hand on both cups, where the rims meet, in order to be sure they stay in place.
8. Keeping one hand on each cup, slowly turn the cups to one side while holding the middle together.

Be careful to hold them together since they are not sealed.

Note: You may want to put a thin strip of duct tape on two sides of the cup where they come together. This will not hold the cups together as you turn them, but it will make it easier to keep them lined up.
Activity 4.3
You will need to access a storm video on the internet. It should show a building cumulonimbus cloud. Students should see the cloud building from the bottom up and spreading out. The video should enable students to answer the following:

- **What happens to the shape of the cloud?** *(Observations may include it gets bigger; it looks like clouds are forming inside of the bigger cloud; it is rising from the ground; and near the end, there are little clouds coming out of the top.)*
- **What happens to the size and shape of the cloud?** *(It gets wider and taller.)*
- **Are all parts of the cloud behaving in the same way? Explain your answer.** *(In some parts, there are smaller clouds forming. Some parts of the cloud are getting taller.)*

**SAFETY GUIDELINES**
This lesson presents no unusual safety concerns; however, see IQWST Overview for general laboratory safety.

**Differentiation and Other Strategies**
1. In Activity 4.1, data from the class barometer should be collected each day and recorded. Actual pressure readings from the daily weather report should be recorded as well. The class will return to this activity in Lesson 5 to examine the data and develop a definition of air pressure.
2. Reading the water level of the barometer can be done by the students. Each group can be responsible for a day. Students should record the water level in the tube at approximately the same time each day (e.g., the beginning of class). They should record the information on the board (or class chart) so that everyone can copy it onto their SEs.
3. Recording the actual barometric pressure from the weather report can be done through the internet or newspaper. Be sure to use the same source each time.
Teaching Lesson 4

Overview

Activity 4.1
Construct a barometer to investigate the idea that air has pressure.

Activity 4.2
Observe a simulation using water (representing air) in order to develop the concept of a front and lift caused by density differences.

Activity 4.3
Add to the model they began in Lesson 3 to complete the model of what happens in a storm.

Learning Performances
Students will

• construct and defend an explanation for how the degree of temperature difference between two air masses affects air movement.
• revise their models of convective movement of air masses to explain the phenomena of lift and instability.
• revise their models of convective movement of air masses to explain the causes of energy flow, precipitation, and air movement in convective storms.

Building Coherence
Students investigate pressure as another weather condition and simulate the processes and interactions of the conditions that lead to a storm. In Lesson 3, students discovered that differences in temperature between two air masses can cause air to move and that this movement creates wind. They created a model of how energy moves in the atmosphere. In this lesson, they build on those ideas in order to create a model of a storm, which they will test against data in Lesson 5.

Timeframe
Two to three 50-minute class periods
Activity

Activity 4.1: Constructing a Barometer

Building toward Performance Expectation MS-ESS2-5
Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.

Disciplinary Core Idea ESS2.C: The Roles of Water in Earth’s Surface Processes
- 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.

Science and Engineering Practices: Planning and Carrying Out Investigations; Analyzing and Interpreting Data; Constructing Explanations and Designing Solutions; Developing and Using Models

Crosscutting Concepts: Cause and Effect; Energy and Matter

Materials

For the Teacher Demonstration
- (1) 250mL beaker
- (1) length of glass tubing
- (1) ruler
- food coloring (red or blue)
- (1) small ball of modeling clay
- tape

For Each Student
- SE Activity 4.1

Equipment included in the kit.

Introducing the Activity
Students concluded Lesson 3 with a model of how air moves in the atmosphere via convection. Since they know that air moves, ask what else about air they need to understand in order to explain a storm.

- In your model, what caused the air to move? (Temperature differences cause air to move.)
- How were the molecules arranged in your model? (The hotter molecules were farther apart; the cooler molecules were closer together.)
- What does that tell you about the density of the hotter and cooler air? (The cooler air is denser than the hotter air.)
Based on the students’ model, they should be able to link temperature differences with density differences. Use the DQB to remind students of the other conditions they identified from the weather data.

- Do you think any of these other conditions could be related to density?
- Do you think pressure and density could be related? Why? Have students review what they know about density and pressure.
- What is the movement of molecules in an object? (kinetic energy)
- What is the total kinetic energy of all the molecules in an object? (thermal energy)
- How is thermal energy measured? (by temperature)
- If the same number of molecules is compressed into a smaller space, do the molecules become denser, and how does that affect temperature? (Yes, the molecules become denser. They are packed together more tightly and have less room to move. Therefore, less thermal energy equals lower temperature.)

Students should understand that there seems to be a relationship between temperature and density, and that pressure can cause a change in density. Ask students if they think air has pressure.

Let students know that air pressure is difficult to understand, so they are going to use a model in order to help them understand that air has pressure.

In this activity, you will construct a glass barometer so that students can observe the effect of air pressure. They will record their observations daily for two weeks. While this activity will span two lessons, it gives students the opportunity to collect their own data and observe air pressure changes.

- What do you think air pressure means? Use this question to construct a working definition of air pressure. This definition will be revised at the end of this activity and added to the Word Wall.
- Do you know what instrument scientists use to measure air pressure? Students may have heard of a barometer or barometric pressure from listening to weather reports or previous science classes.
- Do you think there is air pressure in the classroom? Why?
In this activity, construct a glass barometer for the class in order to see if they can measure air pressure. Explain each step of the setup and use the prompts to help students understand each of the parts.

**Guiding the Activity**

**Setting Up the Barometer**

1. Place a ruler in a large beaker with straight sides and tape it to one side. Make sure the numbers are visible. Review with students the markings on the ruler and how to read the measurements.

2. Tape a piece of clear plastic tubing onto the ruler in the beaker. Make sure the tubing is not touching the bottom of the beaker.

3. Fill the beaker about halfway with water. Add a drop or two of food coloring and mix. Ask students why they think you are adding the food coloring. *(The food coloring is added in order to see the change in water level more easily.)*

4. Using the tubing like a straw, carefully draw water up the tubing until the water level is the same in the beaker and the tubing. This means that the pressure is the same inside the tube and outside. Ask students why making sure that the pressure is the same inside and outside the tube is important. *(Beginning with equal pressure makes any changes easier to see.)*

5. Using your finger, trap the water in the tube. Then seal the end of the tube with modeling clay. Make sure that no air can enter the tubing. *(You may need to add more clay after a day or two to make sure the seal is still tight.)*

6. Record the level of the water in the tube. Ask students why it is important to record the starting level. *(In order to observe change, it is important to know the starting water level.)*

7. At the same time every day for the next 10 days, record the water level in the tube.
Example Setups: Making Predictions about the Barometer

Once the setup is complete, have students fill out the first section on SE Activity 4.1. If students are having difficulty with their predictions, use the following prompts:

- If you think that air has pressure, where in your setup would the air be able to push down? *(The air would push down on the water in the beaker.)*
- Why is it not pushing down on the water in the tube? *(The tube is sealed.)*
- Can the water from the beaker get into the tube? *(Yes, it can get in through the bottom of the tube because it is not sealed.)*
- If there is more pressure pushing down on the water in the beaker, where will it go? *(Students should be able to reason that the only place it can go is into the tube. Therefore, the water level in the tube would rise.)*

Discussion: Synthesizing

Purpose: To analyze and interpret data about air pressure and how that relates to local weather.

Give students a few minutes to complete SE Activity 4.1. Explain that they will come back to the data they collect about air pressure at the end of Activity 4.3. The class barometer will allow students to observe that air exerts pressure on what is below it. Since readings need to be taken over several days, students will continue to investigate what is happening with weather conditions to create a storm. Using the Convection in the Atmosphere consensus model, summarize with the class what they know about what is happening.

- What do you know about the air mass on the left side of the model? *(It is denser, has higher pressure, and is cooler than the air mass on the other side of the model.)*
- What about the other side of the model? *(It is less dense, has lower pressure, and is warmer.)*

Label the high- and low-pressure areas on the model. You may want to develop Principle #5 at this point. Low-density air columns have low pressure and high-density columns have high pressure.

- Which way did the air move when convection is taking place? Cooler to warmer or warmer to cooler? *(Cooler, more dense air moves toward warmer, less dense air. We saw this in the convection box.)*
- Since you know that convection does not always cause a storm, what else could be going on here?

Students know that temperature/density differences cause convection. Ask: “Could the size of the difference in temperature/density between the two air masses make a difference?” In the next activity, students will try to figure out the answer to the question.
Activity 4.2: Temperature Difference and Movement of Air Masses

Building toward Performance Expectation MS-ESS2-5
Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.

Disciplinary Core Idea ESS2.C: The Roles of Water in Earth’s Surface Processes
- 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.

Science and Engineering Practices: Developing and Using Models; Analyzing and Interpreting Data; Constructing Explanations and Designing Solutions

Crosscutting Concepts: Cause and Effect; Energy and Matter

Materials

For the Teacher Demonstration
- ♦ (2) large beakers to mix food coloring and water
- (2) clear plastic cups with thick rims
- red and blue food coloring
- warm and cold water*
- (1) transparent sheet
- duct tape* (optional)
- (1) pan
- paper towels*

For Each Student
- ♦ SE Activity 4.2
- ● Lesson 4 Reading One

*This item is not included in the kit.
♦ Equipment included in the kit.

Introducing the Activity
Since students already know that convection occurs because of temperature differences, they need to figure out why convection does not always cause a storm. In this demonstration, they will observe what happens when there are two different temperatures of water that come in contact with each other. You will need to do this demonstration twice, first with blue and red water that have approximately the same temperature. (See Lesson 4 Setup.)
Guiding the Activity

At the end of the last activity, students described the movement of air in the convection box as going from cooler, denser air to warmer, less dense air. Ask students if they think that the water in this demonstration will move the same way.

Since students are trying to figure out if the amount of difference between air masses affects the way they move, let them know that you will do this demonstration twice. The first time, both cups of water will have similar temperatures, so there is little difference between them. The second time, one cup will have hot water and the other cold, so there will be a large difference in temperature.

Briefly show students the setup of the first demonstration. Have them predict what will happen to the red and blue water of similar temperatures when you remove the card. Then proceed with the demonstration. (See Preparation section for directions.)

Trial 1: If this is done correctly, when the cups are turned, the students should be able to see a purplish area between the two water masses. They should also see the blue, colder water move under the red, hot water and push it up.

Trial 2: This time, students should see only a small amount of mixing of the two colors. They should see that the blue, colder water moves under the red, hot water and pushes it up.

After finishing Trial 2, have students complete questions a and b for Trial 2 in their SEs.

Discussion: Synthesizing

Purpose: To demonstrate how air masses interact.

Use the following prompts to discuss what students observed in the demonstration:

- **What was the difference between the cups in Trial 1 and Trial 2?** (In Trial 1, the two cups contained water that was the same temperature. In Trial 2, one cup had hot water and the other cold.)

- **Were the results the same in both trials? If not, how were they different?** (When the water masses were similar in temperature, they blended easily. When there was a large difference between the water masses, a boundary formed and the cold water moved under the hot water and pushed it up.)

- **Why do you think the cold water moved under the hot water in Trial 2?** (This should be linked to density differences just like in the convection model. Colder, denser water moved toward the warmer, less dense water. Because it is denser, it stayed on the bottom and lifted the warmer, less dense water up.)

- **How is what we just saw different from the convection box?** (There is no constant heat source in the cup. In the convection box, the cooler air moved in to fill the space left by the rising, warmer air. This continued as long as the air was being heated. In Trial 2,
Students should be able to say that both water and air are fluids and behave the same way. That is why water was used in this demonstration. Therefore, if two air masses collide, the results would be the same. Return to the model of air movement in the atmosphere from Lesson 3 and review what it shows. The following ideas are identified in the discussion questions that follow, and should be added to the model.

- High/low pressure—Based on density, students should label the denser air mass as high pressure, and the less dense air mass as low pressure.
- Front—This is the boundary between the less dense and denser air mass.
- Instability—Air is said to be unstable when the two masses do not mix quickly and the warmer, less dense, air continues to rise within the cooler air around it.
- Lift—The cooler, denser air mass moves under the warmer, less dense air mass and pushes it up.

- In Activity 4.1, you learned that air that is denser exerts more pressure on what is below it, and you labeled the high- and low-pressure areas on your model. Why does the denser air mass exert more pressure? (There are more molecules in the same amount of space, which means more mass and more pressure.)
- Does the model from Lesson 3 show two air masses of different temperatures and densities coming together and forming a boundary? (Identify this on the model and let students know that this is called a front.)
- Does the model show the cooler air mass moving under the warmer one? If not, how could you show that? (Draw an arrow to show the cooler air mass moving toward the warmer one. If students suggest another way to show this, use their ideas as long as the meaning is clear. Point out that this also shows the denser, higher-pressure area moving toward the less dense, lower-pressure area. It is important for students to understand that air masses move from high pressure to low pressure.)
Equilibrium

Let students know that when two air masses of different temperatures blend so that their temperatures and water vapor content are the same, that blended state is called equilibrium. A front is the boundary between these large air masses. If they are not familiar with the term equilibrium, prompt them to think through a definition. Students will develop this principle at the end of Activity 4.3.

- Reaching equilibrium in the air can happen quickly or slowly.
- In the activity with the cups and water, in which trial did you see the two masses mix quickly?

Trial 1
- Was there much temperature difference between the two masses in that trial? (no)
- Did you see lift? (no)
- When equilibrium is reached quickly, what do scientists call the atmosphere? (stable)
- What is it called if equilibrium is not reached quickly and the warmer air continues to rise within the cooler air around it? (instability)

Trial 2
- Was there much temperature and density difference between the two masses of water in Trial 2? (Yes, there was a much bigger difference between the two water masses than there was in Trial 1.)
- Where on the model would the air show instability?
- How can you show instability on the model? (Suggest to students that they write the word instability along the arrow showing lift. The lift is causing the air to become unstable because of the temperature differences between the rising air and the air around it.)

Once the model from Lesson 3 has been revised, post it on the DQB. The class model should include the following (see sample revised model):

- cooler and warmer air masses showing the arrangement of molecules in each one
- the density of each air mass, labeled: cooler air mass = denser; warmer air mass = less dense
- high- and low-pressure air masses
- warmer air mass rising and a label indicating energy transfer (convection)
- line showing the boundary between air masses, labeled front
- arrow showing cooler air mass pushing under warmer air mass
- arrow labeled lift, showing the direction of the lift
- area of instability, labeled along the lift line
Introducing Lesson 4 Reading One: How Are Oceans Like Air?
You might ask students if they have ridden a bike or skateboard against the wind (with the wind blowing in their faces) versus with the wind (with the wind blowing at their backs) and what differences they noticed. The idea to land on is that moving with the direction of the air is easier than moving against it. You might then relate this to students’ experiences with waves in the water or any other moving water and how different it is to move with versus against the flow of the water. These experiences (or others that your students are likely to relate to) can help them make sense of what they will read about ocean currents and how air and water are similar. Students will read that density differences due to the degree of salinity also influences the movement of ocean currents. Let them know that in the next class period, you want to discuss what these experiences have to do with the weather.

Reading Follow Up
Focus on the “How Do Currents Affect Weather?” section of the reading, perhaps tracing the paths of the two major currents on the class map as you read through the section aloud to be sure that students understand what happens and what effect underwater movement has on weather in various locations.
Activity

Activity 4.3: Is a Storm Cloud Different from Other Clouds?

Building toward Performance Expectation 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.

Disciplinary Core Idea ESS2.C: The Roles of Water in Earth’s Surface Processes
- Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land.

Science and Engineering Practices: Developing and Using Models; Analyzing and Interpreting Data; Constructing Explanations and Designing Solutions; Asking Questions and Defining Problems

Crosscutting Concepts: Energy and Matter; Patterns

Materials

For the Teacher
- PI: Cirrus Clouds
- PI: Cumulonimbus Clouds
- PI: Altocumulus Clouds
- PI: Fair Weather Cumulus Clouds
- U.S. Surface Analysis Map
- Storm video (Refer to the Preparation section.)

For Each Student
- SE Activity 4.3

Introducing the Activity

In this activity, students will build on their prior knowledge about clouds and precipitation and add those ideas to the model from Activity 4.2.

Discussion

Purpose: To articulate that all clouds are not the same and do not all produce rain.

Brainstorm with students what they know about clouds. The purpose here is to arrive at the idea that all clouds are not the same and that all clouds do not produce rain. Use PI: Cumulonimbus Clouds, PI: Altocumulus Clouds, PI: Fair Weather Cumulus Clouds, and PI: Cirrus Clouds to help students visualize various types of clouds they may have seen.
Lessons 4
WHERE DOES THE ENERGY COME FROM IN A STORM?

• What is similar and different about these clouds?
• Which of these clouds do you think will produce rain? Why do you think that?
• What do you know about how clouds form?

Students may use terms like condensation, water vapor, and humidity, and also make reference to the water (hydrologic) cycle (IQWST ES1, IC1).

Guiding the Activity

Review what students have previously learned about the water cycle (IQWST ES1 and IC1 units).

• What happens to the water at the Earth’s surface? (It evaporates and changes into water vapor. The water vapor condenses and becomes liquid and returns to the Earth as precipitation.)

• Can you think of everyday examples of this cycle? (Students may use various examples for evaporation, such as puddles drying up after a rainstorm, water evaporating from a glass, floors drying after being mopped, and wet towels drying. Students may use various examples for condensation, such as the bathroom steaming up when taking a shower causing water to condense on the mirror, and water condensing on the outside of a glass or can of soda.)

If students worked with the IQWST ES1 unit, they studied the water (hydrologic) cycle. They used an aquarium to demonstrate the processes of evaporation, condensation, and precipitation. They put soil in the aquarium, added water, and covered it with plastic wrap. After sitting overnight, students were able to observe that water evaporated from the soil, condensed on the inside of the plastic wrap, and then dropped into a Petri dish sitting on the soil in the bottom of the tank (precipitation).

• What do you call water vapor in the air? (It is called humidity.)

• What examples do you have that there is humidity (water vapor) in the air? (Students may use examples such as feeling sticky in the summer. Condensation is also an example of water vapor in the air. The water that is condensing is coming from the air and not from the thing on which it is condensing. For example, the condensation on the bathroom mirror after you take a shower is coming from the water vapor in the air, not the mirror.)

• What happens when water condenses in the atmosphere? (Students should know that this forms clouds, because water vapor in the atmosphere condenses around particles of dust and other material in the atmosphere and forms a cloud.)

Record the following words on the Word Wall: evaporation, condensation, and precipitation. These three processes move water in the atmosphere.
At the beginning of this activity, students looked at pictures of different cloud types and tried to figure out which one might produce rain or a storm. They have identified the three processes that move water in the atmosphere. In this activity, they are going to view a video of a building storm cloud and try to determine what is occurring.

**Storm Cloud Video**
Students are going to watch a video showing a building storm cloud. Let them know that they will see the video twice. The first time, they should simply watch and observe what is happening. Then, give them time to read through questions a1–a4 for SE Activity 4.3. This will give them a focus for viewing the video the second time. Show the video again, and then have them answer the questions.

Have students share what they observed in the video. Students may answer some of these questions differently. Encourage them to share all their observations.

- What happens to the shape of the cloud? *(Observations may include the following: it gets bigger; it looks like clouds are forming inside of the bigger cloud; it is rising from the ground; and later, there are little clouds coming out of the top.)*
- What happens to the size and shape of the cloud? *(It gets wider and taller.)*
- Are all parts of the cloud behaving in the same way? *Explain your answer.* *(In some parts, there are smaller clouds forming. Some parts of the cloud are getting taller.)*
- What happens to the top of the cloud? *(Little clouds come out of the top. Following this, the top becomes flat and it does not get any taller.)*
- Was there anything else you noticed about the cloud?

At the end of Activity 4.2, students identified clouds and precipitation as two things that still need to be added to the model. After the discussion, have students go back to the Making Sense questions to add any new understandings before they revise their consensus model.

**Discussion: Synthesizing**

Purpose: To synthesize prior knowledge and complete the storm model.

The purpose of this discussion is to use the concepts from previous lessons and units to complete the storm model. Begin the discussion by referring to the Word Wall and evaporation, condensation, and precipitation.
• What is evaporation?

• If water continually evaporates from the Earth’s surface and changes into vapor (humidity), do you think evaporation and humidity should be added to the storm model? Why?

• What examples of evaporation do you know? (puddles evaporating after a rain, water evaporating from a glass that sits overnight, towels drying)

In the IQWST IC1 unit, students learned that evaporation occurs when molecules at the surface of a liquid gain enough energy to enter the gas state.

• In your model, where do you think evaporation is occurring? Why? (Evaporation occurs near the surface of the Earth. That is where the reservoirs of water are found and where air is heated.)

At this point, add evaporation and humidity to the model. Humidity should be labeled as water vapor. (See the example of a completed model at the end of this lesson. This is only a sample and your class model should reflect student ideas.)

• What happens to water vapor when the air cools? (It condenses and forms clouds.)

  • Air cools as it rises, because it is transferring energy to the surrounding air. (This was added to the model in Activity 4.2.)
  • Water vapor in the air condenses and changes to liquid.
  • In order for water to condense, it must condense around something. In the atmosphere, it condenses around dust and other particles in the air. This forms a cloud.

At this point, draw a cloud at the top of the model and label the area condensation. Indicate on the model that this is water vapor changing to a liquid and transferring energy to the surrounding air. In the video students saw earlier, they saw clouds continue to form higher and higher up.

• What is happening to keep the clouds building up higher and higher? (Students should be able to say that since condensation is transferring energy to the air around it, the air has more thermal energy and will continue to rise.)

• What happens to that air as it cools? (It will condense and form more clouds. This will continue until there is no more water vapor in the air and no energy to be transferred by condensation.)
**Discussion: Synthesizing**

Purpose: To develop scientific principles related to how a storm develops.

Write the following question on the board, “How do the conditions of weather (temperature, air pressure, humidity, and cloud formation) interact when two air masses collide?” Allow students to work in groups to come up with language to describe these events before discussing. The principles they develop should explain how temperature, density, air pressure, and humidity differences of colliding air masses contribute to a storm. The students should describe their understanding of how energy is transferred during the processes of evaporation and condensation and should recognize tall billowing clouds as indicators of instability in the atmosphere. Students will be using these principles to develop and explain their consensus model of a storm. Guide students to construct these scientific principles using their words. (Scientific Principles #6–#12)

- Low-density air columns have low pressure and high density air columns have high pressure. Air masses move when high-pressure air pushes into the space of low pressure air.
- When warmer less dense air is lifted by cooler more dense air, the less dense air is said to be unstable as it transfers energy to the surrounding air.
- A front is the boundary between two large air masses. When two air masses of different temperatures blend so that their temperature and water vapor content are the same, we say it has reached equilibrium. If it happens quickly, the atmosphere is said to be stable and if it happens slowly, the atmosphere is said to be unstable.
- The greater the difference of temperature and pressure of two colliding air masses, the more unstable the atmosphere and more likely a storm will develop.
- Water vapor in the atmosphere condenses around particles of dust to form clouds. Humidity is a measure of the amount of water vapor in the atmosphere.
- As water vapor condenses, it changes to a liquid and releases energy to the surrounding air.
- Since condensation is transferring energy to the air around it, the air has more thermal energy and will continue to rise. As it rises, it will continue to condense and form higher clouds until there is no more water vapor in the air and no energy to be transferred.

**Wrapping Up**

- What do we know?
  - Evaporation occurs near the surface of the Earth. That is where the reservoirs of water are found and where air is heated.
  - Air cools as it rises because it is transferring energy to the surrounding air. (This was added to the model in Activity 4.2.)
  - Water vapor in the air condenses and changes to liquid.
  - In order for water to condense, it must condense around something. In the atmosphere, it condenses around dust and other particles in the air. This forms a cloud.
- What do we still need to learn?
- Does our model work?
In previous units, students have tested their model against actual data to see if it works and revise it if necessary. In the next lesson, students will test this storm model against data from an actual storm that occurred in Chicago, Illinois, in June 2010.

**Sample Storm Model**

Candidate words include air pressure, barometer, front, lift, instability, high/low pressure, equilibrium, evaporation, condensation, precipitation, humidity.

**DQB**

Candidate items include photo of clouds and photo or drawing of any investigation set-ups. Record Principles #6, #7, #8, #9, #10, #11, and #12 on the Scientific Principles list, and post either on the DQB or elsewhere in the room. Post new model of convection. Add Humidity to the Energy and Matter Chart, and post the new Storm Model.
Assessing Learning

The final Making Sense question for Activity 4.2 enables you to assess how students are thinking about the “why” of the phenomenon they observed. In a complex model such as the consensus model that will be developed following Activity 4.3, it may be helpful to ask some students to explain verbally what the model shows, or to use the model to explain how storms occur/what causes a storm. (Models should now include fronts, equilibrium, lift, and instability.) The model now also includes cloud formation and precipitation. The discussion in which students develop Scientific Principles (in their own words) may first be done—in part—individually, in pairs, or in small groups, providing students with opportunities to make general statements about what they have learned based on evidence from their investigations.
Activity 4.1: Constructing a Barometer

What Will We Do?
We will collect data to determine if air exerts pressure on the Earth’s surface.

Prediction
Predict what you think will happen to the water level in the tube (and why) if the air pressure (a) goes up or (b) goes down.

Answers will vary.
Procedure

☐ a. Draw a diagram of the barometer that is set up in your classroom.
b. Every day for 10 days, record the following data:
   □1. readings from your class barometer
   □2. air pressure reported in the weather report
   □3. a brief description of the weather on each day

**Data**

<table>
<thead>
<tr>
<th>Date</th>
<th>Class Barometer</th>
<th>Air Pressure (Weather Report)</th>
<th>Weather Description</th>
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**Making Sense**

1. How did the data from the class barometer compare to the air pressure shown in the weather report?
   Answers will depend on local data.
2. Was there a change in the weather when the air pressure changed? Describe what happened.
   
   Answers will depend on local data.

3. Using what you know about air pressure, explain what happened with the class barometer and why.

   When the air pressure went higher, the water in the tube rose because the air pushing down on the water was denser. It forced the water up the tube.
Activity 4.2: Temperature Difference and Movement of Air Masses

What Will We Do?
We will investigate what happens when water masses of different temperatures come in contact with each other.

Procedure
After each trial in the demonstration, answer the following questions:
☐ a. Describe the water in the two cups.

Trial 1:

Trial 2:

☐ b. What happened when the card between the cups was removed?

Trial 1:

Trial 2:
Making Sense

1. Why do you think the hot and cold water behaved the way they did?
Lesson 4 Reading One: How Are Oceans Like Air?

Getting Ready
On January 10, 1992, a cargo ship was traveling from Asia to North America. In the middle of the North Pacific Ocean (around 44° N latitude and 180° E longitude), a storm struck. Twelve containers fell overboard. One of them spilled and dumped 28,800 floating bathtub toys like this one into the ocean. In August and September that year, people walking along the beach near Sitka, Alaska, found hundreds of toys washed up on the shore. Twelve years later, people were still finding the floating toys.

How do you think that toy ducks could get from the middle of the Pacific Ocean to the coast of Alaska?

Why Does Ocean Water Move?
If you said that ocean waves must have moved the ducks, you were close. It is ocean movement that moved the ducks. But, rather than waves, it is ocean currents that were responsible. How do ocean currents work? You may already know that there are currents in rivers, lakes, and oceans. But did you know that there are patterns in how currents move? It may be helpful to revisit what you have learned about air to help you understand oceans. You have learned that the sun warms the Earth’s surface, which then heats the air above the Earth. Warmer air is less dense than cooler air, so the warmer air rises. As it rises, it transfers thermal energy to the cooler air around it. This air movement causes wind. Wind is actually a current in the air. The air moves, and you feel it as wind, because of differences in the temperature of air masses.

The same thing happens in water. There is a current in the ocean called Deep Ocean Circulation or the global conveyor belt. A conveyor belt is what moves groceries toward the cashier at the grocery store. Escalators and moving sidewalks are also conveyor belts. They all move continuously in a loop, as long as there is a source of energy. The same thing is true of the current in the ocean. Ocean currents move because of density differences. Air currents and water currents are both...
affected by temperature. Ocean currents are also affected by how much salt is in the water. The word for this is *salinity*. Cold, salty water is dense. Just like with air, cooler (and saltier) water sinks to the bottom of the ocean. Warmer water is less dense and remains on the surface.

You saw the difference in class as you used blue water and red water to model what happens in the air. Now, you can think about the blue water and red water as modeling water. When the colder, blue water and warmer, red water met, the cold, blue water sank and pushed the warmer, red water upward. Cold water is more dense and sinks, just as cooler air does. As that happens, it pushes less dense, warmer water upward, just as happens with warmer air.

**How Does the Global Conveyor Belt Work?**

The global conveyor belt begins on the surface of the ocean, near the North pole. In the far North Atlantic, the water is chilled by arctic temperatures. The water there is cold and salty. When sea ice is formed, the water freezes, but the salt does not. That means the salt is left behind in the unfrozen (liquid) water. Cold, saltier water is denser and sinks toward the bottom of the ocean. Warmer surface water moves in to replace the sinking water. The moving water creates a current.

Deep ocean water moves south and begins to warm near the equator. It continues south to the edge of Antarctica. There, where temperatures are very cold, the water cools and sinks again. It behaves just as it did in the North Atlantic. This gives the conveyor belt a new push. The cold water again moves, but this time it moves northward toward the North Atlantic. In a loop, the cycle continues. Scientists have estimated that it can take 1,000 years for a “parcel” of water to make a complete loop on the conveyor belt.

**Why is Understanding Currents Useful?**

The *Gulf Stream* is the name of a powerful, warm, and fast Atlantic Ocean current. It begins at the tip of Florida. The Gulf Stream follows the eastern coastlines of the United States and Newfoundland before it crosses the Atlantic Ocean. Eventually it splits in two. The northern stream crosses to Northern Europe, and the southern stream moves toward West Africa. People have been aware of the Gulf Stream for hundreds of years. But it wasn’t until 1770 that Benjamin Franklin drew the first map of it. This drawing shows how he mapped the Gulf Stream path along the coast of the U.S.

Because Franklin was able to map the path of the Gulf Stream, ship captains were able to use the current to help their ships sail faster between England and the U.S. Think about this: Which is easier, riding your bike with the wind blowing toward you, or having the wind blow against your back? You have to work harder to ride into the wind because the wind pushes against you, pushing you backwards. But, if the wind is at your back, you can go faster, and it’s easier to
pedal. If you go surfing, paddling out to catch a wave is harder because the water is pushing you toward the shore, but riding the wave back in is much easier as you move toward the shore with the push of the water. Once ship captains learned the direction the water was flowing, they could move with the water, and use the force of the water to push them along. Knowing about this helped ship captains save two weeks off their sailing time.

The *Ocean Conveyor Belt* is the large loop that water makes around the globe. However, by studying how objects drift in the ocean, scientists have learned that water moves in smaller rings or circles called *gyres*. The two gyres located north of the Equator contain two powerful currents: the Gulf Stream in the Atlantic, and the Japanese current in the Pacific. On either side of these two large oceans, continents or other land masses affect how the currents move. Land masses stop the natural path of currents, and force them in a different direction.

**How Do Currents Affect Weather?**

Scientists now understand that not only does the Gulf Stream move water along the coast and across the Atlantic Ocean, but the Gulf Stream also transfers energy. You have learned that the air near the surface of the Earth is heated from the Earth below it. If the water in the Gulf Stream is warm, then the air above it will be warm, too. Water in the oceans absorb energy from the sun, and release some of that energy as the water warms the air above the ocean. The areas along coasts that warmer water passes will be warmer than the land further inland. It is ocean currents that redistribute energy as they transfer energy between hotter and colder water masses, and as they transfer energy between the surface of the water and the air above it.

This photo of palm trees looks like it could be on a tropical island, but it was taken in Ireland. What keeps Ireland’s temperature warm enough that palm trees can grow there? The warm waters of the Gulf Stream heat the air near the west coast of Ireland, and make it warmer in the winter than other cities at the same latitude.

Currents happen in the Pacific Ocean as well as the Atlantic. The North Pacific Current begins off the coast of Japan and moves across the Pacific Ocean. It carries warm water, just like the Gulf Stream does. When it gets to the west coast of North America, it splits in two. Part of it moves north to Canada and Alaska. The other part moves south along the coast of the U.S. Because this current brings warm waters to the area, the climate is milder than other cities at the
same latitude. That warmer and wetter climate makes it possible for palm trees to grow in Canada and strawberries to grow in Alaska, just like palm trees grow in Ireland.

As you can see, water transfers energy around the Earth just like air does. That means that the ocean affects temperature, especially in cities located on coasts. Like air currents, ocean currents move because of temperature differences in masses of water. But, unlike air currents whose density and movement depends on temperature changes, the salinity of an ocean also affects the density of the water and how it moves. The saltier the water, the more dense it becomes, and the more it will sink and push less salty water upward.

**Explaining the Rubber Duck Voyage**

Look back at your answer to the rubber duck question at the beginning of this reading. Use the space below to provide an explanation that shows what you have learned. How did the floating rubber ducks get from the coast of Japan all the way across the Pacific Ocean to Canada and Alaska? (It may be helpful to mark ideas in the reading that will be helpful in writing your response.)

Students should add that there are currents in the ocean like the Gulf Stream and Pacific Current that move in specific patterns. They learned that the current coming from Japan splits in two sending warmer water north and south. If the water moves in a specific pattern, then so would anything in the water. (Just like the pepper in the pan.) The rubber ducks would have been moved by the current across the ocean and ended up in Alaska. If a student responded “currents” at the beginning of this reading, the answer here needs to be more specific, using information learned in the reading.
Activity 4.3: Is a Storm Cloud Different from Other Clouds?

What Will We Do?
We will determine how storm clouds are different from other clouds and revise the storm model.

Procedure
□ a. You will look at a video of storm clouds that are forming. Your teacher will show you the video two times. The first time, you should watch and observe what is happening. Before you watch the video the second time, read the following questions and then look for the answers as you watch the video. Record your answers after the video is finished.

□ 1. What happens to the size and shape of the cloud?
   The cloud gets bigger and higher.

□ 2. Are all parts of the cloud behaving in the same way? Explain your answer.
   The cloud seems to be moving up from the bottom and pushing the cloud above it higher.

□ 3. What happens to the top of the cloud?
   The top of the cloud eventually flattens out.

□ 4. Was there anything else you noticed about the cloud?
   Answers will vary.
Making Sense

1. List any questions you have about what was happening in the storm cloud. After the class discussion, return to these questions to see if you can answer them.
   
   Answers will vary.

2. Record any answers to the questions that you learned from the class discussion.
   
   Answers will vary.

3. When your class has finished revising the storm model, create a final model in the following space.
   
   Answers will vary.
STANDARDS ADDRESSED IN THIS LESSON

Building toward Performance Expectation MS-ESS2-5
Earth’s Systems
Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.

Clarification Statement: Emphasis is on how air masses flow from regions of high pressure to low pressure, causing weather (defined by temperature, pressure, humidity, precipitation, and wind) at a fixed location to change over time, and how sudden changes in weather can result when different air masses collide. Emphasis is on how weather can be predicted within probabilistic ranges. Examples of data can be provided to students (such as weather maps, diagrams, and visualizations) or obtained through laboratory experiments (such as with condensation). [Assessment Boundary: Assessment does not include recalling the names of cloud types or weather symbols used on weather maps or the reported diagrams from weather stations.]

Preparation

Background Knowledge

Satellite Images
- The images of clouds on weather maps are taken by infrared satellites. Infrared satellite technology works by sensing the temperature of infrared radiation being emitted into space from the Earth and its atmosphere.
- Weather satellites not only sense this infrared light but also sense the temperature of the infrared emissions. The warmest emissions are displayed as dark grays on an infrared satellite image, while cold emissions are displayed as bright white. Computer enhancement of an infrared satellite picture increases the contrast between the different cloud features and the background, which makes more detailed analysis possible. Colors are added to make interpreting the image easier.
Radar Images
- Radar works by sending out a beam of energy, then measuring how much of that beam is reflected back and the time needed for the beam to return.
- Radar intensity is a way to see through rain. A pulse of energy is beamed through a cloud and the amount of echo returned will give the intensity of precipitation. The echo is actually a reflection of the energy, and a computer will generate a color code to indicate the amount of precipitation.
- Objects that reflect the beam back to the radar include rain, snow, sleet, and even insects. If more of the beam is sent back, the object is said to have a high reflectivity and is indicated by a bright color. Objects that return a small part of the beam have a low reflectivity and are indicated by darker colors.
- Television stations usually describe their radars as Doppler, but the images you see are almost always reflectivity images. Some radars operated by television stations have Doppler capability to show wind direction and speed, but the images are extremely complex and are much more difficult to understand than reflectivity images.

Measuring Pressure
- Scientists have several units of measure in which they report pressure. Most weatherpersons report pressure in inches of mercury (in Hg). This is what is seen on the weather report and in newspapers and is the unit of measure in the city data students received. One inch of mercury is equivalent to 33.86 millibars or 25.40 millimeters.
- Another unit of measure is the bar. The bar is a unit of pressure roughly equal to the atmospheric pressure on Earth at sea level. Pressure is also recorded in millibars: a millibar = 0.001 bar.
- Isobar is a line of equal or constant pressure. The prefix iso means equal, and bar is a unit of measure of pressure. Isobars are lines drawn on a map joining places of equal average atmospheric pressure reduced to sea level. In meteorology, the barometric pressures shown are reduced to sea level, not the surface pressures at the map locations. This allows different locations to be compared regardless of elevation.
- Average sea level pressure is 29.92 in Hg or 1013 millibars (mb).

Pressure Gradient
- The change in pressure measured across a given distance is called a pressure gradient. It is directed from areas of high pressure to low pressure. The pressure gradient force is responsible for triggering the initial movement of air.
- It is not necessary for students to learn the term pressure gradient, but they should understand the idea that the pressure changes gradually between the isobars. The closer the isobars are together, the stronger the wind.
Setup

Activity 5.2
In Activity 5.2, students will use the class barometer set up in Lesson 4.

SAFETY GUIDELINES
This lesson presents no unusual safety concerns; however, see IQWST Overview for general laboratory safety.

Differentiation and Other Strategies
Students who would be supported by additional practice with maps could use other local maps or maps from other areas or cities they have visited, cities where they have relatives, cities their families are from, cities they find interesting, or cities they are studying in social studies.
Teaching Lesson 5

Overview
Activity 5.1
Interpret the symbols on a weather map.

Activity 5.2
Investigate air pressure and its role in weather.

Learning Performances
Students will

• analyze weather maps to identify and track movement of high- and low-pressure areas.
• analyze weather maps to interpret data on cloud cover and precipitation.

Building Coherence
Students make the connection to the elements in their model from Lesson 4 and the symbols on weather maps. This is in preparation for interpreting data about a specific storm and using the model from Lesson 6. In addition, students will further develop their understanding of how air pressure is represented on maps and how it relates to fronts and weather.

Timeframe
Three 50-minute class periods
Activity 5.1: What Can Weather Maps Tell Us?

Building toward Performance Expectation MS-ESS2-5
Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.

Disciplinary Core Idea ESS2.C: The Roles of Water in Earth’s Surface Processes
- 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.

Disciplinary Core Idea ESS2.D: Weather and Climate
- Because these patterns are so complex, weather can only be predicted probabilistically.

Science and Engineering Practices: Developing and Using Models; Obtaining, Evaluating, and Communicating Information; Asking Questions and Defining Problems; Analyzing and Interpreting Data

Crosscutting Concepts: Scale, Proportion, and Quantity; Systems and System Models

Materials

For the Teacher
- PI: U.S. Surface Analysis Map (3/9/12)
- PI: U.S. Satellite Map (3/9/12)
- PI: U.S. Radar Map (3/9/12)
- PI: Map Overlay

For Each Student
- SE Activity 5.1
- Lesson 5 Reading One

Available on the Teacher Portal

Introducing the Activity

Students will test their models against actual data about a storm in order to see if it is correct. In this lesson, students will look at several different types of weather maps to learn how these conditions are represented. Review the model with students. Remind them that each piece of the model fits what they know, but they still need to see if all the pieces together can explain what they observe in a storm.
In order for students to fit the model to the storm data, they need to be able to interpret the information presented on weather maps, as well as numerical data. The maps in this activity are from March 9, 2012, and represent data collected within a one-hour period on the same day. This activity is to give students practice interpreting the information on weather maps.

This activity is structured around a series of weather maps. Before the class discusses each map, students will discuss each map in small groups and record their ideas about what the map shows as well as questions they have. Following each discussion, there is a list of the key ideas that students should have about each map.

**Guiding the Activity**

Project PI: U.S. Surface Analysis Map (3/9/12). This map shows clouds, precipitation, and pressure on a single map. This is the type of map that is used in weather reports on TV and in the newspaper. It can be difficult to interpret all of the conditions that are represented together on this map. In this activity, students will look at separate maps for each condition, in order to learn how each one is represented. They will return to this map at the end of the activity to see how all the data are combined into one surface analysis map to tell the weather story.

Have students use SE Activity 5.1 and work in small groups to answer Question #1 about this map. There is a copy of the map in the student book. When the groups finish, have them share their ideas and list them on the board. Use student ideas to identify the various representations on the map.

- **Have you seen this kind of map before? Where?** (Most students should be familiar with this representation from newspapers or TV weather.)

  Use the model from Lesson 4 on the DQB and connect that to what students saw on the map. This map is a combination of three different sets of data (cloud cover, precipitation, and pressure) that scientists have put together in one map. Prompt students to identify elements of the map and model that are similar.
On SE Activity 5.1 question 2, have students record any questions they have about this map.

Some classes may be more familiar with these representations than others. It is necessary that students understand what is shown in these representations in order to complete the activities in Lesson 6.

After the discussion, have students answer the second part of Question 2 about what they learned. If they still have questions, they should record those as well. Show students PI: U.S. Satellite Map (3/9/2012). (There is an annotated map at the end of this lesson.) This map is a satellite map of clouds over the U.S. Begin by having students answer Questions 3 and 4 about the cloud map in their SEs.

- **What elements of the model are represented on this map?** (Clouds, pressure, and possibly precipitation—this could be inferred because of the cloud cover.)
- **What do you think the letters H and L represent on the map?** (These represent areas of high and low pressure.)
- **What do the red and blue lines indicate?** (Red lines indicate warm fronts, and blue lines indicate cold fronts.)
- **What do you think the blue arrows and red circles on the lines show?** (These indicate the directions the fronts are moving.)

This is a satellite image (taken from space) that shows clouds over the U.S.

- **Are all the clouds the same color?** (Some are very light gray and others are very white.)

Understanding the Image

- Depending on students’ experience with maps, you may need to explain that in order to help understand where the clouds are located, lines have been added to the map to show where state and country boundaries are, along with lines of latitude and longitude.
- In the reading following the discussion, students will read more about satellite images of cloud cover, radar images of precipitation, and how they are produced.
- Some classes may be more familiar with these representations than others. It is necessary that students understand what is shown in these representations in order to complete the activities in Lesson 6.
Discussion: Synthesizing

Purpose: To identify and explain what color variations and symbols mean on a weather map.

Have students share what they know about visible light and infrared light (IQWST PS1).

- Visible light is light that they can see.
- Infrared light is light that they cannot detect with their eyes.

If students have worked in the IQWST PS1 unit, they have had experiences with visible light and developed a model to explain how they see.

The satellite that took this picture picks up the infrared light and shows the relative warmth of objects. Colder objects are brighter and warmer objects are darker.

• **Which clouds in the picture are warmer?** *(The clouds that are gray. These gray clouds are closer to Earth.)*

Students should relate this to what they have learned in Lesson 2 about air being heated from below. If these clouds are closer to the Earth’s surface, they are being warmed by the surface.

• **Which clouds in the picture are colder?** *(The ones that look white. These clouds are higher and thicker.)*

Briefly discuss what students observe about the map. Make sure to include the following:

- Where are the most clouds located?
- What differences do you notice in the clouds? *(Most of the clouds are light gray or white, but some are light blue, dark blue, and even green and orange.)*

Let students know that the warmest (and lowest) clouds are shown in gray. As the clouds get higher, they are shown in white. The coldest (and highest) are shown in shades of yellow, red, and purple.

Explain that the choice of color is arbitrary and not standard. The shades of gray through white are standard and are what the infrared pictures show. The colors have been added to make interpreting the data easier. This is referred to as **false color.**

• **Why do you think the clouds in the Gulf of Mexico appear to go from blue to green to yellow to orange?** *(The clouds are getting higher as they go from blue to green to yellow to orange.)*
After discussing this map, students should be able to:

- Identify clouds on a surface area map.
- Explain what the colors on the map represent.

Allow students time to answer Question 5 and record any questions they still have.

Replace the previous image with PI: U.S. Radar Map (3/9/12). In their SEs, have students record what they think this map shows and any questions they have about it (Questions 6 and 7).

- The information on this map was collected at the same time as the previous map.
- Radar maps show where precipitation is currently located.
- This map indicates the type of precipitation and its intensity by color. Use the color key at the bottom of the map to explain the coloring scheme.

**Type of Precipitation**
- Rain is indicated in yellow to red to show light to heavy rain.
- Snow is indicated in light blue to dark blue to show light to heavy snow.
- A mix of rain and snow is shown in light pink to a dark coral.

**Intensity of Precipitation**
- Rain is shown in green, orange, and red. Green is light rain and red is heavy rain.
- A mix of rain and snow is shown in light pink to red. Light pink is light precipitation and red is heavy.
- Snow is shown in blue. Light blue means light snow and dark blue is heavy.

Have students identify the types of precipitation shown on the map and their intensity.

Most of what is shown is light rain (green). There are some areas of moderate (yellow) to heavy (red) rain. In the Pacific Northwest, there are some areas of mixed precipitation (pink).

**Where would you expect to see clouds?** *(Students should indicate that there would be clouds where there is precipitation.)*

After discussing the satellite map and radar maps independently, project PI: Map Overlay, which shows the two maps merged on top of one another. (The states do not align perfectly, but the emphasis is on the weather data, which do align.)

After discussing PI: U.S. Radar Map (3/9/12) students should be able to do the following:

- Identify types of precipitation shown on the map.
- Label the intensity of the precipitation.
- Connect clouds and precipitation on the map.
Students should record anything they have learned about this map in Question 3c.

Students should know the following about air pressure (Lesson 4):

- High pressure means that the air mass is cooler and denser.
- Low pressure means the air mass is warmer and less dense.
- Cooler, denser air moves to warmer less dense air. (Students saw this in the convection box in Lesson 3.)
- Air pressure can be measured. (Students measured air pressure with their class barometer, and there are air pressure measurements on their city data.)

Ask students what questions they have about this map. Generate a list of questions and record them on the board. Be sure the following ideas are included in the questions:

- What do the dotted lines mean on the map?
- Why are the spaces between the lines not equal?
- Does where the H and L are placed mean something?

In the next activity, students will work with a pressure map to figure out how scientists determine where the yellow lines on the map should go and what they indicate about pressure areas.

Introducing Lesson 5 Reading One: How Do Scientists Get the Data?
This reading contains several images that students need to interpret based on the coloration. It will be available on the IQWST Portal for students to access. However, if that is not an option, it can be done in class so that the images can be projected. To access the IQWST Portal, you will need to log in and navigate to the lesson. The homework is a reading about how satellite and radar images are obtained and what they show. Briefly discuss with students the kinds of images they have seen on weather broadcasts. Ask what they know about how these pictures are taken. This reading will help them understand more about how the images are taken.

Reading Follow Up
Review student understanding of how satellite images are obtained and the kinds of information they provide scientists. Discuss how satellite data are used and its importance in predicting weather and weather patterns. Ask students why radar maps are colored and what coloring the maps helps scientists do. Students should be able to give several examples of how satellite data assist in interpreting weather and predicting oncoming weather patterns.
Activity 5.2: Creating an Isobar Map

Building toward Performance Expectation MS-ESS2-5
Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.

Disciplinary Core Idea ESS2.C: The Roles of Water in Earth’s Surface Processes
- 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.

Disciplinary Core Idea ESS2.D: Weather and Climate
- Because these patterns are so complex, weather can only be predicted probabilistically.

Science and Engineering Practices: Analyzing and Interpreting Data; Developing and Using Models; Constructing Explanations and Designing Solutions

Crosscutting Concept: Cause and Effect

Materials

For the Teacher
- PI: Surface Area Map with Pressure Lines
- PI: Pressure Map
- PI: Map Overlay

For Each Student
- SE Activity 5.2

Available on the Teacher Portal

Introducing the Activity
In this activity, students use a map of the U.S. that shows the air pressure readings for various locations. Have students turn to their city weather data and look at the reports of air pressure. Have several students report the data from one day in their city. Be sure to have them give the unit of measure. The city data readings are recorded in inches. Most weather reports are given in inches of mercury (in Hg). This is a measurement from a mercury barometer. Explain to students that another unit of measure for pressure is called a millibar. The values on the map students will use are in whole millibars. It is not necessary for students to understand how this measurement is derived.
Return to the questions on the board and remind students of what questions they still have about the surface area map. Let students know that in this activity, they will try to answer those questions.

Students will need SE Activity 5.2. Have students look at the map and let them know that the numbers on the map represent the pressure readings in millibars (mb) at specific locations in the U.S. Be sure to clarify that this activity is about how isobars and pressure areas are determined. It is different from their model because it does not show how storms are formed. In the last activity, students learned that the yellow lines on the surface area map indicated areas of equal pressure.

- On your map, do you see any readings that are the same?
- How could you create a line similar to the lines on the surface area map that showed areas of equal pressure? (Students may suggest connecting the numbers that are the same.)

**Guiding the Activity**

Use PI: Pressure Map and walk students through Step 3 on SE Activity 5.2, filling in the images as they draw the lines on their maps. Be sure that students use pencils to do this activity, as they may need to erase lines in order to create isobars that do not cross.

- Use a pencil to lightly draw lines connecting identical values of air pressure. Begin by finding the 1024 mb reading that is highlighted in blue. Draw a line to the next 1024 value to the northeast. Without lifting your pencil, draw a line to the next 1024 value located to the south. Then, connect that line to the one located to the southwest. Finally, return to the value highlighted in blue.

Students now have created an isobar, which is the line that connects areas of equal pressure. Have students look at the surface area map at the end of Activity 5.1, and ask if any of the yellow lines cross over each other. (Students should see that the colored lines all form irregularly shaped ovals and that none of the lines cross.)

Remind them that as they continue this activity, they need to be sure that the lines they draw do not cross one another. Have students follow the directions on the activity sheet and continue to connect readings of equal pressure to create isobars. When they have drawn all the isobars, explain that each isobar needs to be labeled with the appropriate value. In order to make the map easier to read, scientists usually only use the last two digits of the pressure value to label the line. These labels are typically placed around the edges of the map at the end of the line. If the isobar is closed, a space is placed in the isobar with the value inserted into the gap. When completed, students’ maps and the projected image should look like the following example.
Have students complete Part 2 in their SEs by labeling the center of the high-pressure area with an H, and the center of the low with an L. Steps 3 and 4 ask students to connect the areas of high and low pressure to the type of weather they would expect to see there. Review what the class model shows about high and low pressure.

- Low-pressure areas are warmer and less dense.
- Low-pressure areas contain more water vapor.
- The air in a low-pressure area rises and cools, and the water vapor condenses.
- Rain (or some form of precipitation) usually occurs in the area of low pressure.
- High-pressure air mass is cooler and denser.
- The air in a high-pressure area contains less water vapor.
- High pressure usually indicates fair weather.

Students should shade in the areas using green where they would expect to see rain or snow. Then, using yellow, shade in where they would expect clear skies. They should also answer the Making Sense question in SE Activity 5.2.

When students finish, the map should look like the following example.
Isobar Map Showing H/L Pressure Areas

(Yellow indicates area of fair weather, and green indicates rain or snow.)

When they finish, have students come up and show which areas they colored green and yellow. Have them explain why they colored those areas. Ask students the following questions:

- Do your maps look like this?
- Do you agree with the reasons for coloring the map this way?
- How is your map different?

Students should support their ideas with what they know about highs and lows from the class model. Use the discussion questions on SE Activity 5.2 so that at the end of this discussion, students understand that the change in pressure between isobars is gradual. (Some students may think that the pressure remains the same until one isobar comes in contact with another, and then the pressure immediately changes. It is important that students understand that the change is gradual. The closer the isobars are to each other, the faster the change takes place and the stronger the wind.)

Discussion: Synthesizing

Purpose: To analyze how air pressure is related to different kinds of weather.

Use PI: Pressure Map that now has the isobars, high and low centers, areas of precipitation, and clear weather on it.
• What is the difference in pressure between the center of the high and the center of the low? (~16 mb)

• Do you think that is a large or small change?

• Look at the distance between the isobars between the high and the low. Are they close together or far apart?

• Do you think that there will be a strong wind? Why? (The isobars are far apart, so even though there is a big drop in pressure, the wind will not be very strong because the pressure is changing over a large distance.)

Using the Map to Relate Pressure to Weather

Show PI: Surface Area with Pressure Lines and return to the questions from the beginning of this activity.

• Can we now answer the questions we had about the surface area map?

• What do the numbers on the yellow lines mean? (The numbers on the line are air pressure readings. The yellow line connects areas of equal pressure. They are called isobars.)

• Why are the spaces between the yellow lines not equal? (Air pressure changes depending on the temperature and density of the air mass. Every place does not change at the same time or by the same amount.)

• Does where the H and L are placed mean something? (The h and the L on the map indicate where the center of the high or low is. It is the place of highest or lowest pressure in the air mass.)

• Why do Ls appear where there are more clouds and Hs appear where it is clear? (Low-pressure areas are warmer, denser, and contain more water vapor. As the air in a low-pressure area rises, it cools, and water vapor condenses. Rain [or some kind of precipitation] usually occurs in the area of low pressure. Areas of high pressure are cooler and denser. They contain less water vapor and form fewer clouds. They usually indicate fair weather.)

• Where are clouds on the map? (Clouds on the map are mainly where there are low-pressure areas. There is also some rain there, because there are areas of green indicating precipitation.)

Some students may raise the question about the clouds in western Canada where there is a high-pressure area. If this comes up, you can explain to students that this is a mountain range and clouds often form, even in areas of high pressure, because of the evaporating snow increasing the water vapor in the air. Ask if students still have any questions about the representations on the map. At the end of this lesson, students should be able to use a surface area map to do the following:

• Identify clouds on a surface area map.
• Determine what the colors of clouds on the map represent.
• Be able to connect representations of clouds and precipitation on the map.
• Identify areas of precipitation (and the type).
• Identify areas of high and low pressure.
• Identify isobars and explain why the distance between them is important.
• Explain how pressure differences lead to wind.

Students began this activity with questions about the location of high- and low-pressure areas on the surface area map and about what the isobars (yellow lines) indicated. They should now understand how high- and low-pressure areas are determined and how they relate to weather.

Wrapping Up

• What do we know?
  In this lesson, students have learned how to interpret the following representations of weather-related data on a surface area map:
  • cloud cover
  • precipitation and intensity
  • areas of high and low pressure and the direction of their movement
  • isobars
• What do we still need to learn?
  • Can we use a surface area map like the one in this activity in order to test our model?
  • Would we need other data? What kind?

In the next lesson, students will be given maps and additional data in order to identify patterns in the data. In the second activity, they will try to fit their model and the data together.

Candidate words include radar, satellite, isobars.

Candidate items include weather map representations.

Assessing Learning

The "What did you learn from class discussion" prompts for SE Activity 5.1 can be used to assess students’ developing ability to read weather maps, specifically in relation to precipitation and cloud coverage. For Activity 5.2, their isobar maps and the Making Sense questions can be used to assess students’ developing ability to read weather maps, specifically in relation to air pressure.
Activity 5.1: What Can Weather Maps Tell Us?

What Will We Do?
We will interpret representations on a weather map.

Procedure
☐ a. The following is a surface area map like the one your teachers showed you. Look at the map with your group and answer Question a1. After the class discussion, answer Question a2.

Making Sense

Surface Area Map

Weather Forecast for Fri. Mar 09, 2012, issued 3:17 AM EST
DOC/NOAA/NWS/NCEP/Hydrometeorological Prediction Center
Prepared by McReynolds Base on HPC, SPC, and NHC forecasts
1. What do you notice on the map? List everything you can think of.
   The map shows high and low pressure centers. It also shows fronts, clouds, and precipitation.

2. What questions do you have about the map? What did you learn about this map from the discussion in class?
   Answers will vary.

☐ b. Study the following map with your group and then answer the questions. You will come back to Question 5 after the class discussion.

Cloud Cover (3/9/12)
3. Where are clouds in this picture? Where do you think there is precipitation?
   There are clouds in the middle of the U.S. going up into Canada. There are also clouds in the Gulf of Mexico, western Canada, Montana, and Idaho. The map shows precipitation in the south and north along the East Coast. There is also precipitation in Canada and states like Montana and North Dakota.

4. What did you learn during the discussion?
   Answers will vary.

5. What questions do you still have?
   Answers will vary.
c. Study the following map with your group and then answer the questions. You will come back to Question 8 after the class discussion.

**Precipitation (3/9/12)**

6. Where is the precipitation on this map?
   The majority of the precipitation is in Canada and along the Gulf Coast and the Eastern Seaboard.

7. Look back at the map of the clouds in Procedure b. What do you notice about the location of the clouds and precipitation?
   There is some cloud cover everywhere over land. The precipitation is over the East Coast and Canada.
8. What did you learn from the class discussion?
   Answers will vary.

9. What questions do you still have about the map?
   Answers will vary.
Lesson 5 Reading One: How Do Scientists Get the Data?

Getting Ready

Here is a satellite image of a hurricane near Florida. In this picture, you can see Florida and the island of Cuba. You have probably seen pictures like this in the newspaper or on the news.

In class today, you looked at images of clouds over the United States. Clouds can help scientists tell where it is raining. You learned in Lesson 4 that clouds are necessary for precipitation, so it would be important for people who predict the weather to know where the clouds are and where they are moving. The weatherperson on television refers to these as satellite images. Have you ever wondered how they get these images? In this reading, you will learn how these images are taken. You will also learn about how they get the images of rain or snow that you see.

What Is a Satellite?

A satellite is an object that moves around another object. Sometimes these are natural satellites, like the moon that orbits Earth. Sometimes satellites are man-made. Man-made satellites have many purposes. For example, they can be used for telecommunications, such as televisions and cell phones. Some cars have global positioning systems (GPS) that use satellite information in order to get directions or tell drivers exactly where their car is on a map. In the following paragraph, you will learn how satellites are used to gather information about the weather.

How do you think weather satellites gather information about the weather?

All answers are acceptable. Students will learn about how satellites work in the reading.
A weather satellite is a type of satellite that is used to monitor the weather and climate of Earth. The image that these satellites take is in the infrared band of light. In the IQWST PS1 unit, you learned that the light you see is called visible light, and light that you cannot see is called infrared light. Weather satellites are programmed to see infrared light and show the relative warmth of objects. Colder objects appear brighter, and warmer objects appear darker. The advantage to taking infrared images is that scientists can take them day or night, because objects like land and clouds never stop giving off infrared light. Look at the picture of the eastern part of the U.S. taken by a weather satellite.

When you looked at the satellite images in class, you learned that the outline of the states was added to help make the image easier to understand. Scientists have added the outline to Map 1 to help see where the clouds are located. The areas on the map that appear darker are warmer and give off more infrared light. The lighter areas are cooler and give off less infrared light. The light clouds in this image are higher and cooler. The very dark places on the map have no clouds. The darker clouds are lower and warmer. Looking at Map 2, with images that go from white to gray to darker gray to black, it is hard to tell what is going on in some places. Map 3 is from the same time and place as the other maps.
Why Do You Think Color Is Added to the Map?

Scientists often color maps to make it easier for people who are not scientists to interpret. This is called *false color* because it is not in the original image. Adding the color makes the image easier to understand. In the second image of the clouds, some clouds appeared yellow, green, blue, orange, and red. In class, you learned that the dark blue showed the highest and coldest clouds. The orange and red are the warmest and lowest.

How Do They Determine Where the Rain Is?

When giving the weather report on television, the weatherperson usually shows a radar picture of where the rain is. How does radar know where the rain is? Weather radar works just like the radar that the police use to tell how fast a car is going. The radar that the police use sends out a flash of light that cannot be seen called *radio waves*. The radar gun also has a detector in it for this type of light. The light from the radar gun travels to the target car and bounces off back to the detector in the radar gun.

However, weather radar sends out a signal that bounces off drops of water instead of a car. Have you ever noticed lines on the radar image that form a circle just like on this picture? The radar light source and detector are on a tower that rotates 360°. While it scans, the detector will detect any light that comes back to the tower if it is reflected or scattered off airborne particles. From light signals that do bounce back to the tower, weatherpersons can tell how far away the precipitation is, the direction it is moving, how fast it is moving, and whether it is rain or snow. This helps the weatherperson forecast the weather for your area.
Draw a diagram that shows how a weather radar tower can see where the water is in the atmosphere. When you see the weather radar on television, they add color to make it easier to read, just like in the satellite images.

Answers will vary.

Look at the following picture of a radar image of a storm in New York. What can you tell about the precipitation in the storm from this radar image?
What Can You Tell about the Precipitation in the Storm from This Radar Image?

If you said that it was raining, you would be right. Did you also say that the rain was heavier in some places? When you are watching the weather, the weatherperson interprets the pictures for you. On the side of this image, there is a key to help you figure out the colors. The green indicates rain, but how dark the green is tells you how intense the storm is. The next time you are watching the weather on television, think about what you learned in this reading about satellite and radar images. See if you agree with the weatherperson’s interpretation of the images. Maybe you can forecast the weather better than the weatherperson can.
Activity 5.2: Creating an Isobar Map

Part 1
What Will We Do?
We will create a map that represents air pressure data.

Procedure
☐ a. In class, you learned that millibars (mb) are a measurement of air pressure. The following map shows pressure readings for different locations in the U.S. These readings are shown in millibars.
☐ b. Use the following map and complete Steps c through e.
☐ c. Use a pencil to lightly draw lines connecting identical values of air pressure. Begin by finding the 1024mb reading. You have now created an isobar that represents 1024mb of pressure. Everywhere along that line, the pressure is 1024mb.
   Remember: Isobars are smooth lines with few, if any, bumps in them.
☐ d. Repeat this procedure with the next isobar value. This is 1020mb. Be sure that your isobars do not cross each other.
☐ e. Continue with the remaining values until you have each of the remaining values connected with an isobar.
Part 2
What Will We Do?

Isobars can be used to identify highs and lows. In a high, the pressure is greater than the surrounding area. In a low, the pressure is lower than the surrounding area. Using the same map from Part 1, complete Steps f through i.

Procedure

□ f. Label the center of the high-pressure area with a large blue H.
□ g. Label the center of the low-pressure area with a large red L.
□ h. You have learned that low-pressure areas usually have precipitation because as the warmer, less dense air rises, the water vapor condenses, forms clouds, and causes precipitation. On your map, shade in green the areas where you would expect to see rain or snow.
□ i. High-pressure areas are usually clear and dry because the cooler, denser air sinks and has less moisture in it. On your map, shade in yellow the areas where you would expect to see clear skies.
Making Sense

1. Look at the low-pressure area on your map. What is the pressure reading at the center of the low?
   The pressure reading is 1008 mb.

2. What is the pressure reading on the next isobar?
   The pressure on the next isobar is 1012 mb.

3. What do you think is happening to the pressure between those two isobars?
   It shows that the pressure is rising.
STANDARDS ADDRESSED IN THIS LESSON

Building toward Performance Expectation MS-ESS2-5

Earth’s Systems

Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.

Clarification Statement: Emphasis is on how air masses flow from regions of high pressure to low pressure, causing weather (defined by temperature, pressure, humidity, precipitation, and wind) at a fixed location to change over time, and how sudden changes in weather can result when different air masses collide. Emphasis is on how weather can be predicted within probabilistic ranges. Examples of data can be provided to students (such as weather maps, diagrams, and visualizations) or obtained through laboratory experiments (such as with condensation). [Assessment Boundary: Assessment does not include recalling the names of cloud types or weather symbols used on weather maps or the reported diagrams from weather stations.]

Preparation

Background Knowledge

Storm Explanations

Students are developing only a simple model of what happens at Earth’s surface along a single cold front, but the processes that operate at Earth’s surface also operate in the upper atmosphere. Upper-level troughs influence surface features including the formation and movement of low-pressure areas. As air rises, it cools, and moisture condenses, forming clouds and precipitation. Storms form in response to extreme pressure differences, driven by the movement of cooler and warmer air. Warmer, less dense, more humid air is forced up as cooler, denser, less humid air moves in. As warmer air is forced up, surface pressure drops. Cooler air fills the area of lower pressure, displacing warmer air, which then moves upward. As more cool air moves in,
additional warm air is forced upward, developing a cycle. The cycle continues until equilibrium between air masses is established, and calm, less-windy conditions return.

**Dropping Pressure**
- Conditions in the atmosphere change a lot over a small distance in the area of a thunderstorm. Where the rain is falling, the pressure tends to go up by a few millibars (about 0.1 inches of mercury). This is because, as the rain falls, some of it evaporates, which makes the air cooler and heavier.
- Another process is occurring that makes the picture complicated. As the air goes up into the thunderstorm’s updraft, it creates an area of low pressure under the updraft that acts to pull air in from around the thunderstorm. This low-pressure region is also typically a few millibars lower than the environment of the storm. As the rain begins to taper off, the pressure begins to rise as the high-pressure region replaces the low.

**Interpreting the Storm Data**
- Before the storm: 8:51 PM (6/1/10) to 1:51 AM (6/2/10). Note the conditions.
- During the storm: 1:51 AM to 5:51 AM. As a cold front arrives, the barometric pressure falls and then rises. The point where the cold front reached the airport is indicated by the extreme drop in temperature. The pressure continues to fall as the low-pressure air rises, creating clouds and releasing thermal energy. This causes the air to continue to rise and the pressure to drop.
- After the storm: 5:51 AM. Cooler, higher pressure air has replaced the warmer, lower pressure air that was present at the airport before the front moved through. The humidity also begins to drop. Air pressure will continue to rise, because an area of higher pressure moved in bringing cooler temperatures.

**Setup**

**Activity 6.1**
Specific instructions for activity setup are embedded within the lesson.

**Activity 6.2**

**Writing Explanations**
- Students should write their explanation in a cohesive paragraph and not in three separate sections labeled claim, evidence, and reasoning. The question they are trying to answer is, Why did the storm happen?
- Their paragraph should use the causal pattern in the data to explain why the storm happened. The data that they just analyzed are the evidence.
- Use the “Storm Explanation” to help you determine which components you expect your students to explain at this point. They should be able to connect air temperature, pressure, humidity, precipitation and movement on some level, given what they have learned so far and the data they are analyzing. Differentiating support for students in writing this explanation so that you can use it as a formative assessment will enable all students to express their understanding to the best of their ability.
Sharing Explanations

- Some groups may have similar explanations but used different data to support them. Have these groups try to combine ideas and reach agreement about their explanations.
- Multiple groups with similar explanations do not all need to present them but rather share reasoning and evidence as one explanation is presented.

SAFETY GUIDELINES

This lesson presents no unusual safety concerns; however, see IQWST Overview for general laboratory safety.

Differentiation and Other Strategies

1. Depending on students’ ability to read and interpret graphs, the initial questions may need to be done in a more guided way. The activity is constructed so that students are working in groups to interpret the data. If the class struggles with this, it may be necessary to walk through the first graph with them.
2. Students may need support in understanding the precipitation chart. The number at each time stamp indicates the amount of rain that has fallen since the last measurement.
Teaching Lesson 6

Overview

Activity 6.1
Analyze data about a storm in order to identify patterns in the data.

Activity 6.2
- Apply the consensus storm model to data about an actual storm.
- Adjust the consensus model, if necessary, and update the DQB.

Learning Performances
Students will
- apply their storm model to explain patterns in weather.
- evaluate the fit of the model against the data.

Building Coherence
In this lesson, students will apply the model of a storm that they developed in Lesson 4 to actual storm data, revising their model as necessary. This lesson allows them to answer the first part of the Driving Question: What Causes a Storm? It leads to Learning Set 2 and the idea of global patterns rather than local patterns.

Timeframe
Three 50-minute class periods
Activity 6.1: Can We Identify Patterns in Data?

Building toward Performance Expectation MS-ESS2-5
Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.

**Disciplinary Core Idea ESS2.C: The Roles of Water in Earth's Surface Processes**
- 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.

**Disciplinary Core Idea ESS2.D: Weather and Climate**
- Because these patterns are so complex, weather can only be predicted probabilistically.

**Science and Engineering Practices:** Analyzing and Interpreting Data; Engaging in Argument from Evidence; Asking Questions and Defining Problems

**Crosscutting Concepts:** Patterns; Cause and Effect

### Materials

**For the Teacher**
- PI: Surface Analysis (6/2/10)
- PI: Chart of Conditions

**For Each Student**
- SE Activity 6.1

**Available on the Teacher Portal**

### Introducing the Activity

Refer to the storm model that is on the DQB and prompt students to think about how they have used models previously in science.
• What do you know about using models in science? (Students who have done previous IQWST units will have developed a model of how they see in the IQWST PS1 unit. In the IQWST IC1 unit, they developed a model of the particulate nature of matter. If students have not done previous units, have them share examples of other models they have used.)

• How did you decide if your model was accurate? (In IQWST PS1, models explained the anchoring activity. In IQWST IC1 models were used to explain real phenomena or data.)

• How do you think you could test the storm model that the class developed? (Students should suggest that they would need data from an actual storm.)

Guiding the Activity
Establishing the Need to Test Model against Actual Data
Refer to the DQB and the conditions that make up a storm.

• Which of these conditions would you want data about in order to test your model? (Students may respond that all of them are important. The quantitative data that are included in this activity are temperature, air pressure, humidity, and precipitation.)

Students will use the map to identify where clouds are located and precipitation is occurring. Clouds are not quantitatively measured.

• What does a surface area map show you about a storm? (The surface area map shows what is happening at a specific place and time. It does not show how the storm develops or moves. Students should understand that a storm does not just instantly happen. It is a process during which conditions change.)

• How do you know that it happens over time?

• Can you think of an experience with a storm that would support your idea?

• What does the class model show about the storm? (The class model shows that many things occur to create a storm.)

• Would you want data from just during the storm? Why?

• Would it be important to know what was happening before the storm? After the storm?

• How would that help you test the model? (In order to see if the model works, students need to see the change taking place.)

• Why would using data from a specific place at different times help us test the model? (You could see how the conditions change at that place.)

• If all the conditions in the model are necessary for a storm, how would understanding how they change help decide if the model works? (Press students to see how this might help understand how the conditions in a storm are related.)
Let students know that this lesson focuses on a storm that occurred in Chicago, Illinois, on June 2, 2010. The data they will use is actual data from the National Weather Service and was collected at Midway Airport in Chicago. The data show what was happening to the conditions at the airport during an 11-hour period from 8:51 PM on June 1, through 7:51 AM on June 2. All data about conditions (temperature, humidity, pressure, and precipitation) refer to what was happening at Midway Airport at the time indicated on the x-axis of the graphs or at the time points in the charts. It is important that students understand that their model shows what is happening to create a storm in a specific location. In order to test their model, they need to see how a storm develops in a particular location.

Analyzing the Data
All of the data and maps that students use in this activity can be found on SE Activity 6.1. Begin by using PI: Surface Analysis (6/2/10). A copy of this map is also featured in students’ SEs. This representation is similar to the one used in Lesson 5.

Have students interpret what they see on the map using what they learned in the previous lesson. The goal of this brief discussion is to focus attention on what they see happening in the Midwest. Include the following questions:

- **Where are the clouds located? How do you know?** (Since city names are given on the maps, have students use those to indicate the location of the clouds. They should indicate the heaviest clouds are over St. Louis, Chicago, Des Moines, and Kansas City. These clouds are white in color. Students should indicate that they know these are clouds, because they go from gray to white. They know some are high clouds because they are very white.)

- **Where is it raining? How do you know?** (The areas of green, yellow, and orange indicate areas of precipitation. It is raining over Chicago and Kansas City.)

- **Where are the high-pressure areas? Low-pressure areas?** (There is a high-pressure area over Atlanta. There are lows near Des Moines.)

- **Are there any symbols on the map that you did not see in the previous activity?** (Students should indicate the brown line to the west of the storms along the Illinois/Indiana border. There is a second one going from Kansas into Missouri.)

- **What is happening along these brown lines?** (There are storms.)
Explain that these lines are called troughs. They are a second area of low pressure that is caused by upper-level pressure. It creates another front where warmer, less dense air rises and creates precipitation. This makes the storm stronger and more intense.

**What does the model show about the connection between areas of pressure and rain?**
*Students should understand the following:*
- **Rain forms where areas of different pressure meet.**
- **Rain forms just in front of where the two pressure areas meet, because that is where the less dense, lower pressure air is rising and forming clouds.**

Remind students that they identified temperature, precipitation, humidity, air pressure, and clouds as important conditions to look at in a storm. They will try to identify patterns in each of those conditions. The patterns are divided into three groups:

- Before the storm (8:51 PM [6/1/10] to 1:51 AM [6/2/10])
- During the storm (1:51 AM to 5:51 AM). As a cold front arrives in a particular place, the barometric pressure will fall and then rise. This is the point where the cold front reaches the airport. It is indicated by the extreme drop in temperature. The pressure continues to fall as the low-pressure air rises, creating clouds and releasing thermal energy. This causes the air to continue to rise and the pressure to drop.
- After the storm (5:51 AM [6/2/10])

**Storm Periods**
- Before the storm: 8:51 PM (6/1/10) to 1:51 AM (6/2/10). These data show the conditions at the airport before the storm.
- During the storm: 1:51 AM to 5:51 AM. As a cold front arrives in a particular place, the barometric pressure will fall and then rise. This is the point where the cold front reaches the airport. It is indicated by the extreme drop in temperature. The pressure continues to fall as the low-pressure air rises, creating clouds and releasing thermal energy. This causes the air to continue to rise and the pressure to drop.
- After the storm: 5:51 AM. Cooler, higher pressure air has replaced the warmer, lower pressure air that was present at the airport before the front moved through. The humidity also begins to drop after the storm.
- When talking about a storm moving through an area, they are talking about the air moving.
- This movement is both matter (air) and energy.

Each of the graphs has the same x-axis. Have students look at the graphs and ask the following:

**Why is it important that the graphs all have the same x-axis?** *(Students should understand that in order to compare the data during the three time periods [before, during, and after], the data need to be organized around the same time points.)*
Students should draw vertical lines on each of the graphs to indicate the three time periods. They will come back to this and discuss how scientists figure this out using the data. Students will work in groups to use the information to complete the chart on the first page of SE Activity 6.1. The chart has three columns indicating before, during, and after the storm.

Have students work in groups and complete the table and answer the questions in their SEs. Remind them that the goal of this activity is to identify patterns they see in the data. Completing this portion of the activity and the discussion that follows will take more than one class period. Students are asked to analyze four sets of data and complete the table. The Making Sense discussion that follows is critical to writing their explanation in 6.2. Be sure to spend adequate time on the discussion to ensure students' understanding of the data.

**Discussion: Synthesizing**

*Purpose:* To summarize the weather data from the graphs.

*Show PI:* Chart of Conditions. Begin with the Temperature row and have one group share their ideas. Use the following prompts to develop consensus on what the chart should look like.

- Does everyone agree with the information about temperature in the first row?
- Where do you disagree? Why?
- What data do you have to support your idea?
- Does anyone have another idea and data to support it?
- Can we all agree about the pattern in the temperature data before, during, and after the storm? Once agreement has been reached, make sure the responses in the first row fit the consensus.

After filling in the first row, use the same prompts to work through each of the other rows. If students disagree with answers, make sure they support their challenges with data from the appropriate graph. At the end of this discussion, the completed chart should be similar to the following:
### Weather Conditions (at Midway Airport) Chicago, IL

<table>
<thead>
<tr>
<th></th>
<th>Before the Storm</th>
<th>During the Storm</th>
<th>After the Storm</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Temperature</strong></td>
<td>Temperature remained steady.</td>
<td>Temperature dropped 8° at the beginning of the storm. During the storm, the temperature remained steady.</td>
<td>Temperature remained cool and stayed steady.</td>
</tr>
<tr>
<td><strong>Air Pressure</strong></td>
<td>Pressure was steady and then dropped right before the storm.</td>
<td>Pressure continued to drop during the storm.</td>
<td>Pressure rose sharply after the storm.</td>
</tr>
<tr>
<td><strong>Humidity</strong></td>
<td>Humidity remained steady before the storm.</td>
<td>There was a sharp rise during the storm.</td>
<td>After the storm, the humidity finally continued going down.</td>
</tr>
<tr>
<td><strong>Precipitation</strong></td>
<td>There was little to no precipitation.</td>
<td>The heaviest rain was between 2:51 and 4:51, with a total rainfall of 6.2 cm.</td>
<td>Rain tapers off and then stops.</td>
</tr>
</tbody>
</table>

Have students complete the Making Sense question at the end of the activity.
Activity

Activity 6.2: Can the Storm Model Explain the Data?

Building toward Performance Expectation MS-ESS2-5
Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.

Disciplinary Core Idea ESS2.C: The Roles of Water in Earth's Surface Processes
- 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.

Disciplinary Core Idea ESS2.D: Weather and Climate
- Because these patterns are so complex, weather can only be predicted probabilistically.

Science and Engineering Practices: Developing and Using Models; Analyzing and Interpreting Data; Constructing Explanations and Designing Solutions; Engaging in Argument From Evidence; Obtaining, Evaluating, and Communicating Information

Crosscutting Concepts: Patterns; Cause and Effect; Systems and System Models

Materials

For the Teacher
- PI: Temperature Data
- PI: Humidity Data
- PI: Pressure Data
- PI: Precipitation Data

For Each Student
- SE Activity 6.2
- Lesson 6 Reading One

Available on the Teacher Portal

Introducing the Activity
Remind students that the goal of this lesson is to decide if the model of a storm that they developed can be used to explain data from an actual storm. This is how they will test their model and determine if it needs to be revised.
Return to the chart created in Activity 6.1 (PI: Chart of Conditions). Review the patterns students identified for each of the conditions. Using the model, link the conditions on the chart to the model.

- **Are each of the conditions on the chart accounted for in the model?**
- **Are there items in the model that are not on the chart?** (wind, energy transfer, energy conversion, lift, instability, evaporation, and condensation)
- **How is the model different from the data you looked at?** (Students should understand that their model is descriptive and qualitative while the data are quantitative.)
- **How can you use the model to explain the data?** (Because there are patterns in the data, the model should describe those patterns.)

**Guiding the Activity**

Each group will use the model to explain the pattern in the data for that condition. They will record both what their model can explain and what questions they still have. After all groups have finished work on a single condition, groups will jigsaw in order to put together the whole storm story. They will use the data and their model to explain what happens to the matter and energy in the storm.

There are four data sets from the last activity (temperature, humidity, air pressure, and precipitation). Depending on how many students are in the class, more than one group may be working on the same data set. In order to ensure that all students can participate in the group’s discussion, groups should not consist of more than three to four students. Even though students will only be working on one condition in the first part of this activity, they have all of the data sets in their SEs. During the jigsaw, they will record information about the other data sets.

Assign each group one of the conditions on which to work. They should use their model from Activity 4.3 and the data on SE Activity 6.2 for their assigned condition.

**Discussion: Synthesizing**

Purpose: To synthesize group data and revise model if necessary.

Once all groups have identified what the model can and cannot explain about the data and any questions they still have, the groups should jigsaw so that there is a representative from each of the conditions in the new group. The new jigsaw group should combine their information and see if another group can answer any of their questions. After combining their information, each group will write an explanation of the storm based on their model to explain what is happening to both the matter and energy during the storm.
When groups have finished writing their explanations, they will share them with the class. The goal of this discussion is to determine if the class model of a storm can be used to explain actual storm data and revise it if necessary. For this group sharing, have the projected images for this activity available for students to use if they want to reference specific data.

Have one group share their explanation with the class.

- Do you all agree with this explanation of the storm based on the model?
- If you disagree, what data do not fit the model? Why?
- How did your group explain that piece of data?
- Is there other data that this group could have used to support their explanation?
- How was your explanation different?
- What data did you use to support your explanation?
- Does everyone agree?

Press students to question each other’s reasoning and evidence about the model. Students should link matter and energy to the data and what the model shows is happening. Once all groups have presented, ask: “Is there anything in the data that the model cannot explain? What?” (The model does not explain why the pressure continues to drop during the storm. It also does not show that the storm occurs over time and that one condition changing affects other conditions.)

Until now, students were not sure that their model worked to explain how a storm is created. Press them to think about their model.

- What are we claiming this model can do? (It can explain how a storm occurs.)
- Do you see anything missing from the model?
- Does the model need to be changed or adjusted in any way?
- Are you satisfied that this model explains how a storm occurs?

If necessary, adjust the class model and post it on the DQB.
Wrapping Up

Return to the Driving Question and ask students if they can answer either part of it. Students should be able to answer the part of the question that inquires, What Causes a Storm? Post their answer on the DQB. It should be similar to the following:

• Conditions (temperature, pressure, humidity, and wind) do not remain the same from day to day.
• As conditions change, the weather changes.
• Sometimes conditions interact to cause a storm.

Candidate words include trough.

Candidate items include models and explanations developed in this lesson.

Assessing Learning

Students’ responses on the Making Sense question for Activity 6.1 can be used to assess their ability to analyze patterns in weather data, which is critical to writing their explanation in 6.2. Students can also be assessed on their ability to use specific evidence from the data as support for a claim. In Activity 6.2, students’ models and explanations can be used to assess their ability to explain what is happening to both the matter and energy during a storm, and their responses to the last question in Lesson 6 Reading One can be used to assess their ability to use their models to explain other types of storms. At the end of the Learning Set, students should be able to answer with a full, CER explanation using evidence from their investigations: “What Causes a Storm?”

Introducing Lesson 6 Reading One: Is It Going to Snow or Rain or . . . ?

In Learning Set 1, students have developed a model of a storm. Have them think about the kinds of storms that occur where they live.

• Does a storm always have to include rain?
• What other kinds of storms are there?
• What kinds of storms do we have where we live?
Reading Follow Up
In class you have been developing a model of a storm. Discuss how temperature and humidity serve to predict the type of precipitation that will occur with a storm. Remind students that there are other forms of precipitation that might be predicted by temperature and humidity as well. Student responses to questions are good formative assessments of students’ understanding of temperature, humidity, and their relationship with precipitation and storm formation.
Activity 6.1: Can We Identify Patterns in Data?

What Will We Do?
We will find patterns in data from an actual storm.

Procedure
- a. Begin by answering the questions about the surface area map.
- b. With your group, use the data on the pages after the map to complete the table. Be sure to record any changes that occur or patterns that you observe in the data.
- c. Your teacher will have you draw vertical lines on each graph to show the time periods in the table. Those lines will help you to find patterns and compare them.

Data

Midwest Regional Surface Map

![Map of Midwest](image)

June 2, 2010
### Weather Conditions (at Midway Airport) Chicago, IL

<table>
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<tr>
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<td>The heaviest rain was between 2:51 and 4:51, with a total rainfall of 6.2 cm.</td>
<td>Rain tapers off then stops.</td>
</tr>
</tbody>
</table>

* Note that the temperature was reported in degrees Fahrenheit.

### Temperature Data

![Temperature Data Graph](image)

**Midway Airport (Chicago, IL)**

*June 1, 2010, at 8:51 PM through June 2, 2010, at 7:51 AM*
LESSON 6  DOES THE STORM MODEL FIT DATA FROM A STORM?

**Air Pressure Data**

**Humidity Data**
### Precipitation Data
Rainfall is stated in inches in this data set (1 inch = 2.54 centimeters).

<table>
<thead>
<tr>
<th>Time</th>
<th>Rainfall in Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:51 PM</td>
<td>N/A</td>
</tr>
<tr>
<td>9:51 PM</td>
<td>N/A</td>
</tr>
<tr>
<td>10:51 PM</td>
<td>N/A</td>
</tr>
<tr>
<td>12:51 AM</td>
<td>N/A</td>
</tr>
<tr>
<td>1:19 AM</td>
<td>N/A</td>
</tr>
<tr>
<td>1:51 AM</td>
<td>0.00 (amount too small to measure)</td>
</tr>
<tr>
<td>2:51 AM</td>
<td>1.27</td>
</tr>
<tr>
<td>3:51 AM</td>
<td>0.61</td>
</tr>
<tr>
<td>4:51 AM</td>
<td>0.40</td>
</tr>
<tr>
<td>5:51 AM</td>
<td>0.08</td>
</tr>
<tr>
<td>6:51 AM</td>
<td>0.09</td>
</tr>
<tr>
<td>7:16 AM</td>
<td>N/A</td>
</tr>
<tr>
<td>7:51 AM</td>
<td>N/A</td>
</tr>
</tbody>
</table>

**Midway Airport (Chicago, IL)**  
*June 1, 2010, at 8:51 PM through June 2, 2010, at 7:51 AM*

### Making Sense
Using what you learned about the information on surface maps in the last activity, answer the following questions:

1. Where are the storms on the map?
   
   They appear over Kansas City and from St. Louis to Chicago into Indiana and Michigan.
2. Are high-pressure and low-pressure areas shown on the map? How can you tell?
   There is a red L near Des Moines and an H over Atlanta.

3. Did any of the patterns in the data surprise you, given your model? Pick one variable that you found surprising or interesting, and explain what you thought and why.
   Answers will vary.
Activity 6.2: Can the Storm Model Explain the Data?

What Will We Do?
We will use the class storm model to explain the data from an actual storm.

Procedure
- a. Your teacher will assign your group one set of data to try to explain using the storm model your class created. You will be assigned temperature, air pressure, precipitation, or humidity. Refer to the model you created in Lesson 4 to answer the questions your group has been assigned.
- b. Jigsaw with a member from each of the other groups. Discuss what they found out about their data and record it in your own SE.
- c. Your group now needs to write an explanation that will answer the following question: Why did the storm happen? Use your model, the data from Activity 6.1, and information from the following map. Be sure to explain what is happening to the matter and energy before, during, and after the storm.
Data

Midwest Regional Surface Map

June 2, 2010, at 5:00 AM

Temperature Data

Midway Airport (Chicago, IL)
June 1, 2010, at 8:51 PM through June 2, 2010, at 7:51 AM
1. What can our model explain about the data?
   Answers will vary.

2. Is there anything that the model cannot explain about the data?
   Answers will vary.
3. What can our model explain about the data?
   Answers will vary.

4. Is there anything that the model cannot explain about the data?
   Answers will vary.
5. What can our model explain about the data?
   *Answers will vary.*

6. Is there anything that the model cannot explain about the data?
   *Answers will vary.*
**Precipitation Data**

Rainfall is stated in inches in this data set (1 inch = 2.54 centimeters).

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<tr>
<td>7:51 AM</td>
<td>N/A</td>
</tr>
</tbody>
</table>

**Midway Airport (Chicago, IL)**

*June 1, 2010, at 8:51 PM through June 2, 2010, at 7:51 AM*

7. What can our model explain about the data? 
   *Answers will vary.*
8. Is there anything that the model cannot explain about the data?
   Answers will vary.

Making Sense: Using the Model to Explain the Storm

9. Write an explanation to answer the question, Why did the storm happen? (Be sure to support your use of the model with data. Remember, you need to explain what happens to the matter and the energy.)
   Answers will vary.
   In Activity 6.1 students were reminded that temperature, precipitation, humidity, air pressure, and clouds as important conditions to look at in a storm. These conditions should also be represented in their consensus model of a storm. A complete student response may be something like the following:
   The storm happened in Chicago on June 2, 2010 because a cold air mass was colliding with a warm air mass. Our model shows that when a colder, high pressure air mass meets a warmer, low pressure air mass storms are formed. Before the storm, the temperature remained stable at around 75 degrees F but dropped 8 degrees at the beginning of the storm. When the cold, dense, high pressure air mass meets the warmer, humid, less dense, air mass, the warmer air is forced up as the cooler air moves in. Our model shows the place where this happens is called the front. As the warm air is forced up, the surface pressure drops. The air pressure data from Chicago showed that when the temperatures dropped so did the air pressure. According to our model, as the warm air rises it cools and releases thermal energy into the atmosphere. In addition the water vapor in the warm air condenses on particles to form clouds. As more cool air moves in and additional warm air is forced upward (lift), the unstable air forms taller and taller clouds. The radar from the region showed heavy storm clouds over Chicago at the time of the storm. The humidity was steady before the storm and there was no precipitation. Humidity increased during the storm and there was a total rainfall of 6.2 cm. Our model also indicates that precipitation will happen when cold and warm air masses collide.
Activity 6 Reading One: Is It Going to Snow or Rain or . . . ?

Getting Ready
What is the weather like today where you live? Is it clear and sunny? Maybe it is cloudy. Or is it a stormy day?

What conditions or clues do you use to decide if it is a stormy day?

Answers will vary.

In class, you have been developing a model of a storm. When you think of a storm, do you picture rain or some other form of precipitation? You may live someplace where it only rains during a storm, but precipitation can occur in several forms. It can be rain, snow, sleet, or hail. Just as in Lesson 1, where you learned that clouds come in many different types, storms can bring different kinds of precipitation.

What about Rain?
Have you ever played outside in the rain? Has your baseball game or soccer game ever been played in the rain? Or maybe it has been rained out. Almost everyone has been caught in the rain at some time.

Rain is the most common type of precipitation on Earth. The class storm model showed that rain happens when the water vapor in the atmosphere condenses and forms drops of liquid water. These drops of water fall all the way to the surface of the Earth. If the temperature all the way to the Earth’s surface is above freezing, then it is raining. Rain can come in the form of showers or drizzle, or it can be a thunderstorm with heavy rain and thunder and lightning. In the first reading, you learned...
that cumulus (or cumulonimbus) clouds produce precipitation. Most types of precipitation are produced by some type of cumulus cloud.

If cumulus clouds produce precipitation, why doesn’t it rain all the time? Think about the other conditions that you identified as part of a storm in your model. What other condition(s) are important in determining if it will rain or snow? Explain why.

Temperature and humidity are important. The amount of moisture in the air (humidity) will determine if there will be precipitation and the temperature will determine if it will be rain or snow.

**Rain or Snow?**

Snow actually occurs almost every time it rains, but it often melts before it reaches the Earth’s surface because of the temperature of the air around it. In class, you learned that clouds are formed when the water evaporates into the air and the water vapor condenses into liquid around something like dust or other particles in the air. Sometimes if the temperature of the cloud is cold enough, the condensing water turns directly into ice without ever becoming liquid. This happens when the vapor condenses around an ice crystal. This creates snow.

As snow falls to the ground, it often melts on the warm surface of the Earth. However, if the surface is cold enough, it begins to pile up. If there was a lot of water vapor in the air, then there will be more snow. That means that if you live where it snows, you may end up shoveling a lot of snow. Just like when it rains, snow is produced in cumulus clouds. The temperatures in the cloud and on the Earth’s surface determine whether it rains or snows.

**What about Other Forms of Precipitation?**

If you live where the weather can get cold, maybe you have gone outside on a cold morning and found the door to the car frozen shut, or you have slipped on the icy sidewalk. Maybe you have even found a frozen scene like the one in this picture.
The air is heated by the surface below it. If the surface was cold, the air just above the surface was cold and the raindrops froze.

You learned that air at the surface is heated from below. Right above the surface, there is a very cold layer of air because the surface and everything on it is very cold. This cold layer of air makes the liquid water supercooled and ready to freeze up. Because the water molecules are close to the surface, they do not have time to freeze. When they hit the freezing surfaces on Earth, they freeze. This results in a thin layer of ice.

**What about Snow in the Summer?**

Sometimes during a severe rainstorm during the summer, there will be ice pellets, called *hail*, that hit the Earth. These pellets can be small or sometimes as big as baseballs. Hail is formed like snow, but in a severe thunderstorm, the snowflakes and raindrops can be pushed back up into the colder air so that they refreeze around other snowflakes. This process of melting and refreezing can cause the water to form large chunks of ice. When they get so heavy that they cannot be lifted by the wind, they fall to the Earth. Sometimes these ice chunks can be very...
large. When hail falls during a thunderstorm in the summer, it can make the ground look like it
has been snowing. Large, baseball-sized hail can also cause a lot of damage.

You have been reading about different kinds of storms. They are different because they bring
different kinds of precipitation, depending on the temperature.

Do you think that the model of a storm that you developed in class can explain all of the
different kinds of storms you read about? Why?

Student responses should be linked to their model and address more than one type of storm.
Why Does Temperature Vary in Different Locations?

STANDARDS ADDRESSED IN THIS LESSON

Building toward Performance Expectation MS-ESS1-1
Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.
Clarification Statement: Examples of models can be physical, graphical, or conceptual.

Building toward Performance Expectation MS-ESS2-6
Earth’s Systems
Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.
Clarification Statement: Emphasis is on how patterns vary by latitude, altitude, and geographic land distribution. Emphasis of atmospheric circulation is on the sunlight-driven latitudinal banding, the Coriolis effect, and resulting prevailing winds; emphasis of ocean circulation is on the transfer of heat by the global ocean convection cycle, which is constrained by the Coriolis effect and the outlines of continents. Examples of models can be diagrams, maps and globes, or digital representations. [Assessment Boundary: Assessment does not include the dynamics of the Coriolis effect.]

Preparation

Background Knowledge
Equator, Latitude, Longitude
The equator is the largest circle that can be drawn on the spherical Earth. It separates the Earth into Northern and Southern Hemispheres. Each line of latitude is actually a circle on the Earth parallel to the equator, and for this reason, lines of latitude are also known as circles of latitude or parallels. The equator is 0° latitude, and the North and South Poles are located at 90° north and 90° south latitude, respectively. In other words, values for latitude range from a minimum of 0° to a maximum of 90°.
By middle school, students should have an understanding of latitude and longitude and how they are used to determine location on the Earth.

**Light Sensor**

- A light sensor measures the light intensity with the unit of lux. It is not important for students to know the definition of a lux. The important thing for them to understand is that a higher number means more light is entering the sensor.
- The light sensor has three setting ranges and each has a maximum value: the candle = 0 – 2.6; the bulb = 0 – 260; and the sun = 0 – 26,000.
- If students consistently get the same reading, they likely do not have the sensor set on an appropriate range for the light they are measuring. For example, if they are always getting a reading of 260 with the light bulb setting, they need to change the sensor’s setting to the sun level.
- Also, the light sensors may need to be reset after making a large number of readings. If the sensor is not reset, it will no longer make accurate measurements. The sensor comes with written instructions on how to reset it.
- See IQWST Overview for more information about probes.

**Light**

If students did the IQWST PS1 unit, they should understand the following key ideas:

- Light rays travel in a straight line.
- Light can be absorbed, scattered, or reflected.
- Light energy from the sun is absorbed by the Earth’s surface and is then transferred to the air. This increases the thermal energy (TE) of the air. (This was addressed in Lesson 2.)
Activity 7.3: Lantern Preparation

Materials

For Each Lantern

• large Chinese paper lantern (at least 56cm in diameter)
• (7–10) pushpins
• (7–10) wonderfoam cubes
• pieces of white paper* (1/2” square). These are to place between the pushpin and the outside of the lantern.

Depending on the number of students in the class, you will need to prepare four to six lanterns. There can be four to five students in a group. Students can rotate jobs while taking the readings at each pin: reader, recorder, and person to hold the sensor.

*This item is not included in the kit.

To facilitate this activity, it is helpful to have stations with the lantern suspended from the ring stand and the light source opposite it set up before students enter the classroom. Students can complete the setup on their own, but they may need to take the readings the next day.

If there is more than one class doing this activity, leave the setup in place. Setting it up and taking it down between classes is too time consuming.
Lantern Preparation
1. Remove the bottom 1/3 of the lantern. This opening needs to be large enough for students to insert their hands along with the sensor to take the readings.
2. This large-sized lantern has approximately 36 wires equally spaced that can be thought of as equivalent to latitude lines. The spacing between the wires is approximately 5°. Near the top and bottom of the lantern, the spacing between the wires changes so that every two wires are 5°.
3. Beginning at the top of the lantern, insert a pushpin into a piece of paper and push it into the lantern just above the wire. On the inside of the lantern, the pin should be inserted into the cube of wonderfoam. Skip the next wire and repeat this procedure. Continue inserting pins, moving down the lantern until you have inserted two pins past what would be the equator on the lantern. The pushpins should be in a line moving down the lantern. (See previous picture.)

SAFETY GUIDELINES
This lesson presents no unusual safety concerns; however, see IQWST Overview for general laboratory safety.

Differentiation and Other Strategies
1. The introduction to this activity is optional based on students’ knowledge of latitude/longitude. There is a brief review of these concepts at the beginning of SE Activity 7.1. More time may need to be spent on reviewing (teaching) the concepts if students are not familiar with them.
2. If students are comfortable with plotting latitude/longitude, have them quickly plot the location of the cities on the world map, and then move to the temperature discussion toward the end of Activity 7.1.
Overview

Activity 7.1
• Use latitude/longitude to plot the location of group cities.
• Compare the average yearly temperature of each of the cities.

Activity 7.2
Analyze data about hours of daylight and its effect on temperature.

Activity 7.3
Determine if the shape of the Earth affects temperature at different locations.

Activity 7.4
Investigate the effect of angle on light intensity.

Activity 7.5
Construct an explanation about why temperature varies at different latitudes.

Learning Performances

Students will

• analyze patterns in climate data to determine the effects of latitude on average temperature.
• consider, test, and rebut the hypothesis that the average amount of daylight can explain the effects of latitude on temperature.
• use a physical model to test the effect of the curvature of the Earth on the intensity of light hitting the Earth at different latitudes.
• investigate and analyze data about how the angle of light hitting an object affects its intensity.
• construct and defend a model that explains the effects of latitude on average temperature in terms of how the angle the sunlight hits the Earth affects the intensity of the light.

Building Coherence

This learning set focuses on the second half of the Driving Question: Why Is Weather Different from Place to Place? Students make the distinction between climate and weather and look at why climate is a better way to compare conditions from place to place. Latitude, sunlight, and Earth’s shape are investigated in order to answer the Driving Question. Students build on what they learned in Lesson 1 about weather and weather conditions. They use light and energy concepts to try to determine what affects the temperature of different cities.

Timeframe

Four 50-minute class periods
Activity

Activity 7.1: How Can We Compare Cities on Earth?

Building toward Performance Expectation MS-ESS2-6
Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.

Disciplinary Core Idea ESS2.D: Weather and Climate
- 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.

Science and Engineering Practices: Analyzing and Interpreting Data; Using Mathematics and Computational Thinking
Crosscutting Concept: Patterns

Materials

For the Teacher
- (1) wall map of Earth
- PI: Data Table on Temperature

For Each Student
- SE Activity 7.1

Introducing the Activity
Refer to the DQB as students will address, Why Is Weather Different from Place to Place?

Use the following prompts to query students’ prior ideas about weather in various locations:

- What do you know about weather in different parts of the U.S.? (It is hotter in the south than in the north. Some parts are hot and dry [desert Southwest], and other parts get a lot of snow [upper Midwest and Northeast]. Any answers that address variation based on location are acceptable.)
- What do you know about weather in different parts of the globe? (It is cold at the poles, hot at the equator, hot and dry in the deserts, and not all areas are the same.)
- What do you mean by north/south when talking about the whole Earth?
Since students already know that location can make a difference in what the weather is like at a particular place from personal experience and the city data in Lesson 1, the first activity will focus on locating the group cities on a world map to see if there is any relationship between location and temperature.

**Introducing the Activity**

The beginning of this activity is designed to be a short review of latitude/longitude, as well as an opportunity for students to plot the location of their group cities on a map. Although there is a world map on SE Activity 7.1 where students can plot the information, it is suggested that you also use a wall map so that you can easily refer to it throughout this learning set. It is important for students to be able to easily see the relative location of these cities and their proximity to the equator. Students will frequently refer to this map.

In Lesson 1, each group looked at weather data for a particular city.

- **How many of you think you could easily locate your group’s city on a map?**
- **Is there any information that would help you locate it more easily?**
- **Have you heard the terms latitude/longitude?**
- **To what do those terms refer?**
- **Can you show me what you mean on the map?**

**Students should have the following understanding:**

- **North** and **South** globally mean the distance north or south of the equator.
- Areas north of the equator are in the **Northern Hemisphere**, and areas south of the equator are in the **Southern Hemisphere**.
- How can we compare where cities are located on Earth?

**Lines of latitude/longitude**—Imaginary lines on a map or globe that help identify locations on Earth.

- **Latitude**—Horizontal lines that run east to west. They indicate distance north and south of the equator. The numbers used to describe latitude are the number of degrees (°) from the equator. Latitudes labeled °N are north of the equator, and those with °S are south of the equator.
- **Equator**—An imaginary line on the Earth’s surface that is the same distance from the North Pole and South Pole. It divides the Earth into a **Northern Hemisphere** and a **Southern Hemisphere**.
- **Longitude**—Vertical lines that run north to south.
- **Prime meridian**—The line of longitude that divides the planet into **Eastern** and **Western hemispheres**. The numbers used to describe longitude are the number of degrees east or west of the **prime meridian**. Longitudes labeled °E are east of the prime meridian, and those labeled °W are west of it.
Students should conclude that if they had the latitude/longitude of their cities, they could easily locate them on a map. Let them know that they will be given the latitude/longitude of each group’s city to plot. The class will then share ideas and plot the cities on a wall map in the classroom.

**Guiding the Activity**

If students are familiar with using latitude/longitude to plot the location of cities, they can move directly to plotting the group cities on the map for SE 7.1. When students have finished, have the class come together and share where they plotted each city. On the wall map, have an individual student show the location of Atlanta, Georgia. Use a sticky note or other marker to identify the location and name of the city. When finished, there should be a clear, visual representation of each city’s location that students can refer to. They should also make sure that the map in the student book is correct.

Remind students of the city data from Lesson 1. It was for a specific time (five days in January 2011).

- **Did you find the same conditions (variables) in all the cities?** (yes)
- **What were they?** (temperature, clouds, precipitation, wind, and humidity)
- **Were the values of those variables the same in each city?** (no)
- **Was the weather the same in each place from day to day?** (Remind students that weather means what is happening with the conditions at a specific location and time. Students can tell that the weather varied from place to place over those five days by looking at the data.)
- **What are some specific ways the variables were different?** (Students may suggest differences in any of the conditions, but they should cite specific differences in their answers. For example, it was 86°F on January 17 in Buenos Aires, Argentina, but in Oslo, Norway, it was 16°F.)

In Learning Set 1, students learned that temperature was an important condition in determining what the weather would be like.

- What does it mean for one city to be hotter than another city?
- Students should understand that there are two ways to think about the previous question.
  1. On a specific day—Chicago is hotter than Phoenix.
  2. In general—Phoenix is usually hotter than Chicago.
In Learning Set 1, students created a model of a storm and saw that temperature played an important part in the creation of the storm. Guide students to the idea that temperature data would be a good place to start investigating the relationship between location and climate.

Have students turn to the data table at the end of SE Activity 7.1. This table gives the average monthly temperature for each of the group cities. Have students calculate the average yearly temperature for each of the cities and answer the Making Sense questions at the end of the activity.

Using PI: Data on Daylight, have students share the average yearly temperature for each city. If groups do not agree on the average, have a student come to the board and calculate it. Students should change any incorrect averages in their SEs. They will refer to this information in the next activity.

Refer to the model from Lesson 2 and the Scientific Principles about how the Earth and air are heated.

**Discussion: Synthesizing**

Purpose: To explain why climate is used to compare different locations.

When scientists want to compare what weather is usually like in a place, they look at data about conditions over a long period of time. They use the term climate to refer to weather conditions in a particular place averaged over a long period of time. Scientists usually look at data over 30 years or more to determine climate in a particular location.

- **Do you think the location of the cities affects the climate?**
- **What data could be reviewed to check your ideas?** (Students may suggest data about any of the conditions [temperature, wind, precipitation, and so on].)

In Learning Set 1, students created a model of a storm and saw that temperature played an important part in the creation of the storm. Guide students to the idea that temperature data would be a good place to start investigating the relationship between location and climate.

Have students turn to the data table at the end of SE Activity 7.1. This table gives the average monthly temperature for each of the group cities. Have students calculate the average yearly temperature for each of the cities and answer the Making Sense questions at the end of the activity.

Using PI: Data on Daylight, have students share the average yearly temperature for each city. If groups do not agree on the average, have a student come to the board and calculate it. Students should change any incorrect averages in their SEs. They will refer to this information in the next activity.

Refer to the model from Lesson 2 and the Scientific Principles about how the Earth and air are heated.

- **Which of the two previous examples depicts weather?** (Number 1 is an example of weather because it is talking about a specific location and day.)
- **What do you think would be a fair way to compare what the weather in different locations is usually like?**
- **Should you compare the temperature month by month?**
- **What about over a year?**
- **Which would give a better idea about what the temperature in a place is like?**

- Temperature is an important condition in determining weather at a particular location.
- Weather is what the conditions are like at a specific location at a specific time.
- Looking at temperature averages over a longer period of time tells us what the weather is usually like at a specific place. Scientists call this climate.
• How is the air at the surface heated? (It is heated by conduction from below.)
• How is the Earth heated? (The Earth is heated by absorbing sunlight.)
• If areas near the equator are warmer, what does that mean is happening with the energy? (Warmer means that more thermal energy is being transferred.)
• If Earth’s entire surface is heated by the sun, why does the data show that areas near the equator are warmer than areas near the poles? Record students’ responses on the board.
  (Have students brainstorm ideas about this question and record them on the board. Ideas may include the following:
  • Areas near the equator get more sunlight and that is why it is hotter.
  • Areas near the equator are closer to the sun.
  • Some places have six months of daylight and six months of darkness, so they do not get as much light as places at the equator.)
• How could you test the idea that there are more hours of daylight at the equator? (You can test it by looking at the yearly average of hours of daylight.)
• Why is it important to look at the yearly average and not just a month or two? (The hours of daylight may vary from month to month. If you only looked at a month where there were only a few hours of daylight, you would think that the place only got that much light all the time.)

In the next activity, students will analyze data about the hours of daylight at each of the locations and compare that to their temperature data in order to try to determine if there is a relationship between the two.
Activity 7.2: Do the Number of Daylight Hours Vary in Different Locations on Earth?

Building toward Performance Expectation MS-ESS2-6

Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.

Disciplinary Core Idea ESS2.D: Weather and Climate

- 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.

Science and Engineering Practices: Analyzing and Interpreting Data; Using Mathematics and Computational Thinking; Constructing Explanations and Designing Solutions

Crosscutting Concept: Patterns

Materials

For the Teacher
- PI: Data Table on Daylight Hours

For Each Student
- SE Activity 7.1 and 7.2

Introducing the Activity: Analyzing Data about Hours of Daylight and its Effect on Temperature

In this activity, students will use monthly averages of daylight hours to calculate the average yearly hours of daylight for their city.

Using SE Activity 7.2, students should complete the Prediction section. Have each city group calculate the average yearly hours of daylight for their city. Then, have groups jigsaw so that there is one person from each of the cities in the new groups. Each group should accomplish the following tasks:

- Share the yearly average of daylight hours from their city.
- As a group, answer Questions 1 and 2 from the Making Sense section.
• If any pattern was observed, what did it help explain about the relationship of temperature and daylight, or what questions did it raise?
• What conclusion did the group reach about the relationship between temperature and daylight based on the data?

**Discussion: Pressing for Understanding**

Purpose: To determine if the question about the relationship between hours of daylight and temperature has been answered.

Return to the data table at the end of Activity 7.2.

Did you notice any patterns in the average hours of daylight for the year? Did you notice any patterns in the daylight hours each month? Look back at the average temperatures from Activity 7.1. Do you see any connection between the hours of daylight and the temperature for each city?

• **When you looked at the average number of hours of daylight per month, before you figured out the average, did it look like each city received the same amount of light? Give an example to support your answer.** *(When you looked at each month and compared the cities, it seemed like they all got very different amounts of light. In January, Atlanta had 10 hours of daylight, Buenos Aires had 14, and Ushuaia had 16.3.)*

• **Did you see any connection between the number of daylight hours in a particular month and the temperature?** *(For example, Oslo gets 16 hours of daylight in May, and the average temperature = 54°F. Oslo gets 5.7 hours of daylight in December, and the average temperature = 27°F. Oslo is warmest when it gets the most hours of daylight and coldest when it gets the least.)*

• **Did you notice this same kind of pattern for any other cities? Which ones?**

At the end of this activity, students should understand the following key ideas:

• Temperature on a monthly basis varies from place to place and corresponds to the hours of daylight for the month (i.e., more daylight in a month, the higher the temperature).
• Average yearly temperature varies by latitude. It is warmer at the equator all year long and cooler at the poles.
• All places receive the same number of hours of daylight in a year, but it varies by month.
• Why does temperature vary in different locations on Earth?
• Does the data you have explain the temperature differences among locations?
• What could be going on here? (If all places receive the same number of hours of daylight over the course of a year, then they should be getting the same amount of light energy heating them, so that cannot explain the temperature difference by latitude.)
• Why do you think it is cooler at the poles and warmer at the equator?
• What other information might help you figure out why the temperature is different?

In the next activity, students will investigate what a possible cause is for these temperature differences at different latitudes.
Activity 7.3: Does the Earth’s Shape Affect Temperature?

Building toward Performance Expectation ESS1-1
Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.

Disciplinary Core Idea ESS1.A: The Universe and Its Stars
- Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.

Disciplinary Core Idea ESS1.B: Earth and the Solar System
- This model of the solar system can explain eclipses of the sun and the moon. Earth’s spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.

Science and Engineering Practices: Developing and Using Models; Planning and Carrying Out Investigations; Analyzing and Interpreting Data

Crosscutting Concepts: Cause and Effect; Patterns

Materials

For the Teacher
- (1) globe

For Each Group
- (1) prepared lantern model
- (1) ring stand

For Each Student
- (1) lamp with 150-watt bulb
- (1) light sensor*

For Each Student
- SE Activity 7.3

*This item is not included in the kit.
Equipment included in the kit.
Introducing the Activity

Students left the last activity with a question about why latitude seems to have an effect on temperature. They have seen data that showed the following:

- Temperature of a place varies over a year based on latitude.
- Places nearer the equator have a higher yearly temperature average than places that are farther from the equator.
- Monthly variations in temperature correspond to the number of hours of daylight the place receives. The more daylight in a month, the higher the temperature.
- Over the course of a year, all places on Earth receive the same number of hours of sunlight.

**What do you know about light that might help you figure out what is happening with the temperature?**

If students did the IQWST PS1 unit, they should understand the following key ideas:

- Light rays travel in a straight line.
- Light can be absorbed, scattered, or reflected.
- Light energy from the sun is absorbed by the Earth’s surface and is then transferred to the air. This increases the thermal energy (TE) of the air. (This was addressed in Lesson 2.)

**What would you need to know about the light in order to figure out why the temperature is different in different locations?** *(Students may suggest that they could measure the light at different locations. Press them for suggestions about how to do this.)*

Guiding the Activity

If students have done the IQWST PS1 unit, they will have measured light intensity using a sensor. If students have not had experience with light sensors, tell students that this is an instrument that measures the intensity of light at a specific location. Show students the round paper lantern and ask if they could use this as a model of the Earth. Explain that in this activity, they will use this model and a light sensor to measure the intensity of the light at different locations on the globe.

Students should understand the following about the model:

- The circle at the widest part of the lantern represents the Earth’s equator. This represents 0° latitude.
- The remaining wire circles on the lantern are used to represent different latitudes.
- Each of the pushpins represents a specific location on the globe.
- Make the connection to the group cities on the map. Find the corresponding locations on the model for the cities north of the equator.
- All of the pins are above the equator and represent latitudes that are labeled °N on the data table.
• Ask students how the latitude would be labeled if the pins were lined up below the equator.

These photos show the lantern with the pushpins on the outside and the wonderfoam on the inside. The wonderfoam keeps the pushpins from tearing the lantern.

Demonstrate for students how to take the light readings using the model. You will need one student to help you do this.

• Have the students position themselves so that they can see through the hole at the top of the lantern.
• You should insert the probe through the opening in the bottom so that the side of the probe that shows the measurement is facing up. This is so that students are able to see the measurement through the hole in the top of the lantern.
• Place the tip of the probe on top of the wonder foam so that it is perpendicular to the surface of the lantern. The wonderfoam will serve as a guide for students to keep the probe perpendicular.
Students may need support in understanding that they are taking the measurement of the light as it hits the surface of the Earth. The sensor should not be pointed at the light source, but pointed as if it were a person standing on the Earth.

The students should be able to see the reading on the probe and record it.

Explain to students that they should repeat this process for every pin on the lantern. It may take a little practice for students to be comfortable taking the readings.

**Measuring Light Intensity Using the Lantern Model**

Divide the class into groups of four or five students. Three students are needed to take each reading—one to manipulate the sensor, one to take the reading, and one to record the data. Students should rotate jobs within their group so that each of them has the opportunity to use the sensor. Review with students how to use the light sensors.

Begin by having students answer the Prediction question on SE Activity 7.3. Assign each group a station with a model setup. (If you are having students set up their own stations, explain the procedure for getting materials and setting up the lantern.) Check each group to be sure they know how to take the reading based on your demonstration.
Note: It is particularly important that students hold the probe so that it is perpendicular to the surface of the lantern. They want to measure the intensity of the light as it hits the surface of the lantern. Remind them to use the wonderfoam as a guide for aligning the probe. After checking each group, have them take readings and complete the data table on SE Activity 7.3. They should then complete the Making Sense section.

**Discussion: Synthesizing**

Purpose: To model and explain why light intensity varies at different latitudes.

Begin by sharing data that students collected.

- Did you get the same intensity readings at each latitude?
- Where was the intensity reading highest? Lowest?
- What do you think causes this intensity difference?
- What do you think is different about the light at the equator and the higher latitudes?

Draw the Earth and sun on the board. Have a student come to the board and share a drawing. Begin by having the student draw the light rays from the sun hitting Earth. The drawing should be similar to the following illustration.

Using Stick Figures

It is important that students place stick figures on their Earth model, so they can visualize where the surface is. Using an X is not helpful in understanding the angle at which the sun hits objects on the Earth. This idea is critical in the next activity.

- Label the place where their data showed the highest intensity, then the lowest.
- Draw a stick figure at the equator, one where the top ray hits the Earth near the North Pole, and another at a spot in between (for a total of three). Make sure student drawings show the figure standing on Earth. The stick figure at the equator should have its head pointed directly at the sun and its feet on Earth.
Have students compare the drawing on the board to their drawings on SE Activity 7.3. Ask if everyone agrees, or if there are changes that should be made to the class model. When everyone agrees with the model, allow students time to add the stick figures to their model and make any changes.

**Are all of the figures on the model hit by the light rays in the same way?**

**Which one is hit most directly?** (The figure at the equator)

**How is the light hitting the person standing closer to the North Pole?** (It hits the figure less directly, at more of an angle, from the side.)

**Where did you get the highest light intensity reading? Lowest?**

Have students add this information to the drawing.

**Did the light source change?**

**Does the light hit the Earth the same way everywhere?** (Have students look at the stick figures and describe how the light is hitting each of them. For the figure at the equator, the sun is directly overhead. For the figure at the midlatitudes, the light is at a slight angle and not as direct. The third figure closer to the poles has light hitting it at a greater angle that is less intense.)

**How do the intensity readings compare to your temperature data?** (The higher intensity readings correspond to the highest temperatures—at the equator. The lower intensity readings correspond to the lowest temperatures—closer to the poles.)

**Do you think the direction that the light is hitting the Earth could make a difference in temperature? Why?** (Students may recognize that it is warmer in the summer [in the Northern Hemisphere] when the sun is directly overhead. If the sun heats the Earth, then maybe the direction the light hits the Earth could affect temperature. Press students to try to explain why. It is important to arrive at the idea of angle here.)

It is not necessary for students to be able to explain this at this point, but they should begin thinking about this idea as they move into the next activity.

Students should leave this activity with the question, Could the angle that light hits the Earth have an effect on temperature? In the next activity, students will investigate how the angle of light affects intensity.
Activity 7.4: Does the Angle that Light Hits the Earth Affect Intensity?

Building toward Performance Expectation ESS1-1
Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.

Disciplinary Core Idea ESS1.A: The Universe and Its Stars
• Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.

Disciplinary Core Idea ESS1.B: Earth and the Solar System
• This model of the solar system can explain eclipses of the sun and the moon. Earth’s spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.

Science and Engineering Practices: Developing and Using Models; Planning and Carrying Out Investigations; Analyzing and Interpreting Data

Crosscutting Concept: Matter and Energy

Materials

For Each Group
• (1) piece of cardboard (at least 216mm × 279mm [8.5” × 11”])
• (1) sheet graph paper*
• (3) different colored fine point markers*
• (1) flashlight

For Each Student
• SE Activity 7.4

*This item is not included in the kit.
Equipment included in the kit.
Introducing the Activity

Students left the last activity with a question about the relationship of intensity to the angle at which light hits the Earth. Using the model from Activity 7.3, briefly go over what they have discovered so far.

- Light hits the Earth most directly at the equator and less directly farther away from the equator.
- Intensity goes down the farther away from the equator you get.

Ask students what is different about the way the sunlight hits those places. From the model, it looks like the angle is different. Point this out on the model. In this activity, students will measure what happens to light from the same source at different angles.

Working in groups, students should set up the activity following the directions on SE Activity 7.4. You should check each group to be sure that their flashlight is 0.6 m from the graph paper and shining on the center of the paper. Students should use books to support their flashlight. One person in the group should keep his or her hand on the flashlight so that it does not move during the investigation.

Review the data table with students. Explain that measurement #1 represents light at the equator, #2 represents halfway to the North Pole, and #3 represents an area almost at the North Pole.

Guiding the Activity

Each group will need to have at least three people: one to hold the cardboard, one for the flashlight, and one to draw the outline. Students should use a fine-point marker to trace the outline of the light on the graph paper. Markers are easier to use than colored pencils.
After students have drawn the outlines of the three beams on the graph paper, they should count the number of squares covered by each beam. Remind students that when they are counting the outer two outlines, they need to include all the squares that are inside the line. When they are counting the second outline, they need to include all the squares from the first outline as well. Let them know that it is the total area covered by the light that they should count.

**Discussion: Pressing for Understanding**

**Purpose:** To model the angle of light hitting Earth and analyze if that affects light intensity for each representative location.

Once all the groups have collected their data, have students share their results. Groups may not have the same exact count of squares for each angle of light, but they all should be within a similar range. If there are groups that are far out of range from the other groups, ask them to share how they collected their data and counted their squares.

- **Did the number of squares covered by the light change? Describe the pattern that you saw.** *(There are more squares covered when the angle of the board is greater [near the North Pole] than when the board is straight [at the equator].)*
- **Did the light source change in any way during the activity?**
- **Why would you get different numbers from the same light?**
- **What is different about the space covered at each angle?**
- **What did you notice about the light in the smaller outline compared to the larger one?** *(Students should arrive at the idea that it is the same amount of light spread over a greater area.)*

Students should understand the following key ideas about light:

- Light is a form of energy.
- The amount of light reaching a location can be measured (intensity).
- If the same amount of light is spread over a larger area, there is less light energy reaching each spot, and it is less intense.

- **How does the number of squares explain the temperature data from Activity 7.1?** *(Students should connect the higher temperature at the equator with the greater number of squares. It also connects to the light intensity readings from the last activity. The light was more intense at the equator.)*
- **If the amount of light energy did not change in each location, what caused the change in intensity?** *(The only thing that changed in this activity was the angle at which the light struck the paper. This corresponds to the angle at which the light hits Earth. Students should conclude that the angle makes a difference.)*
- **Where would there be less light energy? With a larger angle or a smaller one?** *(There is less energy when the angle is larger. This corresponds to the temperature data and the angle data in this activity. Students should be able to support their answer with evidence from both activities.)*
Activity 7.5: Can We Explain the Pattern in the Data?

Building toward Performance Expectation ESS1-1
Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.

Disciplinary Core Idea ESS1.A: The Universe and Its Stars
- Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.

Disciplinary Core Idea ESS1.B: Earth and the Solar System
- This model of the solar system can explain eclipses of the sun and the moon. Earth’s spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.

Building toward Performance Expectation MS-ESS2-6
Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.

Disciplinary Core Idea ESS2.D: Weather and Climate
- 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.

Science and Engineering Practices: Asking Questions and Defining Problems; Analyzing and Interpreting Data; Constructing Explanations and Designing Solutions; Engaging in Argument From Evidence; Obtaining, Evaluating, and Communicating Information

Crosscutting Concepts: Patterns; Cause and Effect; Energy and Matter

Materials

For the Teacher
- PI: January Average Surface Temperature

For Each Student
- SE Activity 7.5
- Exercise 7.5
Introducing the Activity

In this activity, students are asked to write out a chain of reasoning and create a model that explains the pattern that connects temperature, latitude, and intensity of light.

Review with students each of the activities in this lesson and the ideas that they have added to the DQB. In this activity, they are to connect the ideas of temperature (7.1), latitude (7.2), light intensity (7.3), and the angle that the light hits the Earth (7.4) to construct an explanation for why temperature varies at different latitudes. This explanation should be a chain of reasoning that shows how each of these is connected and explain the pattern. They should also have a model that supports their explanation.

Students should add the following ideas to their class Scientific Principles List: - Intensity of light varies depending how far north or south of the equator you are and how long the light shines on a place. (#10) - Temperatures vary in a predictable pattern depending on latitude. (#11) - Intensity differences explain why temperatures vary in the same pattern. (#12)

Discussion: Synthesizing

Purpose: To explain why the temperature is different at different latitudes.

Begin by having one group share their explanation and diagram about why the temperature is different at different latitudes. Record students’ ideas.

- Are there other groups that agree with the claim?
- Did you use the same evidence to support the claim? If not, what evidence did you use?
- What was your reasoning? How did you connect your claim and evidence?
- Do any groups have a different claim?
- What was your evidence to support your claim?
- How does it connect to your claim?
- Is there anything you would add to the diagram?

When all ideas have been heard, have the class combine their ideas into a single explanation for why the temperature is different at different latitudes. Record this on the board and have students record it in their books. At the end of the next lesson, students will return to this explanation and decide if they want to change it or add to it.
Discussion: Synthesizing

Purpose: To develop three Scientific Principles (#13, #14, #15) based on the activities in this lesson.

- What have we learned affects the intensity of light? It varies depending on what? (The intensity of light varies depending how far north or south of the equator you are, and how long the sun shines on a place at one time.)
- What can we conclude about temperatures from these investigations? (Temperature varies in a predictable pattern depending on latitude. Light intensity explains why temperatures vary in the same pattern.)
- What affects the intensity of light? (Intensity varies depending on the angle of the light hitting a location.) Angle of light is the cause; varied light intensity is the effect.

Wrapping Up

Be sure these ideas are captured on the DQB:

- The temperature on Earth varies by latitude.
- The light intensity varies by latitude and corresponds to temperature.
- The angle at which light hits the Earth affects intensity (more spread out, less intense) and therefore temperature.
- The light from the sun hits the Earth most directly at the equator; therefore the light is more intense. This is where the highest temperatures were.
- What do we still need to learn?
- Does our explanation fit a new set of data?

Introducing Exercise 7.5: Do the Data Match the Explanation?

Use PI: January Average Surface Temperature. Explain that it is a visualization of the Average Surface Temperature for January (1959–1997). Remind students that a visualization is a picture representation of the data. Point out the key at the bottom of the page: red represents the hottest areas and blue the coldest.

This image is available on the IQWST Portal. Note: You will need to log in and navigate to the lesson so students can see the visualization in color.

This exercise requires students to use the explanation they created in class about the difference in temperature at different latitudes to explain what they see in a visualization of the January Average Surface Temperature (1959–1997). They are then prompted to write down any questions they still have. This will be used as the introduction to Lesson 8.
Exercise Follow Up
Use PI: July Average Surface Temperature and ask students to share their ideas. Student explanations should indicate the following:

- Temperature varies by latitude.
- Hotter areas are nearer the equator.
- Cooler areas are nearer the poles.
- Light at the equator is more direct because of the shape of the Earth. It does not hit the Earth at an angle and is therefore more intense.
- More intense light means higher temperature.
- Does the explanation from this exercise fit the visualization? (For the most part, yes.)
- What questions do you still have?
- Is there anything in the visualization that you cannot explain? (Students may notice the following):
  - It is cold at both poles, but the North Pole is colder than the South Pole.
  - There seem to be differences between land and water at the same latitude.
  - The hotter areas seem to be just south of the equator.
  - There are cool spots along the west side of South America.)

WW
Candidate words include latitude, longitude, equator, prime meridian.

DQB
Post Scientific Principles #13, #14, and #15 on the Scientific Principles list, and post either on the DQB or elsewhere in the room. Candidate items for the DQB include the temperature data table, models from the activities, and a sample class explanation after Activity 7.5. Use any questions on the DQB related to seasons to segue to Lesson 8.

Assessing Learning
Activity 7.1 Making Sense questions 1 & 2 can be used to assess students’ ability to analyze data and use it as evidence to support a claim. After Activity 7.4, students should be able to use evidence to answer, "Does the Angle that Light Hits the Earth Affect Intensity?" The model and explanation from Activity 7.5 can be used to assess their understanding of how the varying angles of sunlight affect the Earth’s temperatures at various latitudes. Exercise 7.5 may be used to assess students’ understanding as they apply what they have learned to new data.
Activity 7.1: How Can We Compare Cities on Earth?

What Will We Do?
We will use latitude and longitude to plot city locations and compare the temperatures of the cities based on location.

Part 1: Background on Reading Maps

Procedure
□ a. Review the following information about latitude and longitude. Maps and globes help us understand the location, distances, and relative sizes of places on the planet. Places on a map or globe are described by imaginary lines on Earth’s surface. These imaginary lines are called latitude and longitude.

- Latitude lines are shown as the horizontal lines that run east to west. On a globe, they look something like the rungs of a ladder.
- The equator is the line of latitude that divides the Earth into Northern and Southern Hemispheres, or halves. The numbers used to describe latitude are the number of degrees (°) from the equator. Latitudes with °N are north of the equator, and those with °S are south of the equator.
- Longitude is shown by the vertical lines going north to south. They are curved. On a globe, they look like orange segments.
- The prime meridian is the line of longitude that divides the planet into Eastern and Western Hemispheres. The numbers used to describe longitude are the number of degrees from the prime meridian. Longitudes with °E are east of the prime meridian, and those with °W are west of the prime meridian.
The numbering of the lines of latitude and longitude are the same on a globe as on a map. If you can find the location of a city on a map, you would be able to find it on the globe as well using the same latitude and longitude.

**Part 2: Comparing Data from Different Cities**

**Procedure**

□ b. Using the data from the table that follows, plot the location of each group’s city on the map. Use small black circles to show city locations.

<table>
<thead>
<tr>
<th>City</th>
<th>Latitude/Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atlanta, Georgia</td>
<td>33°N 84°W</td>
</tr>
<tr>
<td>Belem, Brazil</td>
<td>1°S 48°W</td>
</tr>
<tr>
<td>Buenos Aires, Argentina</td>
<td>35°S 58°W</td>
</tr>
<tr>
<td>Oslo, Norway</td>
<td>59°N 10°E</td>
</tr>
<tr>
<td>Singapore, Singapore</td>
<td>1°N 103°E</td>
</tr>
<tr>
<td>Ushuaia, Argentina</td>
<td>54°S 68°W</td>
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</tbody>
</table>
Data

<table>
<thead>
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<tbody>
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<td>Atlanta, Georgia 33°N 84°W</td>
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<tr>
<td>Singapore, Singapore 1°N 103°E</td>
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<td>83</td>
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<td>80</td>
<td>73</td>
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<td>70</td>
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<tr>
<td>Oslo, Norway 59°N 10°E</td>
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<td>26</td>
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<td>33</td>
<td>48</td>
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<tr>
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<td>75</td>
<td>73</td>
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<tr>
<td>Ushuaia, Argentina 54°S 68°W</td>
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</table>

□ c. Plot the location of your group’s city on the map in your classroom.
□ d. Using the chart at the end of the activity, calculate the average yearly temperature for each of the class cities. When you finish, answer the Making Sense questions.
Making Sense

1. Are there any patterns in the temperatures of the cities? Describe them.
   Looking at temperature averages over a longer period of time tells us what the weather is usually like at a specific place (i.e. climate). Students’ descriptions will vary.

2. Make a claim about the relationship between location and temperature.
   In general, cities near the Equator are warmer than cities near the poles.
Activity 7.2: Do the Number of Daylight Hours Vary in Different Locations on Earth?

What Will We Do?
We will investigate the effect of daylight hours on temperature.

Prediction
Do you think the number of daylight hours could have an influence on the temperature difference that you noticed at different latitudes? Why?

Answers will vary.

Procedure
☐ a. Examine the data on the chart at the end of this activity. It shows the average hours of daylight by month for each of the cities.
☐ b. Find the average number of daylight hours in a year for your city. Record your answer in the last column on the chart at the end of the activity.
☐ c. Jigsaw groups so that there is one member from each of the cities in the new group. Record each group’s answer about the hours of daylight on the table.
### WHAT MAKES THE WEATHER CHANGE?

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</tr>
</thead>
<tbody>
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<td>10.9</td>
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<td>13.7</td>
<td>14.2</td>
<td>14.0</td>
<td>13.2</td>
<td>12.2</td>
<td>11.2</td>
<td>10.3</td>
<td>9.8</td>
<td>144</td>
<td>12</td>
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<tr>
<td>Singapore, Singapore 1°N 103°E</td>
<td>11.9</td>
<td>12.0</td>
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<td>12.1</td>
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<td>144.1</td>
<td>12</td>
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<tr>
<td>Oslo, Norway 59°N 10°E</td>
<td>6.5</td>
<td>9.0</td>
<td>11.5</td>
<td>14.3</td>
<td>16.8</td>
<td>18.3</td>
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<td>7.3</td>
<td>5.7</td>
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</tr>
<tr>
<td>Buenos Aires, Argentina 35°S 58°W</td>
<td>14.0</td>
<td>13.2</td>
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<td>11.7</td>
<td>10.2</td>
<td>9.7</td>
<td>9.9</td>
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<td>12.8</td>
<td>13.8</td>
<td>14.3</td>
<td>144.2</td>
<td>12</td>
</tr>
<tr>
<td>Belem, Brazil 1°S 48°W</td>
<td>12.1</td>
<td>12.0</td>
<td>12.0</td>
<td>12.0</td>
<td>12.0</td>
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<td>11.9</td>
<td>12.0</td>
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<td>12.0</td>
<td>12.1</td>
<td>143.9</td>
<td>12</td>
</tr>
<tr>
<td>Ushuaia, Argentina 54°S 68°W</td>
<td>16.3</td>
<td>14.4</td>
<td>12.2</td>
<td>10.1</td>
<td>8.2</td>
<td>7.0</td>
<td>7.6</td>
<td>9.3</td>
<td>11.5</td>
<td>13.6</td>
<td>15.8</td>
<td>17.0</td>
<td>142</td>
<td>11.8</td>
</tr>
</tbody>
</table>
Making Sense

1. What patterns can you identify in the total hours of daylight for the year? Describe.
   All cities received about the same number of hours of daylight for the year.

2. What patterns can you identify in the daylight hours each month?
   Cities near the equator received about the same amount of daylight each month. Other cities had some months where they had more daylight and others where they had less. Cities near the poles had very few hours of daylight for half the year, and in the other half, they had light almost all day.

3. Look back at the average temperatures from Activity 7.1. What patterns can you identify between the hours of daylight and the temperature for each city?
   In the months that a city had more hours of daylight, it had higher temperatures. Fewer hours of daylight showed lower temperatures.
4. What claim can you make about the number of hours of daylight (cause) and how it influences temperature (effect)?
   The more hours of daylight a place receives, the warmer it will be.

5. Look at the prediction you made at the beginning of this activity.
   a. Do the data in this activity support your prediction? Explain.
      Answers will vary.

   b. What questions do you still have?
      Answers will vary.
Activity 7.3: Does the Earth’s Shape Affect Temperature?

What Will We Do?
We will determine if the shape of the Earth affects temperature at different locations.

Prediction
Using what you know about the Earth’s shape and how it is heated, why do you think that temperature varies based on latitude?

Answers will vary.

Procedure
☐ a. If your teacher has already set up your model, check the setup before you begin. Be sure that the light source is approximately 1.5 m from the lantern. It should be directly opposite the equator on your model.
☐ b. Your teacher will show you how to use the light sensor. Remember the following:
   ☐ 1. Make sure that the side of the sensor that shows the reading is facing the hole at the top of the lantern.
   ☐ 2. Rest the tip of the sensor on the top of the wonderfoam inside the lantern. This will help make sure that you hold the sensor in the right position.
   ☐ 3. Be sure to have your teacher check your setup and how you are reading the sensor before you begin to complete the data table.
☐ c. Take the first reading at the equator on your lantern. This is 0° on the data table.
## Data

<table>
<thead>
<tr>
<th>Latitude (°N)</th>
<th>Incoming Light (Lux)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td></td>
</tr>
<tr>
<td>10°</td>
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<tr>
<td>20°</td>
<td></td>
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<td>30°</td>
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<td>60°</td>
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<tr>
<td>70°</td>
<td></td>
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<tr>
<td>80°</td>
<td></td>
</tr>
</tbody>
</table>

## Making Sense

1. Was there a pattern in the intensity of incoming light and the latitude of the pins on your model? If you saw a pattern, describe it.
   
   The light was more intense closer to the equator and got less intense the farther away you got.
2. Using what you know about light, draw a diagram of how light rays from the sun hit the Earth. Be sure to include:
   - Earth and sun.
   - Light rays from the sun.
   - A label showing where the light was most intense in your data.
   - A label showing where the light was least intense in your data.
   Student diagrams will vary but should include the above parts in their diagram.
3. What ideas do you have that could explain this relationship?  
   Responses will vary.

4. What questions do you still have?  
   Responses will vary.
Activity 7.4: Does the Angle That Light Hits the Earth Affect Intensity?

What Will We Do?
We will investigate the effect of angle on light intensity.

Procedure

☐ a. Using masking tape, attach a piece of graph paper to the cardboard.
☐ b. On your desk or lab table, make a stack of books that will be 0.6 m away from the cardboard.
☐ c. Place your flashlight on the books so that it is parallel to the floor. One person in the group should place their hand on the flashlight so that it does not move during the investigation.
☐ d. Hold the cardboard with the graph paper so that it is perpendicular to the floor. The beam of the flashlight should be in the center of the paper.
☐ e. Trace the outline of the flashlight beam on the graph paper.
☐ f. Keep the cardboard the same distance from the flashlight and tilt the board away from and then toward the light. Describe what happens to the light on the board.
   The light spreads out more on the paper.

☐ g. Tilt the board away from the light at a large angle (about half the distance to the table, moving away from the light). Using a different color pen or pencil, draw an outline of the beam on the graph paper.
☐ h. Try a larger angle (moving away from the light and closer to the table). Use a third color and draw an outline of the beam on the graph paper.
☐ i. Take your graph paper and count the number of squares that are inside of the first outline you drew.
☐ j. Record your data in the table. Then, count the squares inside of each of the other outlines.
**Data**

<table>
<thead>
<tr>
<th>Angle of Board</th>
<th>Number of Squares Covered by Light</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1 (at the equator)</td>
<td>Data should show fewer squares covered at the equator and the most at the North Pole.</td>
</tr>
<tr>
<td>#2 (halfway to North Pole)</td>
<td></td>
</tr>
<tr>
<td>#3 (near North Pole)</td>
<td></td>
</tr>
</tbody>
</table>

**Making Sense**

1. Did the number of squares covered by the light change? Describe the pattern.
   Yes. Fewer squares were covered at the equator and more at the poles.

2. Why would you get different readings when the light source remained the same?
   Even though the light source is the same, the same amount of light covers a larger area. This means that each part of the larger area is getting less intense light.
3. How does the number of squares explain the temperature data?
   If the area is getting less intense light, the temperature will not be as warm. This matches what we saw with the daylight and temperature data about the cities. It also happened with the lantern.
Activity 7.5: Can We Explain the Pattern in the Data?

What Will We Do?
We will construct an explanation about why temperature varies at different latitudes.

Procedure
In this lesson, you have looked at data about the temperature and latitude of six cities. You also plotted their location on a map. You did two investigations about the intensity of light in different locations. In this activity, you will construct an explanation and diagram that answers the question, Why is the temperature different at different latitudes?

☐ a. Draw a model that shows the pattern that connects temperature, latitude, and intensity of light.

☐ b. Below your drawing, explain what your model shows.
   Students should be able to articulate the following ideas:
   • The temperature on Earth varies by latitude.
   • The light intensity varies by latitude and corresponds to temperature (i.e., greater intensity equals higher temperature).
   • The angle at which light hits the Earth affects intensity (more spread out, less intense) and therefore temperature.
   • The light from the sun hits Earth most directly at the equator, making the light more intense. This is where the highest temperatures were.
Exercise 7.5: Do the Data Match the Explanation?

In class today, you constructed an explanation to answer the question, why is the temperature different at different latitudes? To apply what you’ve learned, use the explanation you created in class about the difference in temperature at different latitudes to explain the following visualization of the Average Surface Temperature for January (1959–1997). Then, write down any questions you still have.

To help you interpret the visualization, you need to understand what the colors represent. Each color indicates the average temperature for that location. The data have been averaged over 30 years. The color scale goes from red (the hottest) to yellow to light blue and then to dark blue (the coldest).
1. How does what you learned in class explain this visualization?
   Students should be able to link the idea that it is warmer at the equator and cooler the farther away you get from it.

2. List any questions you have about temperature and latitude.
   Possible questions include the following:
   • Why do colder temperatures cover more of the Northern Hemisphere than the Southern Hemisphere?
   • Why is everything at the equator not heated the same?
STANDARDS ADDRESSED IN THIS LESSON

Building toward Performance Expectation MS-ESS1-1
Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.
Clarification Statement: Examples of models can be physical, graphical, or conceptual.

Building toward Performance Expectation MS-ESS2-6
Earth’s Systems
Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.
Clarification Statement: Emphasis is on how patterns vary by latitude, altitude, and geographic land distribution. Emphasis of atmospheric circulation is on the sunlight-driven latitudinal banding, the Coriolis effect, and resulting prevailing winds; emphasis of ocean circulation is on the transfer of heat by the global ocean convection cycle, which is constrained by the Coriolis effect and the outlines of continents. Examples of models can be diagrams, maps and globes, or digital representations. [Assessment Boundary: Assessment does not include the dynamics of the Coriolis effect.]

Preparation

Background Knowledge
Earth’s Spinning on Axis and Revolving around the Sun
When students rotate their Earth model, they should spin it in a counterclockwise direction. Later they will revolve it around the sun, also in a counterclockwise direction. This accurately represents the fact that Earth spins on its axis in the same direction that it revolves around the sun.

Note that, at this point, students are told that the Earth take 24 hours to make a full rotation on its axis. The reading for Lesson 8 indicates “about 24 hours.” A full rotation actually takes 23 hours and 56 minutes, which is why an extra day occurs on the calendar every four years as a Leap Year.
Shape of Earth’s Orbit
The average distance of Earth from the sun is about 150 million kilometers. At its closest point, Earth is about 147 million kilometers from the sun; conversely, the sun is about 152 million kilometers away when it is at its farthest point. Earth’s distance from the sun remains relatively constant throughout its annual orbit. The shape of Earth’s orbit is not quite a perfect circle. It is more like a stretched-out circle. Mathematicians and astronomers call this shape an ellipse. It can be long and skinny, or it can be very round. Scientists need a way to describe how round or stretched out an ellipse is. They use a number to describe this and call it the eccentricity of the ellipse. Eccentricity is always between zero and one for an ellipse. If it is close to zero, the ellipse is nearly a circle. If it is close to one, the ellipse is long and skinny. Earth’s orbit is almost a circle. It has an eccentricity of less than 0.02. That is why the distance from the sun does not change much over the course of the year.

Earth’s Tilt
Earth’s north spin axis points almost directly at the North Star (within a degree). It always remains pointed this way at an angle of 23.5°. This is why the North Star always stays in the same spot in the sky and why other stars appear to move around it.

Common Student Ideas
Shape of Earth’s Orbit
A common student misconception is that Earth is closer to the sun in the summer. This would make Earth’s orbit oval, and the sun would not be in the center. The Earth’s orbit is elliptical, not oval.

Distance from Sun and Temperature
Some students may conclude that the Northern Hemisphere is closer to the sun during the summer because of the tilt. Technically, it is closer than the Southern Hemisphere. However, the distance by which it is closer is less than the diameter of the Earth. The change in temperature is less than 2%. This turns out to be only 5°C, which is less than the temperature change between winter and summer in most places.

Setup
Activity 8.1
Specific instructions for activity setup are embedded within the lesson.

Activity 8.2
- This activity is designed as a teacher-led, whole-class activity with students having their own Earth model. Depending on the number of students, it may also be done in groups with one person representing the group and the rest watching and taking notes.
- This activity requires a light source in the center of the room so that students can form a circle around it. The light source should be a bulb that is uncovered. A table lamp without a shade is one example.
Guiding the Discussion

It is not important which pattern students identify first. The plan is a suggestion for one possible path through the data. The order is not as important as long as the major ideas for each pattern are identified, discussed, and linked to the visualization and explanation from Lesson 7.

Materials

For the Teacher

- PI: July Average Surface Temperature
- PI: Comparison of July and January Visualizations

Repeating Demonstration of Seasons and Earth’s Orbit

You may wish to repeat this activity. This time, as each stop is made, ask students, “Everyone who is having summer on their model, raise your hands.” If there is disagreement over which models are having summer, have students explain their thinking.

SAFETY GUIDELINES

This lesson presents no unusual safety concerns; however, see IQWST Overview for general laboratory safety.

Differentiation and Other Strategies

1. Activity 8.4—If there are some students in the class who are more advanced and would benefit from doing this activity individually, that would be an excellent way to allow them to move at their own pace.

Graphing the Data

2. An alternative to using the lamp would be to have a student stand in the center of the room to represent the sun. It is more effective to use an actual light source, but depending on the configuration of the classroom and accessibility to an electric outlet, using a student as the sun may be a better option.

3. Depending on students’ ability to graph data, you may choose to have them work in groups to complete the graphing portion of the activity. However, each student should have a copy of the group’s graph to refer to throughout the lesson.
Teaching Lesson 8

Overview

Activity 8.1
- Graph city temperature data from Lesson 7.
- Compare that data to two visualizations of average surface temperature.

Activity 8.2
Review the ideas of the Earth’s rotation and revolution.

Activity 8.3
- Investigate the relationship between Earth’s tilt and seasons.
- Revise the model from Activity 7.5.

Activity 8.4
Construct an explanation to answer the Driving Question: Why Is Weather Different from Place to Place?

Learning Performances
Students will
- extend their previous model of sunlight and latitude to include the tilt of the Earth in orbit and explain how the light varies across the year to cause patterns in seasonal changes in climate.
- apply their model of seasonal changes in climate to explain why seasons vary in the Northern and Southern Hemispheres and evaluate the fit of the model against yearly patterns in temperature across the globe.

Building Coherence
This lesson investigates the relationship between Earth’s tilt and seasons. In the last lesson, students explained the relationship between temperature, latitude, and light intensity. In the final activity, they used their explanation to explain a visualization of temperature data for January. This lesson begins by comparing that data to data for July and realizing that their explanation from Lesson 7 does not fit the new data.

Timeframe
Four to five 50-minute class periods
Activity

Activity 8.1: Does the City Data Match the Visualizations?

Building toward Performance Expectation MS-ESS2-6
Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.

Disciplinary Core Idea ESS2.D: Weather and Climate
• 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.

Science and Engineering Practices: Asking Questions and Defining Problems; Developing and Using Models; Analyzing and Interpreting Data; Constructing Explanations and Designing Solutions; Engaging in Argument From Evidence

Crosscutting Concept: Patterns

Materials

For the Teacher
- PI: City Temperature Data
- PI: July Average Surface Temperature
- PI: Comparison of July and January Visualizations
- paper lantern model from Lesson 7

For Each Student
- SE Activity 7.1 (city temperature data)
- SE Activity 8.1
- (6) colored pencils* (six different colors)

*This item is not included in the kit.

Introducing the Activity
Students have an explanation that, for the most part, fits the visualization for January. Ask them what they think a visualization of average surface temperature for the month of July would look like based on their explanation. Keep track of students’ ideas.

Possible responses may include the following.

• It would look the same because the sun heats the Earth all year, and the shape of the Earth does not change, so the intensity would be the same.
• Where we live is hotter in the summer, so the visualization should show that. For example, we live in Chicago and I know it gets hot here in the summer, so the map should show that it is hotter.
• The idea of seasons may come up at this point. If it does not, do not raise it. It will be addressed later in the lesson.

Once all ideas are shared, show PI: July Average Surface Temperature. Have students share how this visualization compares to what they thought it would show. Then, project both visualizations and have students compare the two (PI: Comparison of July and January Visualizations).

• Does your explanation about the relationship between temperature and latitude work for the visualization of July? Students should point out that there is a significant change in temperature by latitude, so their previous explanation does not work. Students should identify the following changes:
  • The South Pole is now much colder than the North Pole.
  • The band of hot temperatures is now farther north of the equator.
  • Areas north of the equator are now much warmer.

• What other data do you have that you could you use to decide whether these visualizations are accurate? Students should suggest that they have temperature data from their cities in Lesson 7. Point out the location of the cities on the map. They are all at different latitudes. Suggest that they start with this city data to see if it fits the visualizations.

Guiding the Activity

In Activity 7.1, students used the average monthly temperature data for each of the cities to determine a yearly average. Have students take out Activity 7.1 and turn to the temperature data on the last page. Ask the following questions:

• What does this chart show?
• If you are trying to find a pattern in the temperature data, is there an easier way to show the data so that the pattern would be clearer?
• How else could you represent this data?

Students should be familiar with graphs as another way to represent this kind of data. In this activity, they will graph the average monthly temperature for each of the cities in order to describe the pattern.
Students will follow the procedure to graph the data on SE Activity 8.1. Remind them that they should use a different color pencil for each of the cities. When students have finished creating their graphs, they should answer the Making Sense questions.

**Discussion: Synthesizing**

Purpose: To identify the patterns in the temperature data and compare them to the visualizations.

Have one group share their graph with the class. The class should reach a consensus on what the graph should look like before moving on to the discussion. If students disagree with the graph that the first group presents, have them explain what they disagree with, and what evidence they have that the data are plotted incorrectly. The class consensus graph should be similar to the following example:

Use PI: Temperature Data so that students can use this as a basis for their discussion of the patterns.

- **What is one pattern you can identify in the data?** *(At the top of the graph, there are two lines that overlap along the 80° line.)*
- **What does this pattern tell you about the temperature in these two cities?**

It is not important which pattern students identify first. The plan is a suggestion for one possible path through the data. The order is not as important, as long as the major ideas for each pattern are identified, discussed, and linked to the visualization and explanation from Lesson 7.
WHAT MAKES THE WEATHER CHANGE?

- What does this pattern tell you about the temperature in these two cities? (It does not change much over the course of a year.)
- Where are these two cities (Belem and Singapore) located? (Using the class map, students should see that these two cities are located very close to the equator.)
- What did the visualizations show you about temperature near the equator in January and July? (It was hot near the equator all year long.)
- Do the temperature data for these two cities and the visualization show the same thing about the temperature in these two cities? (Yes. The explanation from Lesson 7 said that the light from the sun hits the Earth most directly at the equator. That means the sunlight there is the most intense and temperatures are the hottest. The data from the graph shows that the two cities closest to the equator are the hottest, so the data fits with the explanation.)

Have students continue to identify patterns. The following is a list of the possible patterns and ideas that should come out of this discussion:

There are two lines that are at their highest from June through August, and two lines that are at their lowest at that time.

- Which two cities have their highest temperatures from June through August? (Atlanta and Oslo)
- Where are these cities located? (Northern Hemisphere; north of the equator)
- Which two cities have their lowest temperatures in June through August? (Ushuaia and Buenos Aires)
- Where are these cities located? (Southern Hemisphere; south of the equator)
- Does this match with what you saw in the visualizations?

Project both visualizations and have students compare the data from the graph to the visualizations. The visualizations show that cities north of the equator have warmer temperatures June through August and that cities south of the equator are cooler during that time.
At this point, students should be able to connect the data on the graph to what they see in the visualization and see that they agree. Return to the paper lantern model of the Earth from Lesson 7. Position the model so that it is directly opposite the light source as it was in Activity 7.3. Remind students that in Lesson 7, they determined the following:

- Light from the sun strikes spots on the Earth that are at the same latitude in the Southern and Northern Hemispheres at the same angle.
- The shape of the Earth affects the angle at which sunlight strikes the Earth.
- Sunlight strikes the Earth most directly at the equator.
- The farther away from the equator a place is, the less direct the sunlight.
- The angle at which light hits the Earth affects its intensity.
- The more intense the light, the higher the temperature of that place.

- What is the coldest time of year for these four cities based on the graph?
- Does this match what is on the visualizations? (Coldest temperatures for Oslo and Atlanta are from December through February, and coldest temperatures for Ushuaia and Buenos Aires are from June through August. The visualizations show this.)
- When cities in the Northern Hemisphere are having their coldest temperatures, what is happening in the Southern Hemisphere? (Cities there are having their warmest temperatures. It is the opposite.)
- Does the temperature in these cities remain about the same during the year or does it vary?
  - The two cities near the equator have nearly the same temperature all year. Is that true for the other places? (no)
- What is that variation in temperature over the course of a year called? (seasons)
- When it is winter in the Northern Hemisphere what season is it in the Southern Hemisphere? (summer)
- How do you know? (Temperatures in the Southern Hemisphere are much warmer than in the Northern Hemisphere.)

Students should be able to reason that if it were just the shape of the Earth, temperatures both north and south of the equator would be the same all year.)
Students are left with two questions:

- What causes the temperature differences over a year that creates seasons?
- Why are seasons the opposite in the Northern and Southern Hemispheres?

Record these questions on the DQB, so students can track what they are trying to answer in the next activity.

Brainstorm with students their ideas about the answers to these questions and record them.

**What else do you know about Earth that might affect the temperature?** (Possible ideas might include day and night; seasons; the fact that the Earth revolves around the sun, rotates on its axis, or spins; and the idea of tilt.)

It is not important that students have an understanding of these ideas at this time. In the next activity, students will investigate the ideas of rotation and revolution. Tilt will be investigated in Activity 8.3, and it is not necessary to raise it as a possibility here if students do not bring it up.
Activity

Activity 8.2: How Does the Earth Move?

Building toward Performance Expectation MS-ESS2-6
Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.

Disciplinary Core Idea ESS2.D: Weather and Climate
- 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.

Building toward Performance Expectation MS-ESS1-1
Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.

Disciplinary Core Idea ESS1.A: The Universe and Its Stars
- Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.

Disciplinary Core Idea ESS1.B: Earth and Solar System
- This model of the solar system can explain eclipses of the sun and the moon. Earth’s spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.

Science and Engineering Practices: Developing and Using Models; Planning and Carrying Out Investigations; Constructing Explanations and Designing Solutions; Obtaining, Evaluating, and Communicating Information

Crosscutting Concepts: Scale, Proportion, and Quantity
Introducing the Activity
Students left the last activity with two unanswered questions and some possible ideas for answers. Refer to the two questions on the DQB and the ideas that students brainstormed. In this activity, students will use a ball model of the Earth to investigate the Earth’s rotation on its axis and revolution around the sun to see if those movements can answer their questions.

Guiding the Activity
Setting Up the Earth Model
Distribute materials and guide students through the setup of their models on SE Activity 8.2.

Have students begin by drawing a black line around the middle of their Styrofoam ball to represent the equator.

Complete the remaining steps. Be sure to question students about what the markings on the ball represent. (Refer to the questions that follow.)

- Mark the North and South Poles with a red dot.
- Approximately halfway between the equator and the North Pole, place a green dot.
- Between the green dot and the North Pole, place a blue dot. This dot should be closer to the pole than the green dot. The three dots (red, blue, and green) should be in a line.
- Halfway between the equator and the South Pole, place another green dot.
- Between the green dot and the South Pole, place a blue dot.
- Place two yellow dots just above and just below the equator.

When students finish, their models should look like the following representation.
The chart on SE Activity 8.2 asks students to make the connection between the location of the dots on their model and the latitude of the cities they have been studying. Using the map where the cities are plotted, make sure students understand that the cities do not all line up along the same longitude. They are looking at latitude, because the data showed that cities at the same latitude (whether north or south of the equator) had approximately the same temperature. Longitude was not a factor. In this model, the cities are lined up along the same longitude so that it is easier to compare the variation caused by latitude. Allow students a few minutes to fill in the chart and then review it with them.

The answers are as follows:

**North of the Equator:**
- yellow = Singapore
- green = Atlanta
- blue = Oslo

**South of the Equator:**
- yellow = Belem
- green = Buenos Aires
- blue = Ushuaia
Have students push the pencil into the ball at the South Pole.

If the pencil were long enough and could extend out the point where the North Pole is, what would this represent? *(Earth’s axis)*

Students may be familiar with this term from previous science classes.

They should understand the following key ideas:

- Earth’s axis is an imaginary line that runs from the North Pole to the South Pole through the center of Earth.
- Earth rotates one full turn around its axis each day. This is why people experience day and night. Place a lamp without a shade in the center of the room to represent the sun.

**Investigating Earth’s Movements Using the Model**

Students should form a circle around the sun, holding their models by the pencil. They should keep the pencil perpendicular to the floor, holding their model vertically. Have all students orient their models so that the dots are directly facing the sun.

- **What time of day would people standing on Earth where the dots are be experiencing now?** *(The time of day would be noon.)*
- **How do you know?** *(They are directly facing the sun.)*

Have students spin their model 180° so that the dots are now facing away from the sun, opposite from where they started. They should rotate their Earth in a counterclockwise direction.

- **What time of day would it be where the dots are now located? How do you know?** *(It would be night because no light is reaching the dots.)*
- **What is this spinning of the Earth called?** *(It is called rotation.)*
- **What does this create?** *(It creates day and night.)*
- **Why is it night on the side of the Earth that is facing away from the sun?** *(The sun’s rays are blocked by the Earth and cannot reach the side that is facing away from the sun.)*

Students should understand that light travels in a straight path. Light from the sun cannot curve around the Earth to reach the opposite side. This concept was explored in the IQWST PS1 unit.
Answer Questions 1, 2, and 3 in Part 1 on SE Activity 8.2.

- In this model, do all parts of the Earth receive the same number of hours of light in a day? (yes)
- Does that agree with your data on hours of daylight from Activity 7.2? (The data showed that the number of hours of daylight that a location received varied each month over the course of the year. However, during an entire year, all places on the Earth receive the same number of hours of sunlight.)
- If all places got the same number of daylight hours each day like in this model, would the number of hours of daylight each month vary?
- Does the rotation of the Earth on its axis creating day and night answer your two questions? If not, what can rotation not explain? (In this model, rotation creates day and night with all places on the globe receiving the same number of hours of daylight each day. This does not fit the data from 7.2 that showed the hours of daylight varied by month. It also does not explain why the Northern and Southern Hemispheres have opposite temperatures at the same time of year.)
- If day and night cannot answer your questions, what else do you want to investigate?
- What other movement besides rotating on its axis does the Earth make?
- In Lesson 7, you looked at data over the course of a year. What is a year? (Some students may offer the idea of the Earth moving around the sun and that it takes a year for it to happen. If “revolve around the sun” does not come up, suggest it here.)
- How long does it take Earth to revolve around the sun one time? (Students should know that it takes the Earth one year to complete one orbit around the sun.)

Students will model Earth revolving around the sun to see if this movement can answer their questions:

1. What causes the temperature differences that create seasons?
2. Why are the seasons opposite in the Northern and Southern Hemispheres?

Have students fill in the Prediction section in Part 2 on Activity 8.2. This asks them to draw what they think Earth’s orbit looks like and explain why they think it looks that way. After completing their predictions, have students share their ideas about the shape of the Earth’s orbit by drawing them on the board. Be sure to get all ideas posted. Students will revisit this prediction after they complete Activity 8.3.

Turn on the light in the center of the room. The main source of light in the room should be the lamp. You may need to turn off the lights and pull down the shades. Have students form a circle around the light. Position the circle around the lamp so that the sun (lamp) is in the center.
What makes the weather change?

Have students change the shape of the orbit to match some of the suggested possibilities from their predictions. For each new orbit shape, ask them if any part of the Earth stays in the light longer. Students should see that all parts are receiving the same amount of light no matter what shape the orbit is, because the Earth is being held vertically.

Have students complete the Making Sense questions.

Discussion: Synthesizing

Purpose: To explain why Earth has seasons.

Do any of these orbits explain why there are seasons? (Some students may suggest that the orbit that shows the sun closer to the Earth at one time of year explains summer and winter.)

Remind students that there are two questions they are trying to answer. Ask if any of the orbits that have been suggested can answer their question about why the seasons (temperatures) are opposite in the Northern and Southern Hemispheres.

Students should be able to state that the light from the sun would be the same at 30°N latitude as it would be at 30°S. Cities such as Oslo and Ushuaia would be receiving about the same amount of light and the same intensity of light, so their temperatures should not be very different.

Let students know the following about Earth’s orbit:

- Earth’s orbit is almost a circle around the sun.
- Draw the Earth’s orbit on the board with the orbit being elliptical (but almost a perfect circle) and the sun slightly off from the center. Compare this to the drawings students did. If there are students’ drawings that are approximately correct, leave them posted on the DQB. If there are none, post your drawing.
- The Earth is slightly closer to the sun in January.
- The farthest the Earth is from the sun is 152 million kilometers. The closest is 147 million kilometers. Let students know that the percentage change in distance from the closest to
the farthest point from the sun is only 3%. Link this difference to the local temperature students experience. Ask the following questions:

- How hot does it usually get here in the summer?
- How cold is it in the winter?
- Is that more than a 3% difference?

At the end of this activity, students should understand the following:

- Earth rotates on its axis once every 24 hours, creating day and night.
- Earth revolves around the sun once a year.
- Earth’s orbit is almost a circle, and its distance from the sun does not vary much over the course of a year.
- If Earth is straight on its axis and making these two movements, students still cannot answer their questions.

- Do these four ideas help you answer your questions? (In Activity 8.2 part 1, students learned that rotation produces day and night, but still cannot explain seasons. In Activity 8.2 part 2, they learned that revolution around the sun occurs once a year but cannot answer both questions.)

- Does the shape of the Earth’s orbit answer both questions? (If the Earth were closer to the sun in the summer and farther away in the winter, that could explain seasons, but it does not work because it cannot explain why seasons are opposite in the Northern and Southern Hemispheres.)

- What ideas do you have about what could be causing the differences?

- Do you think your model is an accurate representation of what is happening with the Earth? Why?

- What do you think you could change about the model to make it more accurate? (Some students may suggest that the Earth should not be vertical but rather should be tilted. In previous science classes, students may have heard that the Earth is tilted.)

- What do you mean by tilted, and why do you think it is important?

In the next activity, students will use this same model, only with a tilted Earth to see if that can answer both of their questions about seasons.

Introducing Lesson 8 Reading One: Day and Night
Imagine you are hanging with friends. Perhaps you are at the local pool or playing soccer at the park. Imagine no one brought their phone and nobody has a watch with them. How would you try to keep track of the time so you are home for dinner?

Lesson 8 Reading One Follow Up
Ask the students how shadows change during the seasons. Are the length of shadows different at different latitudes? Add any questions that arise to the DQB.
Activity

Activity 8.3: Does a Tilted Earth Explain the Seasons?

Building toward Performance Expectation MS-ESS1-1
Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.

Disciplinary Core Idea ESS1.A: The Universe and Its Stars
- Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.

Disciplinary Core Idea ESS1.B: Earth and Solar System
- This model of the solar system can explain eclipses of the sun and the moon. Earth’s spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.

Science and Engineering Practices: Asking Questions and Defining Problems; Developing and Using Models; Planning and Carrying Out Investigations; Constructing Explanations and Designing Solutions; Engaging in Argument From Evidence; Obtaining, Evaluating, and Communicating Information

Crosscutting Concepts: Cause and Effect; Energy and Matter

Materials

<table>
<thead>
<tr>
<th>For the Teacher</th>
<th>For Each Student</th>
</tr>
</thead>
<tbody>
<tr>
<td>• (1) lamp without shade (from Activity 8.2)</td>
<td>• Styrofoam ball Earth model (from Activity 8.2)</td>
</tr>
<tr>
<td></td>
<td>• SE Activity 8.3</td>
</tr>
<tr>
<td></td>
<td>• Lesson 8 Reading Two</td>
</tr>
</tbody>
</table>

Introducing the Activity
Students are trying to answer the following two questions:
- Why does temperature vary over the course of the year causing seasons?
- Why are seasons in the Northern Hemisphere opposite those in the Southern Hemisphere?
At the end of Activity 8.2, students suggested some ideas about what else they could test with their model. It is assumed that tilt will be on the list. If it is not, prompt students to add:

- Are you familiar with the idea that the Earth is tilted?
- What does it mean for the Earth to be tilted on its axis?

In this activity, students will investigate what will happen if the Earth is tilted rather than being vertical.

Have all students tilt the North Pole of their models toward the sun and spin their models.

- Do all the dots (cities) have day and night? (yes)
- Which cities have longer days? Shorter?
- Can someone show me what that would look like using your model? (Northern Hemisphere cities have longer days; Southern Hemisphere cities have shorter ones.)
- How many hours of daylight would there be at the North Pole? South Pole? (North Pole receives 24 hours of daylight; South Pole receives 24 hours of darkness.)
- What season is it in the blue and green dot cities in the Northern Hemisphere? (The season is summer.)
- Is the temperature the same in both cities? Why? (The blue dot city receives more hours of daylight and would be warmer than the green dot city. The more hours of daylight a place receives, the higher the temperature. Data from Activity 7.2 show this.)
- In your model, you have the Northern Hemisphere tilted toward the sun. Is this how it is all year? How do you know?
- What happens to cause the seasons to change during the year?

At this point, students may suggest that the tilt changes so that sometimes the North Pole points toward the sun and sometimes the South Pole does. This changing direction of the poles is a common student misconception about what causes seasons.

- Have a student demonstrate what this would look like.
- Does the Earth rock back and forth like that? (Tell students that as the Earth moves around the sun in its orbit, the North Pole is always pointing at the North Star. This tilts the Earth’s axis at an angle of 23.5°.)
**Guiding the Activity**

Pick a spot in the classroom to represent the North Star. This can be a clock or a poster mounted high on the wall. (You can also use a corner of the room where the wall meets the ceiling.) Have students tilt the North Pole of their model toward the North Star. Go around the circle to check student positions. They should be positioned as follows:

- Students standing between the sun and the North Star should have their North Poles facing away from the sun.
- Students standing on the opposite of the “orbit” should have their North Poles facing toward the sun.
- Students standing midway between these places in the orbit should have their North Pole facing somewhat sideways.

See the following model.

Once students have their models positioned correctly, move around the orbit and use the following prompts.

Reminder: Students may need to be reminded that “tilted toward the sun” does not mean that the North Pole is pointed directly at the sun. It means that the Northern Hemisphere is facing in the direction of the sun at an angle. Begin with the place in the circle (orbit) where the Northern Hemispheres on student models are facing toward the sun.
• **When the Earth is in this part of its orbit, which hemisphere is facing toward the sun?** *(It is the Northern Hemisphere.)*

• **What season are the blue and green cities on your model having? Why?** *(It is summer because they are facing the sun more directly and are getting more intense light. They are also experiencing more hours of daylight.)*

• **Is it the same season for the blue and green cities in the Southern Hemisphere? Why?** *(The Southern Hemisphere is having winter. It is facing away from the sun and gets less intense light and fewer hours of daylight.)*

Move around the “orbit,” making a total of four stops. Repeat these questions at each point in the orbit.

When students seem able to demonstrate their understanding of tilt and how it affects seasons, have students complete the model on SE Activity 8.3 that asks them to draw and label a model of the Earth’s orbit, tilt, and seasons. This should diagram what they just physically demonstrated in class.

**Discussion: Synthesizing**

Purpose: To connect the ideas of tilt and seasons.

When students have finished, have someone put their model on the board (or project it using a document cam).

Using the student model as a focus for the discussion, encourage students to think about the following:

• **Does the model show the shape of the Earth’s orbit?**

• **Is there anything about the shape you would change? Why?**

• **Does the model show Earth in the correct position for winter in the Northern Hemisphere? Why?**

• **How would you change it? Why?**

• **What about summer in the Northern Hemisphere? Why?**

• **What would you change, and why?**

• **Are spring and fall identified correctly?**
Continue to press students for understanding until the class seems to be able to explain the model and agree on it. Post the final model of the seasons on the DQB.

Use the DQB to review what students learned about light in Lesson 7:

- The temperature on Earth varies by latitude.
- The light intensity varies by latitude and corresponds to temperature (i.e., greater intensity equals higher temperature.)
- The angle at which light hits the Earth affects intensity (more spread out, less intense) and therefore temperature.
- The sun hits the Earth most directly at the equator, making the light more intense. This is where the highest temperatures were.

Use the light source and lantern from Lesson 7 to show students the following:

- The shape of the Earth affects light intensity and temperature.
- The light at the equator was more intense and the temperatures were highest.

**Would tilting the lantern model affect intensity? How?**

Tilt the lantern so that the North Pole is pointed away from the light source. Have students discuss in their groups what they think would happen to the intensity of the light in the Northern Hemisphere and the Southern and why. Give students about five minutes to discuss their ideas. Then, bring the class together and have them share their ideas. After all ideas have been shared, ask them if they can think of a way they could test their ideas. Could you measure the intensity using the light sensor? Enlist the help of two students and measure the light intensity at the equator and in two spots both north and south of the equator while the lantern is tilted. Students should see the following.

- The equator is no longer the hottest. Ask where the hottest latitude is now.
- The two spots north of the equator had much less intense light than the two spots south of the equator.

**How do these readings compare to the data from Activity 7.3?**

- How would those intensity readings affect the temperature of cities north of the equator? (colder)
- What about cities south of the equator? (warmer)
- What season would it be north of the equator? (winter)
- What season would it be south of the equator? (summer)
Discussion: Synthesizing

Purpose: To bring together the ideas about light, temperature, tilt, and seasons.

Create a three-column table that lists the big ideas (Scientific Principles) from Lessons 7 and 8 and the evidence that supports them that students have collected. Use the column in the middle to tell how the evidence supports the principle.

<table>
<thead>
<tr>
<th>Big Ideas (Scientific Principles)</th>
<th>How Evidence Supports the Principle</th>
<th>Evidence</th>
</tr>
</thead>
</table>

Have students return to SE Activity 8.3 and answer the final question. This asks for a scientific explanation to answer the two questions students have been working on throughout this lesson. These are the two questions that students have been trying to answer:

- What causes the temperature differences that cause seasons?
- Why are seasons opposite in the Northern and Southern Hemispheres?
At the end of this activity, students should understand the following:

1. The intensity of the light reaching the Earth at different latitudes varies because of the Earth's shape.
   - Evidence—Lantern activity where light intensity was measured at various latitudes, and the readings, showed the light was less intense the farther away from the equator a site was.

2. The difference in intensity is because the same amount of light is being spread over a larger area.
   - Evidence—Graph paper activity where the flashlight was tilted and the light covered more squares of the graph paper.

3. Light intensity is greatest at the equator.
   - Evidence—Lantern activity that showed the light sensor had the highest readings at the equator.

4. The more intense the light, the higher the temperature.
   - Evidence—City data showed that the cities close to the equator had higher temperatures than the cities farther away.

5. Because Earth is tilted, there are seasons. (This explains seasons but not why the hemispheres are different.)
   - Evidence—Lantern activity showed that if the Earth were vertical, the cities at the same latitude north and south of the equator would get the same intensity of light and their temperatures should be the same all year. Data from cities showed this was not true.
   - Evidence—Class modeling of Earth's movements. Revolving around the sun when Earth was not titled did not make any difference in the Northern and Southern Hemispheres.
   - Evidence—The tilted Earth model also showed that during the summer, the areas north of the equator got more hours of daylight. This means more light energy can be transferred, and they would be warmer.

6. The Earth is tilted so that the North Pole always is pointed toward the North Star. This keeps the Earth at the same tilt all year long. The way the Earth is tilted, and the fact that it orbits the sun, is what cause seasons to be different in the Northern and Southern Hemispheres.
   - Evidence—Class physical models showed this. At one time of year, the Northern Hemisphere was facing the sun and experiencing summer. The light that was hitting the Northern Hemisphere would be more direct and more intense, causing higher temperatures. At the same time, the Southern Hemisphere was facing away from the sun, and the Southern Hemisphere was experiencing winter. The light would be less direct and less intense, so temperatures would be lower.

The class should reach consensus on these ideas before moving on.

In this lesson, students have explained a complex phenomenon and will now apply those ideas to answer the final question on the DQB. Remind students that they have not answered the second part of the Driving Question: Why Is Weather Different from Place to Place? In the next activity, they will explain why the weather is not the same in two of their case study cities.

Ask the students, "If you could spend any season in a different state or country, where and when would you go? Why did you choose that place?" Reading follow up: Ask the students "Why do you think it was important for people to be able to tell how long it would be before the seasons changed? What other ancient civilizations created monuments to help them keep track of the passing year and seasons?"
Activity 8.4: Why Isn’t the Temperature the Same Everywhere?

Building toward Performance Expectation MS-ESS1-1
Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.

**Disciplinary Core Idea ESS1.A: The Universe and Its Stars**
- Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.

**Disciplinary Core Idea ESS1.B: Earth and Solar System**
- This model of the solar system can explain eclipses of the sun and the moon. Earth’s spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.

**Science and Engineering Practices:** Constructing Explanations and Designing Solutions; Engaging in Argument From Evidence; Obtaining, Evaluating, and Communicating Information

**Crosscutting Concepts:** Patterns: Cause and Effect; Energy and Matter

**Materials**

**For Each Student**
- SE Activity 8.4

**Introducing the Activity**
Students still have not answered the second part of the Driving Question: Why Is Weather Different from Place to Place? In the last activity, students explained the answers to two questions that should help them answer the final part of the Driving Question. In this activity, students will work in groups to use the data about two of the case study cities, along with evidence gathered in Lessons 7–8, to write an explanation that will answer the question.
Using the map in the room (or in the SEs), review the location of each of the cities on the map. Ask students what kind of data they have for each of the cities:

- latitude/longitude
- average monthly temperature
- hours of daylight by month and total for year

Use the DQB to review the data they have collected in class:

- light intensity using the lantern
- effect of angle on light intensity (flashlight and graph paper)

Ask if they have anything else that will help answer the question:

- model of Earth’s orbit
- model of Earth’s position during different seasons

**Guiding the Activity**

Explain to students that they will work in groups to complete this activity. Each group will choose two cities from the six case study cities. One city should be from the Northern Hemisphere and one from the Southern Hemisphere. It does not matter which two cities they pair together.

Put students into groups of three or four. They should first make sure that they have all of the data and models they will need. Then, have them choose their cities. There are nine possible combinations, so it is possible that no two groups would have the same pair. However, if groups do want to use the same pair of cities, this would be fine and would give them an opportunity to evaluate each other’s ideas before writing their final explanation. Each student should then write his or her own explanation to answer the Driving Question: Why Is Weather Different from Place to Place?

Students should be given 1–2 days to organize their data and ideas and write their explanations. They then can meet with their group to compare ideas and evidence.

**Discussion: Synthesizing**

Purpose: To explain what causes two cities to have different weather.

After the explanations are complete, have students share some of their explanations with the class. After a student has read his or her explanation, have others share why they agree or disagree.

- Do you agree with the evidence they used?
- Does the evidence support the big ideas?
- Is there anything you would add to this explanation? All explanations do not have to be shared.
Wrapping Up

- Which model helps you answer the question about why weather is not the same from day to day?
- What evidence do you have to support your answer?
- Which model explains why the weather is not the same everywhere? How?

DQB

Develop Principle #16; record on the Scientific Principles list, and post either on the DQB or elsewhere in the room. Answer all remaining, answerable questions on the DQB. Unanswered questions may be turned into independent research or investigative projects for individuals or groups. Post final explanation on the DQB.

Assessing Learning

The table from Activity 8.3 can be used to assess students’ ability to identify appropriate data as evidence to support the scientific principles they have developed.

In Activity 8.4, students apply their model of seasonal change to explain yearly patterns in temperature data across the globe. By the end of the unit, students should be able to answer with a full, CER explanation based on evidence from their investigations: “Why is weather different from place to place?” and “What makes the weather change?”

Introducing Lesson 8 Reading Two: Seasons of the Year

Ask the students, “If you could spend any season in a different state or country, where and when would you go? Why did you choose that place?”

Lesson 8 Reading Two Follow Up

Ask the students “Why do you think it was important for people to be able to tell how long it would be before the seasons changed? What other ancient civilizations created monuments to help them keep track of the passing year and seasons?”
Activity 8.1: Does the City Data Match the Visualizations?

What Will We Do?
We will compare city data to identify patterns in the city temperature data and compare them to the visualizations.

Procedure
□ a. You will need the city temperature data from SE Activity 7.1. Plot the monthly temperature for each city on the graph.
□ b. Label the x-axis (horizontal axis) with the months of the year. Label the y-axis (vertical axis) with temperature. Each line on the vertical axis should represent 10°F.
□ c. Use a different color pencil for each of the cities. Be sure to fill in the key below the graph to show what colors you are using.
□ d. Begin with Oslo and plot a point for each of the average monthly temperatures. When all 12 months are plotted, connect the points so that you have a line graph of the temperature for Oslo.
□ e. Repeat Step d for each of the five remaining cities.
□ f. When your graph is complete, answer the questions under the Making Sense section.

Data
The following is a sample graph showing the relationship between the six cities.
Making Sense

1. Describe any patterns you see in the graph.
   There are two lines at the top of the graph that overlap most of the year. The two cities near the equator have nearly the same temperature all year.
   There are two lines that are at their highest June through August and two lines that are at their lowest at that time.
   When cities in the Northern Hemisphere are warmest, the ones in the Southern Hemisphere are coldest.

2. Does the latitude of the cities explain the patterns? Why?
   Latitude cannot explain everything, because cities that are the same distance from the equator should get the same amount of light and have the same temperature, but they do not.
3. Can the shape of Earth explain the patterns in the data? Why?
   The shape of Earth can only explain part of the pattern but not the difference between
   summer and winter in the Northern and Southern Hemispheres.

4. List any ideas that you have that might explain the patterns you observed in the data.
   Possible student responses include seasons make it different, the Earth is tilted, and
   the Earth rotates around the sun.
Activity 8.2: How Does the Earth Move?

What Will We Do?
We will investigate Earth’s movements to answer the question about temperature variation at different latitudes.

Part 1
Procedure
Follow these steps to create your Earth model.
Important: The dots you mark on the model should form a straight line from the North Pole to the South Pole.

☐ a. Draw a black line around the middle of the Styrofoam ball to represent the equator.
☐ b. Place an X on the top of the ball to mark the North Pole. On the opposite side of the ball, make a dot to represent the South Pole. It is important that you can tell which mark is the North Pole and which is the South Pole.
☐ c. Approximately midway between the equator and the North Pole, make a green dot.
☐ d. Between the green dot and the North Pole, place a blue dot. This dot should be slightly closer to the North Pole than the green dot.
☐ e. Halfway between the equator and the South Pole, place another green dot.
☐ f. Between the green dot and the South Pole, place a blue dot.
☐ g. Place two yellow dots just above and just below the equator.
Data

The green, blue, and yellow dots each represent one of the six case study cities. Using the map in your classroom or the map from Activity 7.1 where you marked the location of these cities, fill in the chart.

<table>
<thead>
<tr>
<th>Dots North of the Equator</th>
<th>City</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue</td>
<td>Oslo</td>
</tr>
<tr>
<td>Green</td>
<td>Atlanta</td>
</tr>
<tr>
<td>Yellow</td>
<td>Singapore</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dots South of the Equator</th>
<th>City</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue</td>
<td>Ushuaia</td>
</tr>
<tr>
<td>Green</td>
<td>Buenos Aires</td>
</tr>
<tr>
<td>Yellow</td>
<td>Belem</td>
</tr>
</tbody>
</table>

Making Sense

In class, you modeled Earth spinning on its axis (rotation). Use what you learned to answer the following questions:

1. In the model, did all parts of the Earth receive the same number of hours of daylight in a day?
   
   Our model showed that everywhere on Earth would get the same number of hours of daylight in a day.
2. Does your answer from Question 1 agree with the data about hours of daylight from Activity 7.2? Support your answer with evidence.
   No, the data showed that cities got different amounts of daylight. Students should cite specific examples.

3. Does the rotation of Earth on its axis, creating day and night, answer the two questions the class still has? Be specific about what it can and cannot answer.
   a. What causes the temperature differences that create seasons?
      Answers will vary.
   b. Why are seasons the opposite in the Northern and Southern Hemispheres?
      Our model of Earth’s rotation cannot explain either of the questions we still have. If all places receive the same amount of daylight, then the temperatures should be the same all year everywhere. We know that is not true, because of the data on daylight and temperature.
Part 2

4. Draw what you think Earth’s orbit looks like. Be sure to include the sun, Earth, and a line showing the shape of the orbit.
   
   Answers will vary.

5. Explain why you drew the shape of Earth’s orbit the way you did.
6. Does the shape of the Earth’s orbit answer the two questions the class still has? Be specific about what it can and cannot answer.

a. Question one: What causes the temperature differences that create seasons?
   The temperature differences on Earth are caused by the shape of the Earth. Those temperature differences are also impacted by Earth’s tilt giving some areas more hours of daylight at certain times of the year.

b. Question two: Why are seasons the opposite in the Northern and Southern Hemispheres?
   Seasons are opposite in the Northern and Southern Hemispheres because of Earth’s tilt as it revolves around the sun.
7. Return to Question 4 where you drew Earth’s orbit. Redraw your model and explain what you changed and why. If you did not change anything, explain how your model answers both questions.

Student diagrams may differ somewhat but should show the tilted Earth revolving around the sun.
Lesson 8 Reading One: Day and Night

Getting Ready

Have you ever wondered how you would keep track of time if all of the clocks in the world disappeared? Long, long ago, our ancestors were faced with a problem just like that. Clocks had not been invented, and they needed a way to tell time so that everyone could understand it.

Every day you can see the sun as it seems to rise from the eastern horizon, move across the sky, and set in the west. Once the sun has set, the night follows. This difference between the dark nights and the daylight was probably the first way ancient people began to tell time, but how could they tell the difference between early morning, noon, and late afternoon in an accurate way? You tell time by looking at your watch or checking the time on your phone. Ancient people looked at shadows.

Think about what you know about how shadows are created. How could ancient people have used shadows to tell the time? If you remembered that the length of a shadow changes over the course of a day, you would be right. During the day, people saw that the shadow cast by a tree, a rock, or even their own body was long in the early morning and grew shorter and shorter until it disappeared when the sun was overhead in the middle of the day. As the afternoon went on, they noticed that the shadow got longer again—only on the other side of the object.

Using Shadows to Tell Time

After a while, people were able to tell how much of the day was over by looking at the shadows. The first clock was probably invented by a person who put a stick into the ground and made marks in the dirt to show where the stick’s shadow was every hour.

Look at the picture. What time of day do you think it is based on the length of the shadow and why?

Students should be able to say that it is either early morning or late in the afternoon.
In class, you used a ball and a pencil to make a model of Earth to show day and night. It showed you that the sun is not really moving at all. It only seems to move because Earth is spinning around. You see the sun during the day because you are on the part of the Earth facing the sun. You do not see it at night because Earth has rotated so that you are on the side away from the sun.

Imagine that you are sitting on a chair that can spin and a friend is standing next to you holding a stick. Because the shadow cast by the stick is very long, it is either early in the morning or late in the afternoon. Shadows are the longest at sunrise and sunset. People judged the time of day by the length and position of the stick’s shadow. After a while, people divided the daylight into 12 hours and designed sundials like the one pictured. These sundials had the hours marked on them. By watching where the shadow fell, people would use the numbers to name what time of day it was.

Why Do Sundials Work?

Just like us, ancient people saw that the sun seems to move across the sky, starting in the east in the morning, moving toward the south in the afternoon, and then toward the west at the end of the day. Long ago, people believed many strange things about how the sun traveled across the sky. For example, the ancient Greeks believed that the sun rode across the sky in a chariot that was pulled by four white horses and driven by one of their gods, called Heléius. They believed that Earth was the center of the universe and the stars and other planets moved around it. They used the movement of the sun in the sky as evidence for their belief.

Is the sun actually moving across the sky? Explain your answer.

The sun is not moving. Earth is rotating on its axis. It just appears that the sun is moving across the sky.
candle. You first see the candle out of the corner of one eye. If you spin slowly in the chair, you can see the candle move from the side until it is right in front of you. Then, it seems to move to the other side until it disappears. It is now behind you. If you did not know you were spinning, you might think the candle was moving around you in a circle. This is the same thing that happens with the Earth and the sun. Instead of the chair spinning, it is Earth that spins. People are on the surface of the Earth as it points them in the direction of the sun and then away from it. This same thing happens every single day. You experience sunrise and sunset because Earth is spinning on its axis. Actually, the terms sunrise and sunset are misleading, since the sun does not actually move around Earth; it just appears to do so.

In your model in class, you used a pencil to represent Earth’s axis. Remember that Earth’s axis is an imaginary line that runs from the North Pole to the South Pole through the middle of the Earth. Earth completes one full turn around its axis once every day. That means it takes about 24 hours for Earth to do a complete turn. This rotating (or spinning) is why people experience day and night. One half of Earth faces the sun and is lit by the sun. At the same time, the other half faces away from the sun. The sun’s rays are blocked, so it is dark (or night time) on that side of Earth. As Earth spins on its axis, different parts turn to face the sun. This is what causes people to experience day and night.

**Back to the Sundial**

How does the spinning Earth help you understand the sundial? A sundial relies on the fact that as Earth rotates, the sun seems to travel across the sky. Any object standing in the sun blocks the sun’s rays and creates a shadow. Shadows change position and length depending on the time of day. That means that the different times of day can be marked around a stationary object and, during daylight, an estimate of the actual time can be made.

Think about the question you were asked at the beginning of this reading. What would you do if all of the clocks in the world disappeared? Do you think that you could still tell time?

Look at the homemade sundial. What time does the sundial show? How do you know?

Answers will vary.

If you want to try making your own sundial and see how well it works, search the internet for some simple instructions.
Activity 8.3: Does a Tilted Earth Explain the Seasons?

What Will We Do?
We will investigate whether Earth’s tilt could create temperature differences causing seasons.

Procedure

□ a. In class, you created a model of a tilted Earth and its path (orbit) around the sun that created seasons. Draw a picture that shows the following:
  • Earth’s orbit around the sun. Be sure to label the sun in your diagram.
  • The position of Earth in all four seasons—summer, fall, winter, and spring in the Northern Hemisphere. (You will need to draw four Earths on your diagram and label them with the seasons.) Then, label the equator and the North and South Poles on each Earth. Next to each of the four Earths, indicate which season is represented.
□ b. Answer the following questions to explain your diagram.
  □ 1. Look at Earth in your model that has the Northern Hemisphere in winter. Explain why you positioned Earth that way to make it winter.
    In the winter, the Northern Hemisphere is colder, so the light that reaches it is less intense. Earth needs to be positioned so that the North Pole is tilted away from the sun so that the light from the sun hits the Earth at a greater angle. The light will be more spread out and less intense and the temperature will be cooler.
2. Now look at the Earth that is in the summer position for the Northern Hemisphere. Why did you position it in this way?
   In the summer, the Northern Hemisphere is warmer and receives more direct light from the sun. That increases the intensity of the light and the temperature will be hotter.

3. Does the way you have the Earth positioned in your diagram show that the seasons are opposite in the Northern and Southern Hemispheres? How?
   Answers will vary depending on students’ diagrams.
### Making Sense

1. List all of the evidence you have from Lessons 7 and 8 and connect it to the scientific principles you have developed. In the column in the middle, tell how the evidence supports the principle.

<table>
<thead>
<tr>
<th>Big Idea (Scientific Principle)</th>
<th>How Evidence Supports the Principle</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>The intensity of the light reaching the Earth at different latitudes varies because of the Earth’s shape. Light intensity is greatest near the equator.</td>
<td>Readings from the lantern activity showed the light was less intense the farther away from the equator the site was. The highest readings were at the equator.</td>
<td>Lantern activity where light intensity was measured at various latitudes.</td>
</tr>
<tr>
<td>The difference in intensity is because the same amount of light is being spread over a larger area.</td>
<td>The activity showed that the tilted light covered more squares on the graph paper as the sun would cover more space on the tilted Earth.</td>
<td>Graph paper activity where the flashlight was tilted on graph paper.</td>
</tr>
<tr>
<td>The more intense the light, the higher the temperatures.</td>
<td>The city temperature data showed that the cities close to the equator where the light is most intense had higher temperatures.</td>
<td>City temperature data.</td>
</tr>
<tr>
<td>Because Earth is tilted, there are seasons.</td>
<td>Revolving around the sun makes no difference in temperature if the Earth is not tilted.</td>
<td>Class modeling of Earth’s movements.</td>
</tr>
<tr>
<td>Big Idea (Scientific Principle)</td>
<td>How Evidence Supports the Principle</td>
<td>Evidence</td>
</tr>
<tr>
<td>-----------------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------</td>
<td>---------------------------------------</td>
</tr>
<tr>
<td>Because the Earth is tilted, there are seasons.</td>
<td>If Earth were vertical, the cities at the same latitude North and South of the equator would get the same intensity of light and their temperatures the same but the data did not support that.</td>
<td>Lantern Activity</td>
</tr>
<tr>
<td>Because the Earth is tilted, there are seasons</td>
<td>During the summer, the areas north and south of the equator got more hours of daylight. This means more light energy can be transferred, and they would be warmer.</td>
<td>The tilted Earth model.</td>
</tr>
<tr>
<td>The Earth is tilted so that the North Pole always is pointed toward the North Star. The Earth is at the same tilt all year long. The way the Earth is tilted, and the fact that it orbits the sun, are what cause seasons to be different in the Northern and Southern Hemisphere.</td>
<td>At one time of year, the Northern Hemisphere was facing the sun and experiencing summer. The light that was hitting the Northern Hemisphere would be more direct and more intense, causing higher temperatures. At the same time, the Southern Hemisphere was facing away from the sun, and was experiencing winter with less direct light and lower temperatures.</td>
<td>Class physical models showed this.</td>
</tr>
</tbody>
</table>

Answers will vary depending on what students use to support their arguments. They should use principles from the Scientific Principles list and evidence from the data collected in the unit.
Lesson 8 Reading Two: Seasons of the Year

Getting Ready
All parts of the Earth experience seasons. In some places, the differences between one season and the next are large. It may be 32°C (89.6°F) in the summer, but in the winter the temperature may only reach –15°C (5°F). Each season is different in some ways from the other seasons, no matter where you are.

Before you read, think about what the different seasons are like where you live. Describe how summer and winter are different. Remember, the differences do not have to be just about temperature. Think about the other conditions you learned about in Lesson 1.

Students’ answers should be specific to the part of the country in which they live. Answers should include references to temperature, precipitation, wind, and humidity.

What Did Ancient People Know about Seasons?
More than 3,000 years ago, people in England built Stonehenge, which is a giant monument made of stone. Somehow these ancient people managed to move and stack these gigantic stones. Some were almost 8 m high and weighed as much as 25 tons! Nobody really knows why people built Stonehenge, but one of the reasons might have been to mark the longest day of the year.
In the last reading, you learned about sundials and how ancient people told the time of day. People noticed not only that there was day and night, but they also saw patterns in the year. At certain times of the year, days were longer than at other times. The stones in Stonehenge were placed so that they line up with the sunrise on the longest day of the year. Every year on this one day, the sunrise appears on the horizon, directly aligned with one giant stone. It makes sense that the people who built Stonehenge created it as a way to mark the longest day as the beginning of each year. They could then count the number of days between these annual occurrences and determine the length of the year. It is obvious that the ancient people in England already knew about seasons. They knew that the hottest time of year, summer, was when the days were the longest. They saw that when the days got shorter, the temperature got colder. They called this time of year with colder temperatures and shorter days winter. Stonehenge was a kind of calendar that helped them keep track of the passing of the year and the seasons.

Why do you think it was important for people to be able to tell how long it would be before the seasons changed? If they were in the middle of summer, why would they want to know how many days it would be before winter?

Answers will vary.

What Are Seasons?

What do you think of when you hear the word seasons? Depending on where you live, it may mean different things. Much of the world experiences four seasons: summer, fall, winter, and spring. Each of these brings changes in temperature and precipitation, as well as changes to the living things in the area. In some places, fall brings cooler temperatures and changing color in leaves. By winter,
the trees have lost their leaves. In spring, the leaves begin to grow again. Here are photographs of the four seasons in one location.

In some places, the seasons do not look like these pictures. Some places only have two seasons that they call wet and dry. Other places have two seasons that they call summer and winter, but in winter they never get snow, only rain. All places on Earth experience seasons.

Describe the seasons where you live. How many seasons do you have? Does it get cold in winter and snow?

Answers will vary.

Why Does Earth Have Different Seasons?
Many people think that the seasons are a result of the Earth getting closer to or farther from the sun as it travels in its orbit around the sun. It makes sense to think that when Earth is closer to the sun, it is warmer, and it would be summer. When it is winter, Earth should be farther away because it is cooler, but that is not true.
Activity 8.4: Why Isn’t the Temperature the Same Everywhere?

This page is for groups to organize their information for the final group project to answer the Driving Question.

We know that temperature is an important condition in weather. In previous lessons we learned that temperature differences in large air masses can cause predictable changes in daily weather patterns. But why is the overall weather different from place to place? We know from our graph paper activity that light intensity varies by latitude and corresponds to temperature. The greater the intensity of sunlight the higher temperature. Our city data showed us that cities closer to the equator have higher average yearly temperatures while cities farther away from the equator have lower average yearly temperature. Our lantern activity showed us that if the Earth were vertical, the cities at the same latitude north and south of the equator would get the same intensity of light and their temperatures should be the same all year. However, because the Earth is tilted so that the North Pole is always tilted toward the North Star, cities that are in opposite hemispheres have different temperatures although they may be a similar distance from the equator. Atlanta, Georgia is at 33 degrees North of the equator and has an average temperature in January of 5.6 degrees C, while Buenos Aires, Argentina sits at 35 degrees S of the equator and has an average January temperature of 27.2 degrees C. In January, the northern hemisphere is tilted away from the Sun and the southern hemisphere is tilted toward the Sun so that Atlanta experiences winter while Buenos Aires has summer. The number of daylight hours will also affect the temperature of a place. The tilted Earth model showed us that during summer the areas north of the equator got more hours of daylight. This means more light energy can be transferred, and they would be warmer. Evidence of this can also be seen in Atlanta and Buenos Aires. In July, Atlanta receives 14 hours of sunlight a day and has an average temperature of 26.1 degrees C. Buenos Aires receives an average of 9.9 hours of sunlight in July and has an average temperature of 10 degrees C. Overall, weather is different from place to place because of the tilt of the Earth and the unequal heating of the Earth’s surface.
Appendix
Building toward Performance Expectation MS-ESS2-1
Earth’s Systems
Develop a model to describe the cycling of Earth’s materials and the flow of energy that drives this process.

Clarification Statement: Emphasis is on the processes of melting, crystallization, weathering, deformation, and sedimentation, which act together to form minerals and rocks through the cycling of Earth’s materials. [Assessment Boundary: Assessment does not include the identification and naming of minerals.]

Building toward Performance Expectation MS-ESS3-5
Earth and Human Activity
Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.

Clarification Statement: Examples of factors include human activities (such as fossil fuel combustion, cement production, and agricultural activity) and natural processes (such as changes in incoming solar radiation or volcanic activity). Examples of evidence can include tables, graphs, and maps of global and regional temperatures, atmospheric levels of gases such as carbon dioxide and methane, and the rates of human activities. Emphasis is on the major role that human activities play in causing the rise in global temperatures.

Preparation

Background Knowledge
Global Warming and Climate Change
Global warming is the gradual temperature increase throughout Earth’s atmosphere due to the greenhouse effect caused by greenhouse gases, which trap thermal energy. Climate change refers to changes in climate patterns, both globally and regionally, especially (increased) changes observed since the Industrial Revolution.
Greenhouse Gases
The greenhouse gas that most contributes to global warming is carbon dioxide, which is predominantly produced in the burning of fossil fuels. Carbon dioxide is also released in other processes, such as deforestation, respiration, and volcanic eruptions. Since the Industrial Revolution, the concentration of carbon dioxide has increased by more than 30%. The next largest contributor to global warming is methane, which is released from natural gas and petroleum, livestock, wetlands and rice fields, and landfills. Methane is the main component of natural gas and petroleum. Livestock release methane in the digestive process. Animal manure also releases methane. Wetlands, rice fields, and landfills are rich in organic matter. Bacteria decompose the organic matter for energy (food), and the process releases large quantities of methane. The third-largest contributor is nitrous oxides, which are used in fertilizers and other chemicals. The fourth-largest greenhouse gas is chlorofluorocarbons (CFCs—labeled F-gases in the circle graph), historically used as aerosols and refrigerants, but they are mostly banned now.

Greenhouse Effect
Greenhouse gases—carbon dioxide, methane, nitrous oxide, and fluorinated gases—absorb and trap thermal energy in the atmosphere. These gases absorb the thermal energy generated by the sun and reflect it back to Earth’s surface, increasing the temperature of Earth’s surface. This process is called the greenhouse effect. Without greenhouse gases, thermal energy would leave the atmosphere and release into space. If all greenhouse gases were released into space, Earth’s surface would be far below freezing. Greenhouse gases absorb about 90% of the radiated thermal energy from Earth and re-radiate it back to Earth’s surface, warming the planet. Therefore, greenhouse gases are important for keeping the Earth warm. However, accumulation of greenhouse gases in the atmosphere can cause the Earth to increase in temperature such that the surface becomes too warm. Human activities play a significant role in increasing the amount of greenhouse gases in the atmosphere.

Greenhouse Effect Model: Limitations
In Activity 3.2, students use a lamp and two clear plastic bottles (one sealed with plastic wrap) to model the greenhouse effect. This is a simplistic model that shows how trapped greenhouse gases increase the temperature of air trapped in contact with the sun. The plastic wrap is used to simulate greenhouse gases and how they trap thermal energy in our atmosphere. Greenhouse gases do not trap thermal energy in the same way plastic wrap does, but scientists have found that small-scale experiments with carbon dioxide do not produce reliable results. Greenhouse gases prevent thermal energy from leaving the atmosphere by radiation, which is the direct transfer of thermal energy. In contrast, using plastic wrap as a seal prevents thermal energy loss by radiation and also from convection, which is the movement of air.

Global Climate Change: NASA Website
This interactive website, http://climate.nasa.gov, enables you to project, or students to explore on their own, various aspects of climate change through visual representations and text. For example, a statement about the disappearance of ice on Earth is accompanied by options for observing how climate change has affected glaciers, sea ice, and continental ice sheets in the Arctic, Antarctic, Greenland, and Iceland.
Interpreting Graphic Representations
Many students find data interpretation challenging. Learning to read and interpret various types of graphs is an important scientific (as well as mathematics and language arts) practice. For example, support students, as necessary, in making sense of correlation versus causation, and in determining how and when causation is suggested by data. This lesson uses a circle graph and several line graphs, all of which require individual interpretation first, and then summarizing, evaluating, and comparing the information communicated by various data sources in order to draw conclusions.

Data Used in These Representations
Ice Cores
Ice core samples are used to determine much of the history that helps scientists understand changes, such as in CO₂ concentrations, over time. An excellent source on how ice cores are drilled is available here: National Ice Core Laboratory, http://icecores.org/icecores/drilling.shtml. More specific information is available at: http://cdiac.ornl.gov/trends/co2/ice_core_co2.html.

The Mauna Loa Observatory
The Mauna Loa Observatory (MLO) in Hawaii has collected data related to changes in the atmosphere since the 1950s. Due to the relatively undisturbed air, remote location, and minimal influences of vegetation and human activity, the observatory is ideally suited for monitoring elements

Given that Mauna Loa is an active volcano, how do scientists know that data are not skewed by emissions from the volcano? That question has been asked and answered here: http://earthobservatory.nasa.gov/blogs/climateqa/mauna-loa-co2-record/.

Ppmv
Parts per million—ppm—is commonly used as a measure of small levels of pollutants in air. Parts per million is the mass ratio between the pollutant component and the solution and is further explained mathematically here: http://www.engineeringtoolbox.com/ppm-d_1039.html. Parts per million by volume is the measure used in one of the graphics in this lesson.

Setup
Activity 1.1
Display the five graphic representations one at a time, guiding students, as needed, to interpret the information presented in each of them. Distribute copies to students (in kit) so that groups have the graphics to examine closely during discussion.

Activity 1.2
You will need two 2-liter clear soda bottles for each group of students. Rinse, dry, remove labels, and cut the top 10cm evenly off the bottles. Set up stations for each group with the materials for the greenhouse effect experiment.

SAFETY GUIDELINES
This lesson presents no unusual safety concerns; however, see IQWST Overview for general laboratory safety.

Differentiation and Other Strategies
1. Activity 1.1 begins with generating student questions about climate change, global warming, the greenhouse effect, or air pollution—any questions they raise about human impacts on planet Earth that have not yet been addressed. Several of their questions will likely be addressed in this lesson. However, any leftover questions may be used for independent,
pairs, or group projects and/or presentations. Students’ own, original questions can prompt
deep learning as they search for more information and read about a topic that genuinely
interests them. Closing this unit with a research project that interests students and that
enables them to integrate information from class investigations, class readings, and exter-
nal readings ensures important learning about human impacts on Earth and Earth’s
systems.

2. Parts of the reading for this lesson may be especially challenging for some students. This
is a good opportunity for you to read portions aloud as students follow along. In that way,
students have an opportunity to hear good, fluent reading in science, which middle school-
ers have few opportunities to hear. Limited oral reading by you can also keep students from
getting bogged down in details rather than learning the key ideas—or the gist—of the read-
ing. You might assign individual students to read only some portions of the reading, and
jigsaw groups the following class period so students can share a single main idea that they
learned or found interesting.
Teaching Lesson 1

Overview

Introduction
• Identify human impacts on climate change.

Activity 1.1
• Interpret and compare graphics showing carbon dioxide emissions, atmospheric carbon dioxide concentrations, global population, and global temperature.
• Identify evidence that humans affect carbon dioxide emissions and global temperature.

Activity 1.2
• Carry out an investigation that demonstrates how trapped gases increase air temperature.
• Argue from evidence that the global rise in temperature is due to the greenhouse effect and is caused by human activity, including burning fossil fuels.
• Examine positive impacts of human intervention and the role of society in decreasing greenhouse gases.

Learning Performances

Students will

• analyze and interpret data about factors that have caused a global increase in temperatures.
• communicate the connection between human activities and greenhouse gas concentrations.
• construct an explanation of the relationship between the release of greenhouse gases from human activity and the increase in global temperatures.
• carry out an investigation demonstrating how trapped gases increase air temperature.
• obtain, evaluate, and communicate methods of positive human intervention and the role of society in decreasing greenhouse gases.
Activity 1.1: Global Warming

Building toward Performance Expectation MS-ESS2-1
Develop a model to describe the cycling of Earth’s materials and the flow of energy that drives this process.

Disciplinary Core Idea ESS2.A: Earth Materials and Systems
- All Earth processes are the result of energy flowing and matter cycling within and among the planet’s systems. This energy is derived from the sun and Earth’s hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth’s materials and living organisms.

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

Disciplinary Core Idea ESS3.D: Global Climate Change
- 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 of human behavior and on applying that knowledge wisely in decisions and activities.

Science and Engineering Practices: Developing and Using Models; Analyzing and Interpreting Data; Constructing Explanations and Designing Solutions; Obtaining, Evaluating and Communicating Information

Crosscutting Concepts: Patterns; Cause and Effect; Stability and Change
What makes the weather change?

Introducing the Activity

Discussion: Brainstorming

Purpose: To engage students in sharing their understandings of how humans impact the Earth, the greenhouse gases, and global warming.

A greenhouse traps the sun’s energy and keeps plants warm.

• What other ways do you think that humans have an impact on Earth? Let’s take a minute to have you write on sticky notes any questions that you have about human impacts on the environment in ways we haven’t studied yet. Are there ideas that you have been wondering about? (Have students share their questions. Use any you can to lead into the problem of or language for talking about greenhouse gases, the greenhouse effect, and climate change.)

Materials

For the Teacher

- PI: Greenhouse Gases
- PI: Carbon Dioxide Emissions and Atmospheric Carbon Dioxide Concentrations
- PI: Global Population and Carbon Dioxide Emissions
- PI: Carbon Dioxide Concentrations and Global Temperature
- PI: Historic Carbon Dioxide Concentrations

For Each Group

• packet of graphs for this lesson

For Each Student

• SE Activity 1.1
• Lesson 1 Reading One
• pencil*
Guiding the Activity

In this activity, you will introduce greenhouse gases via a circle graph, and then use four additional visual representations (line graphs) to support students in comparing carbon dioxide emissions, atmospheric carbon dioxide concentrations, global population, and global temperature. As a class, you will discuss evidence that humans affect carbon dioxide emissions and global temperature.

Students will need varying degrees of assistance in reading and making sense of these graphic representations.

The goals of this activity are to 1) increase students’ understanding of the connection between human activities and greenhouse gas concentrations, 2) identify the relationship between the release of greenhouse gases from burning fossil fuels and an increase in global temperatures, and 3) describe potential solutions to reduce greenhouse gases.

As an introduction to the activity, project the image Greenhouse Gases (circle graph) and discuss their sources.
What do you notice about this graph? (Support students in making sense of this graph. Most important is to realize that carbon dioxide is the most abundant of the greenhouse gases, and to recognize how carbon dioxide is produced.)

After discussion of this graph, project the other four graphs, one at a time, as students look more closely at the versions in their packets. Support students in interpreting the graphs: 1) Carbon Dioxide Emissions and Atmospheric Carbon Dioxide Concentrations, 2) Global Population and Carbon Dioxide Emissions, 3) Carbon Dioxide Concentrations and Global Temperature, and 4) Historic Carbon Dioxide Concentrations.

**Discussion: Pressing for Understanding**

Purpose: To support students in connecting the data trends with their implications for the health of planet Earth.
Let’s look at a line graph. What does each line/color represent? What two types of data does this graph compare? \(\text{(human carbon dioxide emissions and atmospheric carbon dioxide concentrations)}\)

What pattern or trend do you see in these data? Do these data show a correlation between carbon dioxide emissions and carbon dioxide in the atmosphere—meaning, do the two seem to be connected to one another? \(\text{(As the carbon dioxide emissions increase, so do the carbon dioxide concentrations in the atmosphere.)}\)

So, we know that both occur at the same time. How could we know whether two things that occur at the same time happen because one CAUSES the other, and not because they just happened to occur at the same time? \(\text{(because one thing happens first and causes changes to the second variable, and there is no other change happening at the same time that could also be a factor in the change)}\)

Let’s look at the next graph. What does each symbol/color represent? What two types of data does this graph compare? \(\text{(carbon dioxide emissions and global population)}\)

What pattern or trend do you see in these data? Do these data show a correlation between carbon dioxide emissions and global population—meaning, do the two seem to be connected to one another? \(\text{(As the global population increases, so do carbon dioxide emissions.)}\)
Global Population and Carbon Dioxide Emissions

• Let’s look at the next graph. What does each line/color represent? What three types of data does this graph compare? [The historic carbon dioxide levels prior to 1960 were determined by analyzing ice cores. After 1960, the National Oceanic and Atmospheric Administration (NOAA) built the Mauna Loa Observatory (MLO) in Hawaii to monitor the global atmosphere, including carbon dioxide.] (It compares carbon dioxide concentrations (from ice cores and an observatory) with global temperatures.)

• What pattern or trend do you see in these data? Do these data show a correlation between carbon dioxide emissions and global temperature—meaning, do the two seem to be connected to one another? (As the carbon dioxide concentrations increase, so does the global temperature.)
Let’s look at the next graph. What does each line/color represent? What two types of data does this graph compare? (It is a graph of carbon dioxide concentrations in the atmosphere. There’s also a line that shows the carbon dioxide concentration from 1950.)

What pattern or trend do you see in these data? Do these data show a change in carbon dioxide concentrations over time? (The graph shows that carbon dioxide concentrations in the atmosphere have increased significantly since 1950.)

Historic Carbon Dioxide Concentrations

Have students now turn to SE Appendix Activity 1.1, and work in groups to answer the Making Sense questions, using the graphs in their packets.
Discussion: Synthesizing

Purpose: To explain how increases in carbon dioxide relate to global temperature.

In discussion, revisit the learning goals, requiring students to use data as evidence to answer key questions.

- **How do human activities affect greenhouse gases?** (Human activities produce greenhouse gases that are released into the atmosphere. Activities like burning fossil fuels, agriculture, deforestation, etc., cause an increase in greenhouse gases.)

- **Is carbon dioxide good or bad for humans? For animals? For plants? For the environment overall?** (Carbon dioxide is bad for humans and animals; we breathe out to get rid of it. But it is good for plants. We need some greenhouse gases to keep the Earth warm, but too much carbon dioxide in the air is bad because it causes the Earth to get too warm, which is harmful to the environment.)

- **What causes global warming? How does the release of greenhouse gases from activities like burning fossil fuels cause an increase in global temperature? What evidence do scientists have that global warming is a problem for Earth?** (Global warming is caused by greenhouses gases that are released into the atmosphere from human activities such as burning fossil fuels. The gases get trapped in the atmosphere, and as concentrations increase, temperatures increase. Evidence includes increasing temperatures, sea level rise, warming oceans, shrinking ice sheets, declining Arctic sea ice, glacial retreat, decreased snow cover, extreme events, and ocean acidification, which students will read about in Lesson 1 Reading One.)
Introducing Lesson 1 Reading One: Greenhouse Gases

Students will read about several effects of global warming and how countries are working together to reduce greenhouse gases. Ask students whether they think individuals can solve the problem or whether people need to work together to solve the problem. Have them explain their ideas, but allow this to be brainstorming—no right or wrong answers. Let them know that in the next class, you want each person to be able to talk about at least one effect of global warming (one piece of evidence that scientists use) and one thing that’s being done about global warming.

Reading Follow Up

• **What is one piece of evidence scientists use to argue that it’s important for us to do something about global warming?** (Evidence includes increasing temperatures, sea level rise, warming oceans, shrinking ice sheets, declining Arctic sea ice, glacial retreat, decreased snow cover, extreme events, and ocean acidification.)

• **What actions have been taken throughout the world to reduce greenhouse gases?** (Countries have formed compact agreements to work individually and together; groups have set goals to work toward; the United Nations Framework Convention on Climate Change, the Kyoto Protocol, and the Paris Agreement are about countries working individually and together to meet goals to reduce greenhouse gases.)

• **What are some ways the United States is reducing greenhouse gases?** (The United States has reduced total carbon emissions more than any other country in the world. Carbon emissions have been reduced considerably by focusing on energy efficiency and clean energy initiatives. Solar energy has increased tenfold and wind power has tripled in the last 10 years. The United States is the first country to develop carbon emission standards for power plants.

   In 2014, the Environmental Protection Agency developed a Clean Power Plan that required power plants to cut carbon emissions 30% by 2030. Through government actions, over 50 solar, wind, and geothermal projects are now approved on public lands. Collectively, these projects can provide over 20,000 jobs and provide electricity for over 4.8 million homes.

   There is also a large initiative to improve the electrical network in the United States so that it is more robust and efficient.

   In 2009, President Obama created the Advanced Research Project Agency–Energy to research and develop advancements in cleaner and more efficient energy. Improving the design of automobiles so that they are more efficient is another effective way to reduce greenhouse gas emissions. It is currently proposed to have a fuel economy standard of 54.5 miles per gallon required for automobile performance by 2025.

   Another easy and cost-effective way to reduce greenhouse gas emissions is to decrease energy waste in homes, businesses, and factories.)
Activity 1.2: Greenhouse Effect

**Building toward Performance Expectation MS-ESS2-1**
Develop a model to describe the cycling of Earth’s materials and the flow of energy that drives this process.

**Disciplinary Core Idea ESS2.A: Earth Materials and Systems**
- All Earth processes are the result of energy flowing and matter cycling within and among the planet’s systems. This energy is derived from the sun and Earth’s hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth’s materials and living organisms.

**Building toward Performance Expectation MS-ESS3-5**
Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.

**Disciplinary Core Idea ESS3.D: Global Climate Change**
- 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 of human behavior and on applying that knowledge wisely in decisions and activities.

**Science and Engineering Practices:** Planning and Carrying Out Investigations; Constructing Explanations and Designing Solutions

**Crosscutting Concepts:** Patterns; Energy and Matter; Stability and Change
Introducing the Activity

In this activity, students perform an experiment that shows how trapped greenhouse gases increase air temperature. The plastic wrap is used to simulate greenhouse gases and how they trap thermal energy in our atmosphere. (Note: See Teacher Preparation section for limitations of this model.) The model of greenhouse gases trapped in a bottle using plastic wrap will be compared to a bottle that does not simulate the greenhouse effect.

Introduce the greenhouse effect by projecting the following graphic.
Let students know that this is a simplistic model. The radiated thermal energy is the solar radiation not absorbed by Earth. It is not that some places re-radiate too much and others don’t. It’s showing historically how thermal energy was radiated without high concentrations of greenhouse gases and now how thermal energy is re-radiated due to current levels of greenhouse gases. It’s not that there are pockets of greenhouse gases in our atmosphere. Gases are released all over the world and spread (are transported) throughout the atmosphere. So the greenhouse gases we release in the U.S. affect the whole world—and those released in other countries affect the U.S.

**What do you notice as you look at this representation?** *(I see solar radiation from the sun coming to Earth and some of the solar energy is reflected back as thermal energy. Some of the thermal energy reflected goes back to space, and some is trapped by greenhouse gases and comes back to Earth.)*

Let students form groups and construct models to test the greenhouse effect. Prior to the experiment, have students predict what will happen to the temperature in the two bottles and explain their ideas/predictions. As the students perform the activity, have them consider the following questions:

**How are greenhouse gases released into the atmosphere?** *(Human activities, including burning fossil fuels, release greenhouse gases into the environment.)* If students did the IC2 Appendix activity in which they made ethanol, revisit here the fact that the production of ethanol released carbon dioxide into the air (which filled a balloon).

**What effect does that have on Earth’s systems? How could we investigate greenhouse gases to see how global warming actually happens and what effects it has on Earth? What would we need to be able to do?** *(It causes the Earth and its atmosphere to become warmer. We could build a greenhouse and monitor air temperature. We would need to show how temperature changes in a greenhouse compared to one without glass.)*

The goals of this activity are to 1) perform an experiment demonstrating how trapped gases increase air temperature; 2) identify the relationship between the release of greenhouse gases from human activity, such as burning fossil fuels, and an increase in global temperatures; and 3) examine positive impacts of human intervention and the role of society in decreasing greenhouse gases.

**Guiding the Activity**

Have students form groups and construct models to test the greenhouse effect. Prior to the experiment, have students predict what will happen to the temperature in the two bottles and explain their ideas/predictions. As the students perform the activity, have them consider the following questions:
Students will record temperature at the beginning of the experiment and again after 30 minutes. Afterward, they will compare their observations to predictions.

During the 30 minutes between observations, have the students calculate their Personal Carbon Footprint. Search the internet for a carbon footprint calculator that works with the browser students will be using. Students can work individually or in groups and share their results. Have students complete SE Appendix Activity 1.2.

- **How does this activity model human activities on the Earth? What do the bottle, plastic wrap, and lamp represent?** (The bottle represents the atmosphere, the plastic wrap represents carbon dioxide and other greenhouse gases, and the lamp represents the sun.)

- **What effect do greenhouse gases have on temperature?** (They trap heat in the atmosphere, causing global temperature to increase over time. Our evidence is that the temperature difference between our two bottles was X, showing that the one with greenhouse gases got hotter than the one without greenhouse gases.)

- **What is the greenhouse effect? Why is it called the greenhouse effect?** (When gases trap heat in the atmosphere, it causes the Earth’s temperature to increase. The gases do what the glass in a greenhouse does: keep the temperature on Earth/inside the greenhouse warm.)

- **Scientists say that each of us leaves a carbon footprint. What do you think a carbon footprint is?** (A carbon footprint is how much carbon dioxide (and other carbon compounds) a person or group of people contribute to the atmosphere from activities like burning fossil fuels. It’s called a footprint because it is something we leave behind that contributes to the overall concentration of greenhouse gases and impacts the environment.)
Discussion: Synthesizing

Purpose: To consider solutions for reducing greenhouse gases.

In discussion, revisit the learning goals and have students use evidence from the activities and readings to support their ideas.

- At the end of the experiment, there was about a 5-degree difference between the two experimental chambers. It doesn’t seem like a big temperature difference, but it is a great representation of climate change. Scientists estimate temperature has increased by about 1.5 degrees over the last 130 years. (Reported ranges vary.) And they predict temperature will increase between 3 and 10 degrees over the next 100 years. What implications do you think this has for climate change and Earth? (There is already extensive evidence for climate change, even with just a 1- or 2-degree increase over the last century. This shows that just a few degrees’ increase makes a huge difference to the environment. With predictions of a 3- to 10-degree increase over the next century, there could be widespread devastating effects to Earth and all the life it supports.)

- If humans do things that create greenhouse gases, and greenhouse gases are bad for the environment, what are some possible solutions to the problem of greenhouse gases and global warming? (As individuals we could make choices like walking, riding bikes, and carpooling to school and other places. We could also eat more local food, eat less meat, use less packaged food, reduce heat and air conditioning, use solar panels for electricity, and always be sure to turn off the lights when leaving a room. Globally, we could make a commitment to reduce the use of greenhouse gases and develop alternative sources of energy and fuel.)

- What are some potential solutions to reduce greenhouse gases? (People can make changes to their individual daily way of life by walking/biking instead of using automobiles; reducing electricity by turning off lights, using less heat/air conditioning; etc. But to have a global impact, there needs to be global changes: for example, using alternative energy sources, such as solar, wind, and hydroelectric, to reduce emissions; stopping deforestation; and growing more trees.)

As you ask questions to bring this lesson to a close, prompt students to refer to the activities they did in class, the readings, or other resources you may have used as support for their ideas or evidence for the claims they make. An easy way to do this is to follow up their statements with a question such as: “How do you/we/scientists know that?”
Wrapping Up

Questions such as the following may be used to assess students’ overall understanding of the content of this lesson, as they use evidence to explain their ideas or argue for a solution. Rather than using these questions as a test of students’ memory, allow them to use their books and graphic elements (handouts) as they write a response, providing them with an opportunity to marshal data as evidence for any claims they make. Students should make a general statement or claim, decide which data support their claim, and use those data as evidence. You could require that students use several pieces of evidence in their response, or that students use evidence from each of the activities and readings in the lesson. These types of questions could be answered orally only, or with a captioned drawing and an accompanying oral explanation rather than a written response. Posters or other presentations are additional ways that students could represent their understanding of key ideas about how humans impact Earth’s systems.

- Why is reducing greenhouse gases important for the environment? (Greenhouse gases trap thermal energy and increase the temperature of our atmosphere and the Earth, which causes harm to the environment.)
- What do you think would happen if global actions aren’t taken to reduce greenhouse gas emissions and temperatures increase by 3–10 degrees over the next century? (If we don’t take action to reduce greenhouse gas emissions, and temperature increases by 3–10 degrees, massive devastation may result and Earth could become uninhabitable.)
- Explain how humans’ use of natural resources impacts Earth’s systems. Use evidence from class activities and readings in your explanation.
- How does an increase in the human population affect Earth’s natural resources? Use evidence from class activities and readings in your explanation.
- Develop a model and use it to explain how humans’ use of fossil fuels impacts Earth’s systems. (Possible hint: from mining to burning to global warming)
- What are some possible solutions to the problems that humans cause for Earth and Earth’s systems? (Could be used as a follow-up question.)
Activity 1.1: Global Warming

What Will We Do?
In this activity, we will examine data from several graphs. Then we will use these data as evidence to explain how global population affects carbon dioxide emissions and global temperature.

Procedure
- a. Prior to group work, review each of the graphs.
- b. Then, in your group, complete SE Activity 1.1.
- c. Take turns sharing your group’s ideas with the class.

Making Sense
1. There is always CO₂ in the atmosphere. A) When you look at the graph of human CO₂ emissions and CO₂ concentrations in the atmosphere, what do you notice? B) Do you think there is a relationship between human CO₂ emissions and how much CO₂ is in the atmosphere? Explain your ideas.

   As carbon dioxide emissions increase over the years, so does the atmospheric carbon dioxide. I think carbon dioxide emissions released from activities like burning fossil fuels cause the carbon dioxide in the whole atmosphere to increase. There is a certain amount of carbon dioxide in the environment, and when we release more carbon dioxide from human activities, it causes an increase in the total amount of carbon dioxide in the atmosphere.
2. A) What does the graph of global human population and CO₂ emissions show? B) What does this trend indicate? C) What are some ways the human population could influence CO₂ concentrations?

The increase in the human population and carbon dioxide emissions over the years is almost identical. This provides evidence that the human population is the most likely reason for the increase in carbon emissions. Humans can influence the carbon dioxide concentrations because we burn fossil fuels (and other organic matter that produces carbon dioxide as it burns, such as wood). Also, as the global population increases, there are more and more people releasing carbon dioxide when they breathe, causing an increase in the total concentration.

3. A) As CO₂ concentrations increase over the years, what does the average global temperature do? B) Do you think there is a relationship between the two? Explain your ideas.

As carbon dioxide concentrations increase, so does the average global temperature. As the concentration of carbon dioxide increases in the atmosphere, the greenhouse gas molecules trap more thermal energy and cause temperatures to increase globally.
4. What are potential ways to explain the rise in carbon dioxide levels since 1950 compared to before 1950?

   Since the Industrial Revolution, human activities have changed dramatically. Over the years, many modern conveniences have been introduced, including the use of electricity, transportation, and industry that rely on the use of fossil fuels and which contribute significantly to carbon dioxide emissions. Also, the human population is getting bigger and bigger and using more and more fossil fuels, which continues to increase carbon dioxide in the environment.

5. What are some potential solutions to reduce carbon dioxide concentrations and other greenhouse gases to address global warming? What can you do—personally—to make changes in your daily life to reduce how much carbon dioxide you contribute to the problem of global warming?

   People can make changes to their individual daily way of life by walking/biking instead of using automobiles; reducing electricity by turning off lights, using less heat/air conditioning, etc. But to have a global impact, there need to be global changes: for example, using alternative energy sources, such as solar, wind, and hydroelectric to reduce emissions; stopping deforestation; and growing more trees.
Lesson 1 Reading One: Greenhouse Gases

Getting Ready
As you have learned in this lesson, it is important to reduce greenhouse gases to protect the Earth from global warming and climate change. Sometimes people think that they can't make a difference because they are only one person. But you have learned several actions you can take as an individual to reduce greenhouse gases. In this reading, you will learn more about the effects of greenhouse gases on the environment and actions that several countries working together are taking to protect the Earth.

Global Warming and Climate Change
Many people use the terms global warming and climate change like they are the same. But they are not the same. Global warming is the name for the gradually increasing temperature of the Earth. Climate change refers to changes in all climate patterns (not just temperature). More than 97% of scientists agree that increasing levels of greenhouse gases are causing temperatures to increase on Earth. Rising temperatures are affecting many physical features of Earth. Rising temperatures are also affecting Earth's systems, such as ecosystems and living organisms. How do scientists know this? Scientists use data as evidence. As you read, you will learn more about the data scientists have used to identify this problem and to come up with solutions.

What is your favorite temperature for being outdoors? What temperature feels too hot for being outdoors? What temperature feels too cold to you?

Answers will vary.
What Evidence Do Scientists Have for Global Warming?

The Intergovernmental Panel on Climate Change (IPCC) is made up of over 1,300 scientists from countries around the world. These scientists work together to collect and share data. Scientists have used satellites that orbit the Earth, and other technology, to collect data for many years. The ability of carbon dioxide and other greenhouse gases to trap thermal energy was discovered in the mid-1800s. According to the IPCC, the average temperature of Earth has increased by about 1.5°F (2.7°C) from 1880 to 2012. Look at your responses to the questions above. If it were 1.5° (2.7°C) warmer or colder, would that matter to you?

Because of our own experience, we sometimes have a hard time seeing the bigger picture of what is happening. That 1.5°F (2.7°C) change probably seems small. But scientists have evidence that a 1.5°F difference is important. And even more important, scientists use models to project that temperatures will continue to rise from 3°F (5.4°C) to 10°F (18°C) over the next 100 years, depending on what actions people take.

Throughout history, temperatures have always gone up and down. Small differences can be explained as natural variations. But increases this large cannot be explained by natural variations. Scientific data provide extensive evidence that climate change is occurring. You looked at some of the data in class.

What Evidence Do Scientists Have That Global Warming Is Bad for the Earth?

Scientists have also collected data about rising sea levels, warming oceans, shrinking ice sheets, declining Arctic sea ice, retreating glaciers, decreasing snow cover, extreme weather events, and more acidic oceans. Here are some examples:

1. Over the past 100 years, the sea level has risen by almost 17 cm. Oceans absorb a lot of the increased thermal energy on Earth. The top 700 m of ocean water has become about 0.3°F warmer since 1969.
2. Ice sheets are permanent layers of ice that cover an extensive area of land, such as in the polar regions. Greenland lost 150–250 m³ of ice per year from 2002–2006. Antarctica lost about 150 m³ from 2002–2005. Over the past several decades, the total area and thickness of the Arctic sea ice has continued to shrink.
3. Glaciers are retreating throughout the world. One of the largest glaciers in the Himalayas has retreated more than 850 meters in the last 25 years.
4. The amount of spring snow cover has decreased over the last several decades, with snow also melting earlier. Although a given area can experience a snowy winter, the amount of snow cover across the Earth has decreased over time.
5. The frequency of extreme events over the last 50 years in the United States (and worldwide) is increasing, with longer periods of excessively high temperatures, heavy rainfall, floods, droughts, hurricanes, and tornadoes.
6. The increasing concentration of CO$_2$ in the atmosphere is absorbed by the oceans. The estimated 2 billion tons absorbed each year is causing the water to become acidic.

**What Evidence Do Scientists Have That Global Warming Is Bad for Living Organisms?**

Most of the plants and animals on Earth are dependent on specific climate conditions, including temperature, precipitation, and several other variables. Therefore, even a small change in temperature can have a huge impact on plants and animals. This is true for plants and animals that live on land and that live in the water.

Some effects of climate change are already happening. For example, the migration patterns of some birds are changing. Some animals are migrating farther north in order to stay cooler. More diseases are being observed in plants and animals. The growing season for many plants is changing.

The acidity of the oceans has increased 30% since the Industrial Revolution. Organisms that depend on calcium carbonate as the basic building blocks of their skeleton and shells are at high risk because the increasingly acidic water will eventually dissolve the calcium carbonate. This will affect organisms such as clams, oysters, coral reefs, and sea urchins. The loss of these species would have a drastic effect on the ecosystem because many animals, including humans, are dependent on them. If you have never lived in a country that relies heavily on the ocean, you might not realize that over one billion people are dependent on food from the ocean as their main source of protein.

The Environmental Protection Agency predicts that if the Earth continues to warm at the current rate, up to one fourth of all plants and animals on Earth could become extinct within 100 years.

What is one effect of climate change on plants and animals that you think is interesting?

Answers will vary.
Is the Whole World Concerned about Climate Change?

Yes. Scientists around the world agree that global warming is a serious threat to Earth. They also agree that humans play an important role in global warming. Scientists continue to collect data like the data you examined in class. As they share results from their experiments, scientists from many countries are working together on the challenge of climate change. You can make positive changes in your life to make a difference. But people working together around the world can make an even bigger impact on protecting planet Earth.

In 1992, the United Nations Framework Convention on Climate Change (UNFCCC) formed to reduce greenhouse gas concentrations. It was the first international environmental agreement. As of December 2015, 197 countries participate in the UNFCCC. The goal of the organization is to "stabilize greenhouse gas concentrations" to keep them from continuing to affect the Earth in negative ways.

In 1997, the Kyoto Protocol was formed to set emission targets. Some countries of the world are referred to as “developed countries,” which means that they are economically developed and industrialized and have advanced technology and infrastructure. It is developed countries that are the main contributors to greenhouse gas emissions, so it is developed countries that are part of the Kyoto Protocol. The Kyoto Protocol has target goals for two time periods: 2005–2012 and 2012–2020. Starting in 2012, 37 developed countries are obligated to set targets for reducing greenhouse gas emissions.

In December of 2015, the Paris Agreement was formed between 197 countries. It is an agreement to limit global warming. The Paris Agreement is set to begin at the end of the Kyoto Protocol in 2020. Governments around the world have agreed to reduce greenhouse gas emissions. Each country will be required to develop Nationally Determined Contributions (NDCs) to achieve the overall worldwide goal of minimizing global warming by less than 2° Celsius. Representatives from participating countries will meet every five years to report progress on the goals and to develop new targets based on any new scientific evidence. By forming these agreements, countries throughout the world are working together to make changes in human activities to reduce Earth’s vulnerability to the effects of climate change.

How Can We Reduce Greenhouse Gases?

As the population continues to increase throughout the world, people’s energy needs will continue to grow. That makes it more and more important to develop alternative energy sources such as wind and solar energy. You may have examined ethanol as a renewable resource and an alternative to fossil fuels in the IC2 unit, but ethanol is still a fuel that needs to be burned. You learned about living resources such as trees, and how deforestation affects ecosystems. Plants use CO₂, so when we cut down trees, we lose the ability they have to reduce greenhouse gases.

Since 2005, the United States has reduced total carbon emissions more than any other country in the world. Carbon emissions have been reduced considerably by focusing on energy efficiency
and clean energy initiatives. The clean energy initiative focuses on renewable energy, increasing the development and use of solar energy and wind power. Fossil fuels are the main contributor to global warming and climate change. The United States is the first country to develop carbon emission standards for power plants. That means, for example, that when a power plant uses fossil fuels, it must find ways to control how much of the products go into the atmosphere.

**Opportunities to Reduce Carbon Emissions in the Power Sector**

Power plants contribute about 1/3 of greenhouse gases in the U.S. In 2014, the Environmental Protection Agency developed a Clean Power Plan requiring power plants to reduce their emissions by 30% by the year 2030. In 2009, there were no renewable energy projects on public lands, but now over 50 solar, wind, and geothermal projects are operating on public lands. Altogether, these projects provide over 20,000 jobs and provide electricity for over 4.8 million homes. The U.S. also has an initiative to improve its electrical network to be more efficient. Incorporating solar and wind energy into the network will strengthen the electrical network throughout the country and also reduce greenhouse gases.

To meet future targets to reduce greenhouse gases, it is essential to continue to research and develop new and improved technology for cleaner energy. In 2009, President Obama created a new agency to develop cleaner and more efficient energy. One idea is that by 2025 all new automobiles could be required to go 87.7 km for each gallon of fuel. But the easiest and most cost-effective way to reduce greenhouse gas emissions is to decrease energy waste in homes, businesses, and factories. That is something everyone can do to make a big difference and to protect the Earth for future generations!
What will you commit to doing to reduce your carbon footprint?

Answers will vary.
Activity 1.2: Greenhouse Effect

What Will We Do?

In this activity, we will investigate how the greenhouse effect actually works.

Procedure

☐ a. In your group, prepare the experimental chambers to investigate the greenhouse effect. The lamp represents the sun, the plastic wrap represents a layer of greenhouse gases in the atmosphere, and the bottles represent the atmosphere above Earth's surface.

☐ b. Place the thermometers equal distance to the sunlamp for 3 minutes so they both are the same temperature at the beginning of the experiment.

☐ c. Tape a thermometer to the inside of each of the plastic bottles. Thermal energy rises, so it is best to place the thermometers higher rather than lower in the bottle.

☐ d. Cover the opening of one of the bottles with plastic wrap and seal it with a rubber band.

☐ e. Place the containers at equal distance on either side of the sunlamp.

☐ f. Record the temperature in the bottles at the start time, which is 0 minutes, and again after 30 minutes.

☐ g. During the 30 minutes between observations, calculate your Personal Carbon Footprint. Search the internet for a carbon footprint calculator that works with the browser students will be using.

☐ h. Share your Personal Carbon Footprint with your group.

☐ i. Complete the activity.
Data

1. I predict that the container simulating carbon dioxide in the air will cause the temperature to _______________ compared to the container without carbon dioxide.
   increase

2. I predict that the temperature in the container simulating carbon dioxide will change by __________ degrees F compared to the container not simulating carbon dioxide.
   10

3. Complete the following table:

<table>
<thead>
<tr>
<th>Experimental Chamber</th>
<th>Temperature °F (0 minutes)</th>
<th>Temperature °F (30 minutes)</th>
<th>Temperature Change (degrees °F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open bottle</td>
<td>65</td>
<td>69</td>
<td>4</td>
</tr>
<tr>
<td>Sealed bottle (simulating carbon dioxide in the air)</td>
<td>65</td>
<td>75</td>
<td>10</td>
</tr>
</tbody>
</table>
4. How accurate was your hypothesis?
   My hypothesis that the temperature would be higher in the container simulating the presence of carbon dioxide was supported by the data. I predicted it would increase by 10 degrees F, and it did.

5. Based on the Personal Carbon Footprint activity, what was your carbon footprint? How did it change based on your choices to modify your daily activities? How did it compare to the global average carbon footprint?
   Answers will vary. The global average is 1.25 tons of carbon dioxide, which is most likely much lower than students’ results.
6. How many Earths would it take to sustain your current lifestyle? How does that compare to
the number of Earths it would take to sustain the average person?
   Answers will vary, but it is most likely much higher than the average person of 0.56
   Earths.

Making Sense

7. How does the container with the plastic wrap simulate carbon dioxide in the atmosphere?
The plastic wrap is a lot like carbon dioxide because it traps thermal energy, as do
carbon dioxide and other greenhouse gases in the atmosphere.
8. What are some limitations of this as a model of greenhouse gases and global warming?
   This is a simplistic model that shows how trapped greenhouse gases increase air temperature. The plastic wrap is used to simulate greenhouse gases and how they trap thermal energy in our atmosphere. Greenhouse gases do not trap thermal energy in the exact same way that plastic wrap does. Greenhouse gases prevent thermal energy from leaving the atmosphere by radiation, which is the direct transfer of thermal energy. In contrast, using plastic wrap as a seal prevents thermal energy loss by radiation and also by convection, which is the movement of air.

9. How did the air temperature vary between the two experimental chambers? Why?
   The temperature did not increase as much in the container without the plastic wrap—it only increased by 4 degrees compared to 10 degrees for the container with plastic wrap. This is because thermal energy wasn't trapped in the bottle without the plastic wrap.
10. What were some recommendations from the Personal Carbon Footprint activity for modifying your daily activities to decrease the amount of carbon dioxide you are releasing into the atmosphere? Which of these do you plan to start doing?

I would like to start walking, riding my bike, and carpooling to school and other places instead of driving with my parents in a car. I also want to start eating more local food, eating less meat, using less packaged food, reducing heat and air conditioning, using solar panels for electricity, and always turning off the lights if I leave a room.