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Atmosphere and Climate

READING

MOST OF EARTH'S weather occurs in the **troposphere** (TROH-poh-sfeer), the part of the atmosphere that is closest to Earth's surface. In the activity "The Causes of Climate," you learned that the ocean has currents that move warm and cold water from one place to another. The troposphere has currents as well. Similar to the oceans, atmospheric currents move air and the thermal energy it contains from one place to another. The patterns of the currents in the oceans and atmosphere are major factors that help determine regional climates.

GUIDING QUESTION

What role does the atmosphere play in weather and climate?



READING

Use the “Listen, Stop, and Write” strategy to help you with this reading. Listen as your teacher reads aloud. Whenever they stop reading, close your book. Write down the main ideas you just heard.

Earth’s Atmosphere

As you learned in the activity “Local History of Severe Weather,” the atmosphere is the mixture of gases (“air”) that surrounds planet Earth. Compared with Earth’s radius (6,370 km or 3,952 miles), the atmosphere is very thin (~300 km or 186 miles). There are five distinct layers within the atmosphere that are defined by temperature change with altitude (see the table below).

The main gases in “dry air” are nitrogen (78.1%), oxygen (20.9%), and argon (0.9%). Carbon dioxide is the most common gas in the remaining 0.1%. The percentages of these gases remain the same within all five layers. Water vapor is not included in “dry air” percentages. Unlike the other gases, water vapor concentration varies from 0–4% of the atmosphere depending on where and when you take the measurement.

Earth’s Atmospheric Layers

ATMOSPHERIC LAYER	APPROXIMATE HEIGHT ABOVE EARTH’S SURFACE	WHAT HAPPENS IN THIS LAYER?
Exosphere	120 km+	Earth’s atmosphere merges into space.
Thermosphere	80–120 km	The space shuttle orbits the earth.
Mesosphere	50–80 km	Meteors usually burn up.
Stratosphere	12–50 km	Ozone layer absorbs some of the sun’s harmful ultraviolet radiation before it strikes Earth’s surface.
Troposphere	0–12 km	Most weather occurs. Cruising altitude of most commercial aircraft.

Wind and Weather

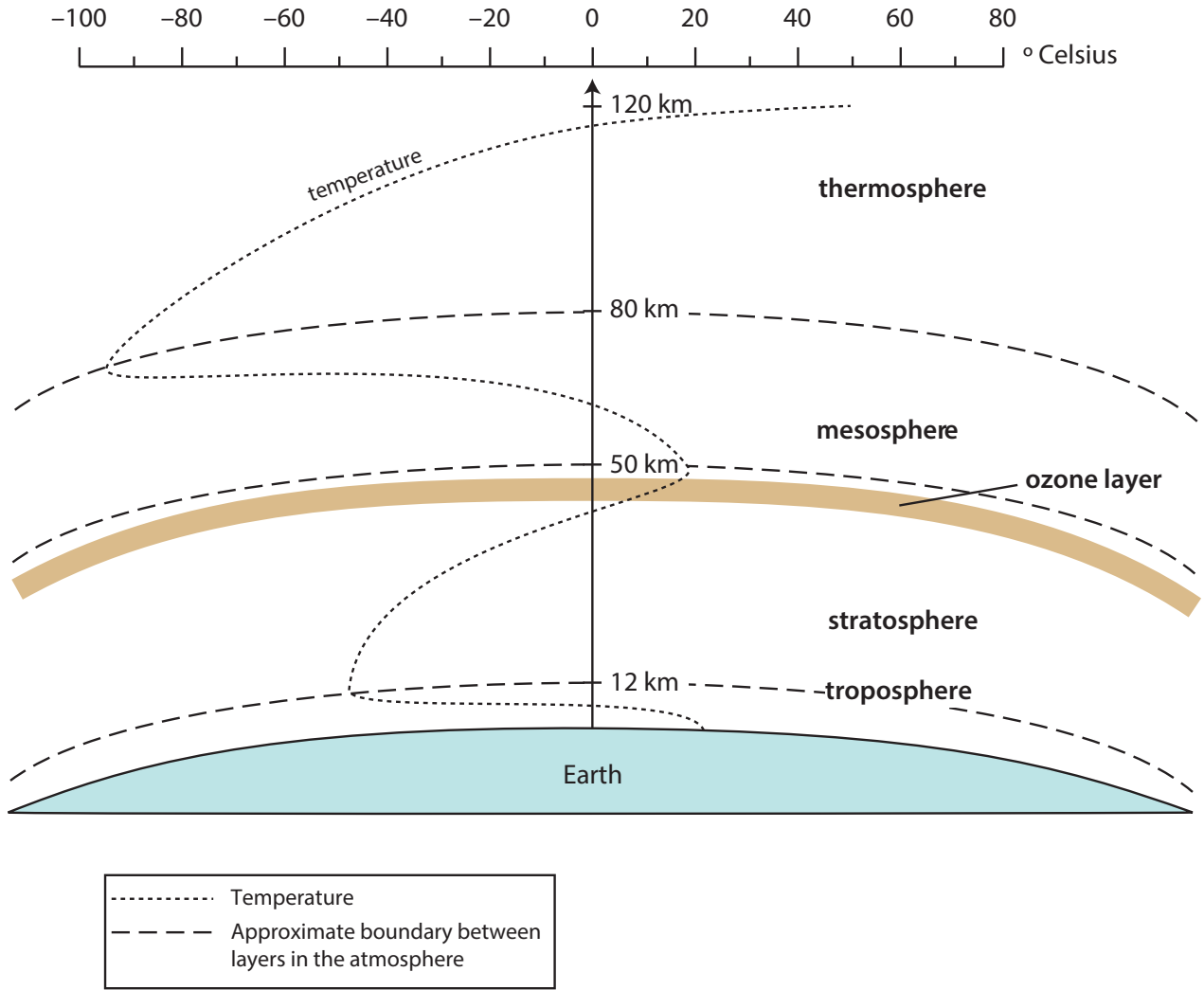
Weather occurs in the layer closest to Earth, called the troposphere. Because the troposphere is heated from the ground up, the temperature tends to decrease as the altitude increases. The materials on Earth’s surface (e.g., rocks, water, plants) absorb some of the sun’s energy and heat up. These materials then heat up the air in the lower troposphere. Since some areas of Earth’s surface heat up faster than others, different areas have different temperatures. Warmer, lower density air rises, creating an area of lower air pressure below it. Differences in air pressure are a driving force of weather and weather systems.



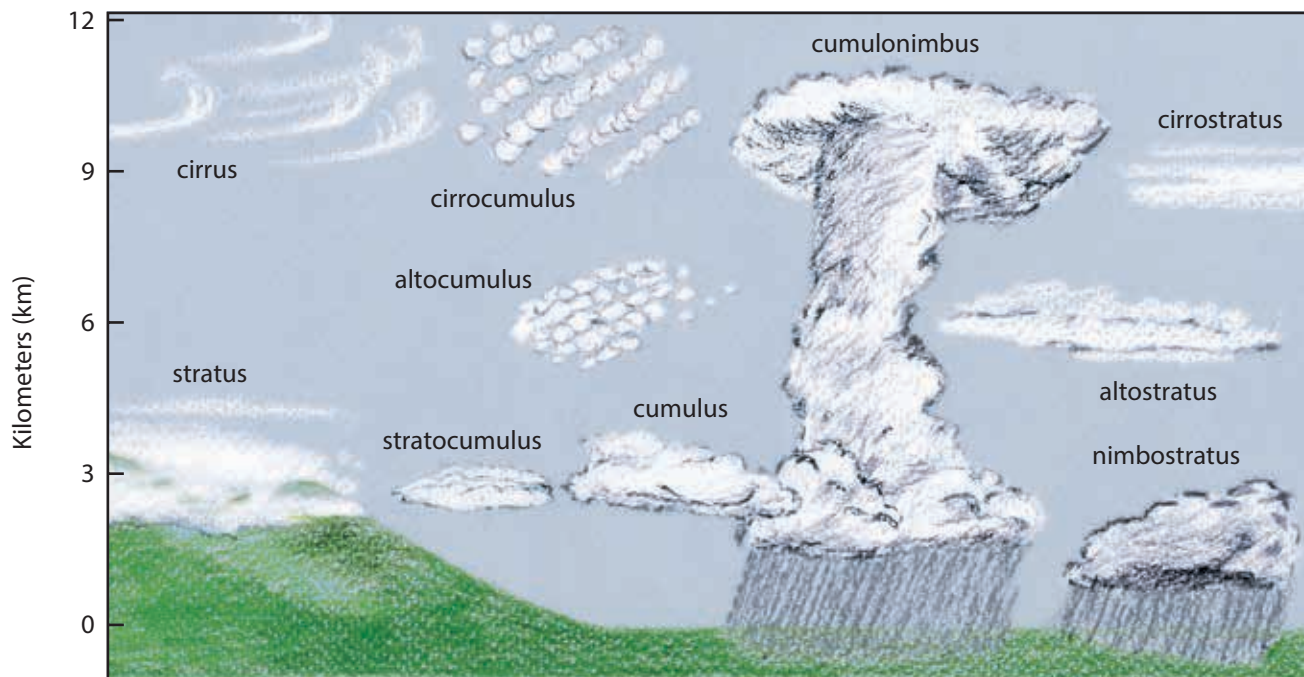
Listen as your teacher reads aloud.

Stop when you see this yellow pencil and close your book.

Write down the main ideas you just heard.

Atmospheric Layers and Temperature

Wind is the movement of air. Wind blows leaves off trees, pushes clouds across the sky, and moves water and thermal energy around the world. Air moves when there is a difference in air pressure. Wind blows from areas of higher pressure towards areas of lower pressure. When there is very little or no difference between pressure in two neighboring regions, the air is calm and there is little or no wind. When there is a lot of difference in air pressure between two neighboring regions, strong winds can occur. In general, wind speeds tend to be higher in the daytime when sunlight can heat earth materials and create greater differences in air temperature and pressure. The fastest wind speed recorded as of 2017 is 513 km (318 miles) per hour during a 1999 tornado in Oklahoma.



Clouds are described by their height in the atmosphere and their shape.

Thermal energy is spread through the troposphere because air moves and contains water vapor. Air near Earth’s surface absorbs water vapor, and as moist air rises in the atmosphere, the water vapor begins to condense. As water vapor condenses, it releases thermal energy and forms clouds. On average, clouds cover 40–50% of Earth at any given time. Clouds are carried through the atmosphere by wind.

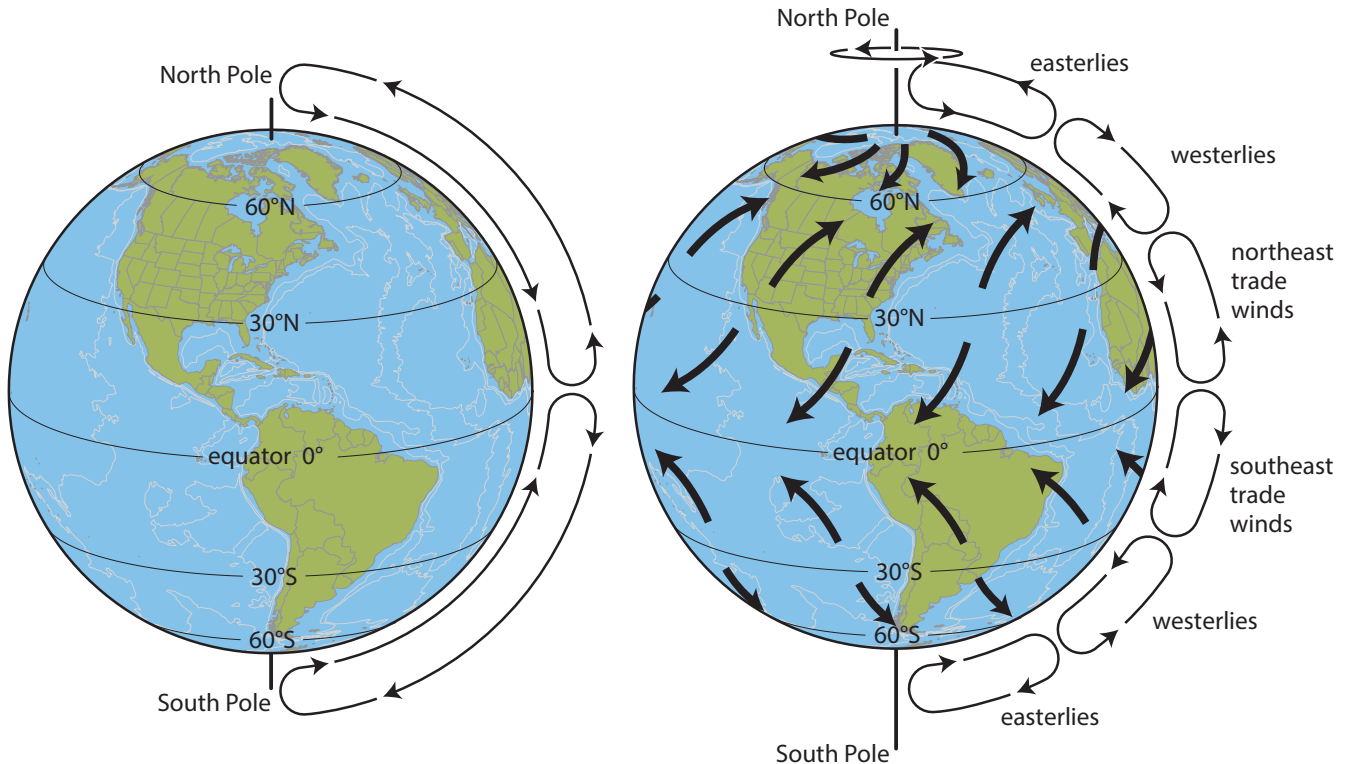
Weather is strongly affected by how stable or unstable the atmosphere is. Stable air is air that is not moving vertically very much, or at all. With stable air, it may rain or snow or it may be sunny, but the weather will not be severe or change quickly. Unstable air moves vertically, which can cause the weather to change quickly with very little warning. The more unstable the atmosphere is, the more likely you are to see clouds and experience storms or even more severe weather, such as tornadoes.

Atmosphere and Climate

The way Earth’s atmosphere interacts with the sun’s energy and the oceans helps determine Earth’s average temperatures and its different climate zones. Because areas nearest the equator receive the most direct sunlight, air around the equator is typically warmer than air at other latitudes. Similar to the oceans, air heated at the equator moves north



and south towards the poles, and this circulation affects climates in all regions. If Earth weren't rotating, there would be only two cells that circulated air, one between each pole and the equator. However, due to the Coriolis force caused by the Earth's rotation, the direction of air (and water) currents bend, creating six cells—three north of the equator and three south of the equator. You found evidence of the existence of these cells in the activity, "Worldwide Wind."



Earth's rotation toward the east causes air currents to bend to the right in the northern hemisphere and to the left in the southern hemisphere. This is the Coriolis effect.

As well as helping move moisture and thermal energy around, the atmosphere affects global climate in another important manner. Some of the sun's energy that strikes Earth radiates back from Earth's surface and would be lost to space if there were no atmosphere. Some surfaces on Earth, such as ice, reflect a lot of the sun's energy back into space. Other surfaces, such as concrete and asphalt, absorb the sun's energy and radiate thermal energy, warming the atmosphere. Some clouds reflect sunlight back into space and cool the planet, while other clouds act more like a blanket and warm it. There are gases in the air that absorb and hold thermal energy that would otherwise escape from Earth. This is called the **greenhouse effect**, and the gases are called greenhouse gases. By trapping some

of this radiated energy, the atmosphere helps create and maintain the different climates on Earth.

Natural processes such as respiration, digestion, and volcanic eruptions add such greenhouse gases as water vapor, methane, and carbon dioxide to the atmosphere. There are also natural processes that remove greenhouse gases, keeping things in balance. Living organisms play a key role in keeping the atmosphere, and thus Earth's climate, stable. Almost all living organisms require gases in the atmosphere for essential life processes. Plants, for instance, require carbon dioxide and produce oxygen; both plants and animals require oxygen and produce carbon dioxide. The cycling of gases between different organisms and the atmosphere helps maintain an environment that supports life and keeps the chemistry of the atmosphere relatively steady. However, a change in the amount of greenhouse gases in the atmosphere can disturb this balance and affect climates around the world.



ANALYSIS

1. What is the relationship between Earth's atmosphere, its weather, and its climate?
2. Acting in the role of an atmospheric scientist, write a paragraph describing the atmosphere and its layers for a weather website entry. Be sure to describe significant similarities and differences among the different layers.
3. All of Earth's organisms interact with Earth's atmosphere in some way.
 - a. How does the atmosphere affect living organisms?
 - b. How do living organisms, including humans, affect the atmosphere?
4. Explain, using a written description and diagram(s), how
 - energy from the sun helps create air and ocean currents.
 - Earth's rotation affects these currents.
 - these currents can affect an area's climate.
5. **Reflection:** If you were an atmospheric scientist, what aspect of Earth's atmosphere would you most like to study? Why?

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History of Earth's Atmosphere

INVESTIGATION

TODAY, EARTH'S ATMOSPHERE is a mixture of gases that includes nitrogen, oxygen, and water vapor. But Earth is more than 4.5 billion years old, and a lot of changes have happened in that time.

Atmospheric scientists and climatologists sometimes drill deep into Earth's surface to collect layers of ice and rock, as shown in the photo below. These layers provide information about what Earth's atmosphere was like hundreds of thousands of years ago.

GUIDING QUESTION

Has Earth's atmosphere always been the same as it is today?

MATERIALS

For each pair of students

- 1 set of 8 Atmosphere Cards



PROCEDURE

1. With your partner, carefully read the information on each Atmosphere Card.
2. Work with your partner to place each card in order from oldest to most recent.
3. Compare how you ordered your cards with the way the other half of your group ordered them. Discuss similarities and differences in your arrangements.
4. With your group, work with one set of cards to place the cards in an order you all agree on, from oldest to most recent.

Remember to listen to and consider the explanations and ideas of other members of your group. If you disagree with others, explain why you disagree.

5. In your science notebook, create a table like the “Earth’s Atmosphere Through Time” table below below, and record your final order for the Atmosphere Cards. Complete the table by writing down information about the gases in the atmosphere and important events during that time.

Earth’s Atmosphere through Time

<i>Card</i>	<i>Gases present in the atmosphere (and percentage, if listed)</i>	<i>Important date and event</i>

ANALYSIS

1. Look carefully at your completed table.
 - a. How has the amount of carbon dioxide gas in the atmosphere changed over Earth's history?
 - b. How has the amount of oxygen gas in the atmosphere changed over Earth's history?
2. What effect have living organisms (including people) had on the composition of Earth's atmosphere? Support your answer with examples from this activity.
3. **Reflection:** Do you think that the atmosphere will have different amounts of oxygen and carbon dioxide in the future? Explain your reasoning.

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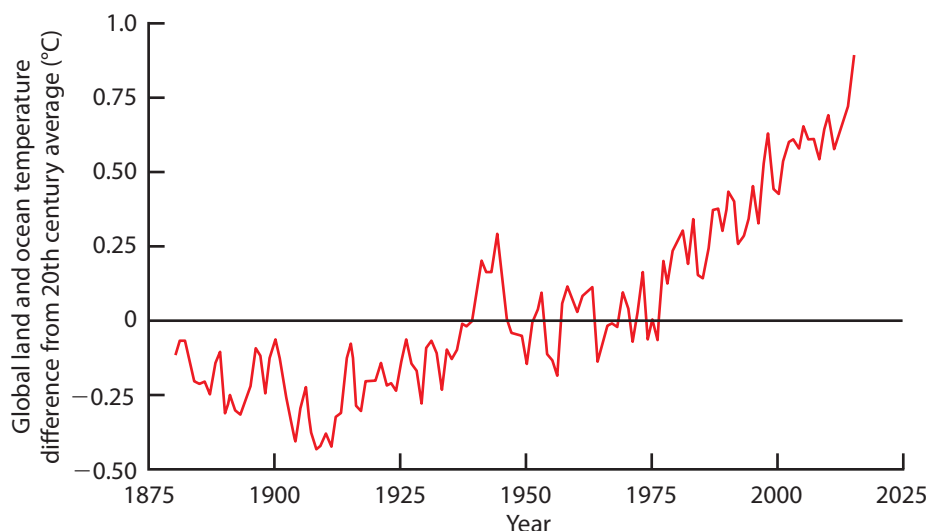
Global Warming

INVESTIGATION

SCIENTISTS BEGAN KEEPING temperature records in the mid-1800s, and these data show that the worldwide average temperature has increased by about 1°C since that time. Evidence suggests that this increase, called **global warming**, is changing climates around the world. Examples of such change include melting sea ice and warming oceans, changes in regional temperature and rainfall patterns, and more severe (in both number and intensity) weather events. There is evidence that Earth's climate has changed many times throughout Earth's history. This includes periods of warming and cooling. Climatologists work to understand what causes global warming. They study factors related to the sun's energy, Earth's surfaces, and Earth's atmosphere.

Scientists, such as climatologists, make observations and collect data. They look for correlations between the sets of data. **Correlation** is a measure of how well one set of data relates to another. Looking at data sets on a graph can help make correlations more obvious. Scientists are also interested in whether a relationship is causal. A **causal relationship** is one in which one factor causes an effect to the other factor. Climatologists analyze data to see which factors are correlated to global warming. They also try to determine which factors have a causal relationship with global warming. This is important in designing potential solutions.

Earth's Surface Temperature Variation Over the Past 100+ Years



GUIDING QUESTION

What is contributing to the current global warming?

MATERIALS

For each group of four students

- 1 computer with Internet access

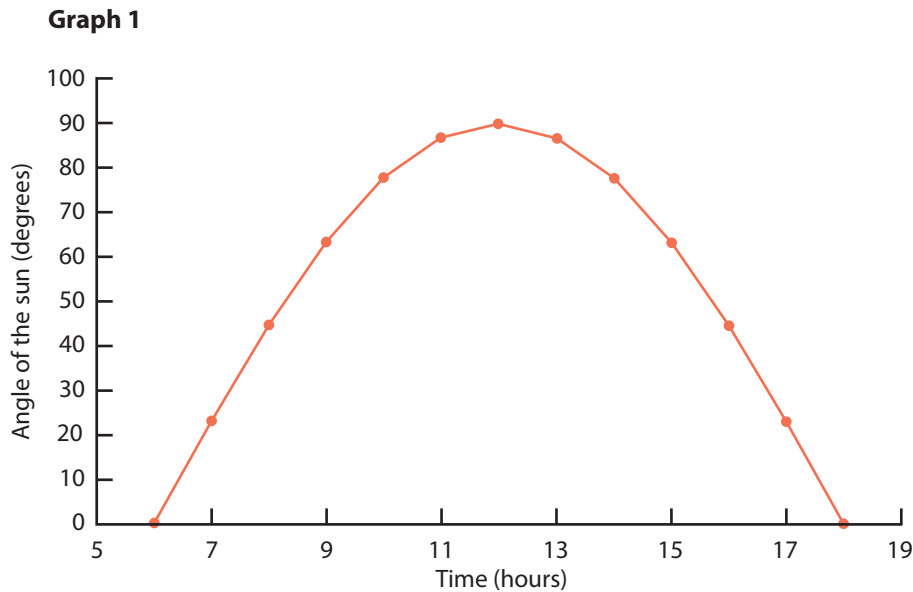
For each student

- 1 Student Sheet 16.1, "Causes of Global Warming"

PROCEDURE

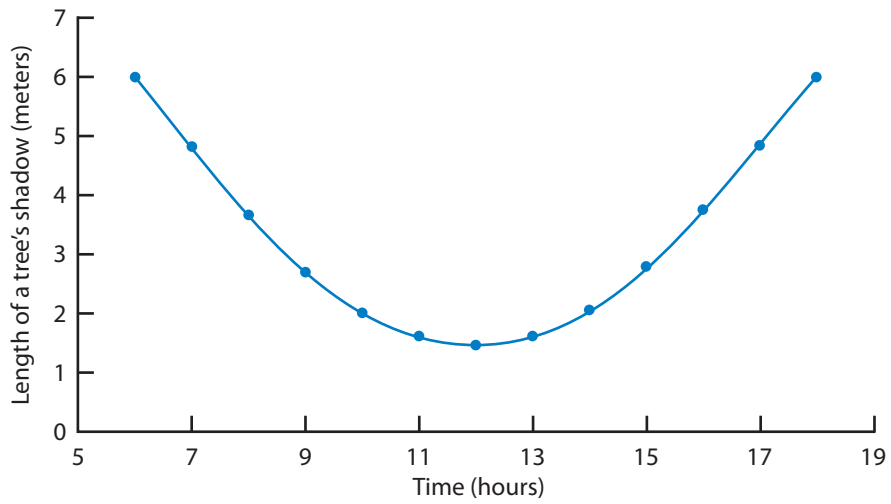
Part A: Identifying Correlations

1. Look at the graph below, and discuss with your partner any patterns you notice.

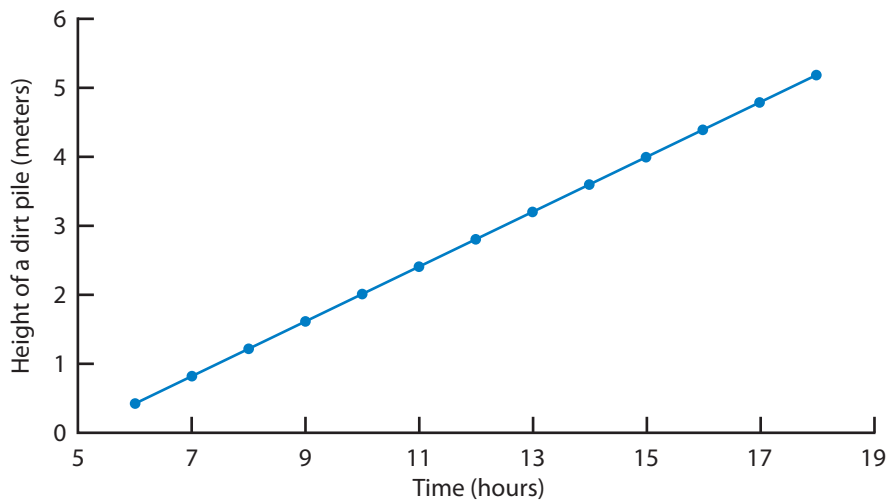


2. Look at each graph on the next page. For each graph, discuss with your partner if it is positively correlated, negatively correlated, or uncorrelated with Graph 1.
3. Read the labeled y-axis for each of the graphs and discuss with your partner if any of the graphs could have a causal relationship with the angle of the sun shown in Graph 1.

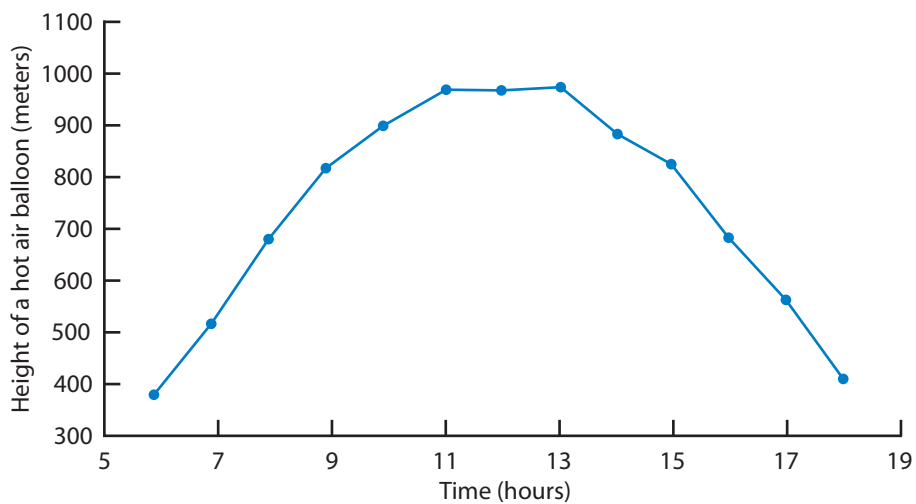
Graph A



Graph B



Graph C



Part B: Analyzing the Data

4. Visit the *SEPUP Third Edition Weather and Climate* page of the SEPUP website at www.sepuplhs.org/middle/third-edition and select the “Global Warming Interactive” link under the activity “Global Warming.”
5. The graph first shown in the Global Warming Interactive is the same graph shown in the introduction of this activity. The table at the top lets you display other sets of data. Click to display each set of the data on the left. Compare each data set to the Earth’s Surface Temperature Variation data.
6. Discuss with your group whether any of the left-hand sets of data show a correlation with changes in global temperature. Briefly describe the evidence for your decisions.

Hint: Look back at Steps 2 and 3.

7. The right side of the table at the top of the Interactive allows you to look at graphs of the level of carbon dioxide in the atmosphere since 1900. Spend some time with members of your group displaying the various graphs.
8. Answer the following questions on Student Sheet 16.1, “Causes of Global Warming.” If you don’t have enough information to answer a question, write down what other data or information you would need to be able to answer the question.
 - Which human activity produces the most carbon dioxide?
 - Without human activities, would there be carbon dioxide in the atmosphere?
 - Without human activities, would carbon dioxide concentrations have increased, decreased, or stayed the same between 1900 and 2000?
 - If human activity doesn’t change, is the amount of carbon dioxide in the atmosphere likely to continue to increase, stay the same, or decrease?
9. Compare and discuss your answers with your partner, and then share your discussion with the rest of your group.

ANALYSIS

1. Describe the relationship between global warming and carbon dioxide produced
 - a. from human activities.
 - b. by natural processes like volcanoes.
2. Your friend claims that there is nothing that humans can do about global warming since Earth's temperature is always slowly rising.
 - a. Do you agree or disagree with your friend? Support your answer with evidence from this activity, and explain your reasoning.
 - b. What other data, or evidence, would you like in order to better evaluate your friend's claim?
3. Two different engineers have come up with plans on how to combat climate change. Read each proposal carefully, and for each proposal, answer the two questions below:
 - a. If the proposal were adopted, could it work?
 - b. What are some negative consequences of the proposal?

Proposal 1: Stop Burning Fossil Fuels!

If the world stopped using fossil fuels, carbon dioxide emissions would decrease dramatically and, over time, carbon dioxide concentrations in the atmosphere would decline, causing Earth's warming to stop. Instead of fossil fuels, we would need to use alternative forms of energy, like nuclear, wind, and solar. Planes and cars would need to be 100% electric or hydrogen powered.

Proposal 2: Deal with the Effects!

We have a world full of wonderful engineers and scientists, and with their skills and knowledge, we can deal with anything that climate change throws at us. If sea levels rise, we'll build on higher ground. If our houses get too hot in the summer, we'll build better air conditioners. If storms get more severe, we'll build stronger buildings.

4. **Climate change** often refers to the effects that increasing temperatures caused by global warming have on Earth's systems.
 - a. List some examples of climate change that you have learned about in this unit.
 - b. Choose one of the examples, and explain how global warming is linked to it.
5. Write your own proposal for combating climate change. Make sure it does at least one of the following: reduces the amount of carbon dioxide being emitted by humans, reduces the amount of carbon dioxide in the atmosphere, or helps people manage the effects of climate change.
 - a. If your proposal is approved, do you think global warming would be reduced immediately or gradually? What evidence do you have to support your answer?
 - b. A **trade-off** is an exchange of one outcome for another—giving up something that is a benefit or advantage in exchange for something that may be more desirable. Describe any trade-offs of your proposal.

EXTENSION

Climatologists make predictions on future climates based on climate models. Climate models are mathematical relationships built by using historical data to see how changes of certain variables, like Earth's tilt, change over time and how those changes affect the climate. As more data have become available, models have improved. Use the Internet to search for climate models that address global warming.

STUDENT SHEET 16.1
CAUSES OF GLOBAL WARMING

1. Which human activity produces the most carbon dioxide?

2. Without human activities, would there be carbon dioxide in the atmosphere?

3. Without human activities, would carbon dioxide concentrations have increased, decreased, or stayed the same between 1900 and 2000?

4. If human activity doesn't change, is the amount of carbon dioxide in the atmosphere likely to continue to rise, stay the same, or go down?
