Section 1

# What Causes Climate?

## Reading Preview

### Key Concepts

- What factors influence temperature?
- What factors influence precipitation?
- What causes the seasons?

### Key Terms

- climate • microclimate
- tropical zone • polar zone
- temperate zone
- marine climate
- continental climate
- windward • leeward
- monsoon

### Target Reading Skill

**Building Vocabulary** After you read the section, reread the paragraphs that contain definitions of Key Terms. Use all the information you have learned to write a meaningful sentence using each Key Term.

Lab zone **Discover Activity**

## How Does Latitude Affect Climate?

1. On a globe, tape a strip of paper from the equator to the North Pole. Divide the tape into three equal parts. Label the top section *poles,* the bottom section *equator,* and the middle section *mid-latitudes.*
2. Tape the end of an empty toilet paper roll to the end of a flashlight. Hold the flashlight about 30 cm from the equator. Turn on the flashlight to represent the sun. On the paper strip, have a partner draw the area the light shines on.
3. Move the flashlight up slightly to aim at the "mid-latitudes." Keep the flashlight horizontal and at the same distance from the globe. Again, draw the lighted area.
4. Repeat Step 3, but this time aim the light at the "poles."

**Think It Over**

**Observing** How does the size of the illuminated area change? Do you think the sun's rays heat Earth's surface evenly?

The weather in an area changes every day. At a given location, the weather may be cloudy and rainy one day and clear and sunny the next. **Climate,** on the other hand, refers to the average, year-after-year conditions of temperature, precipitation, winds, and clouds in an area. For example, California's Mojave Desert, shown below, has a hot, dry climate.

Scientists use two main factors—precipitation and temperature—to describe the climate of a region. A climate region is a large area that has similar climate conditions throughout. For example, the climate in the southwestern United States is dry, with hot summers.

The factors that affect large climate regions also affect smaller areas. Have you ever noticed that it is cooler and more humid in a grove of trees than in an open field? A small area with climate conditions that differ from those around it may have its own **microclimate.**

An oasis in the Mojave Desert ▼

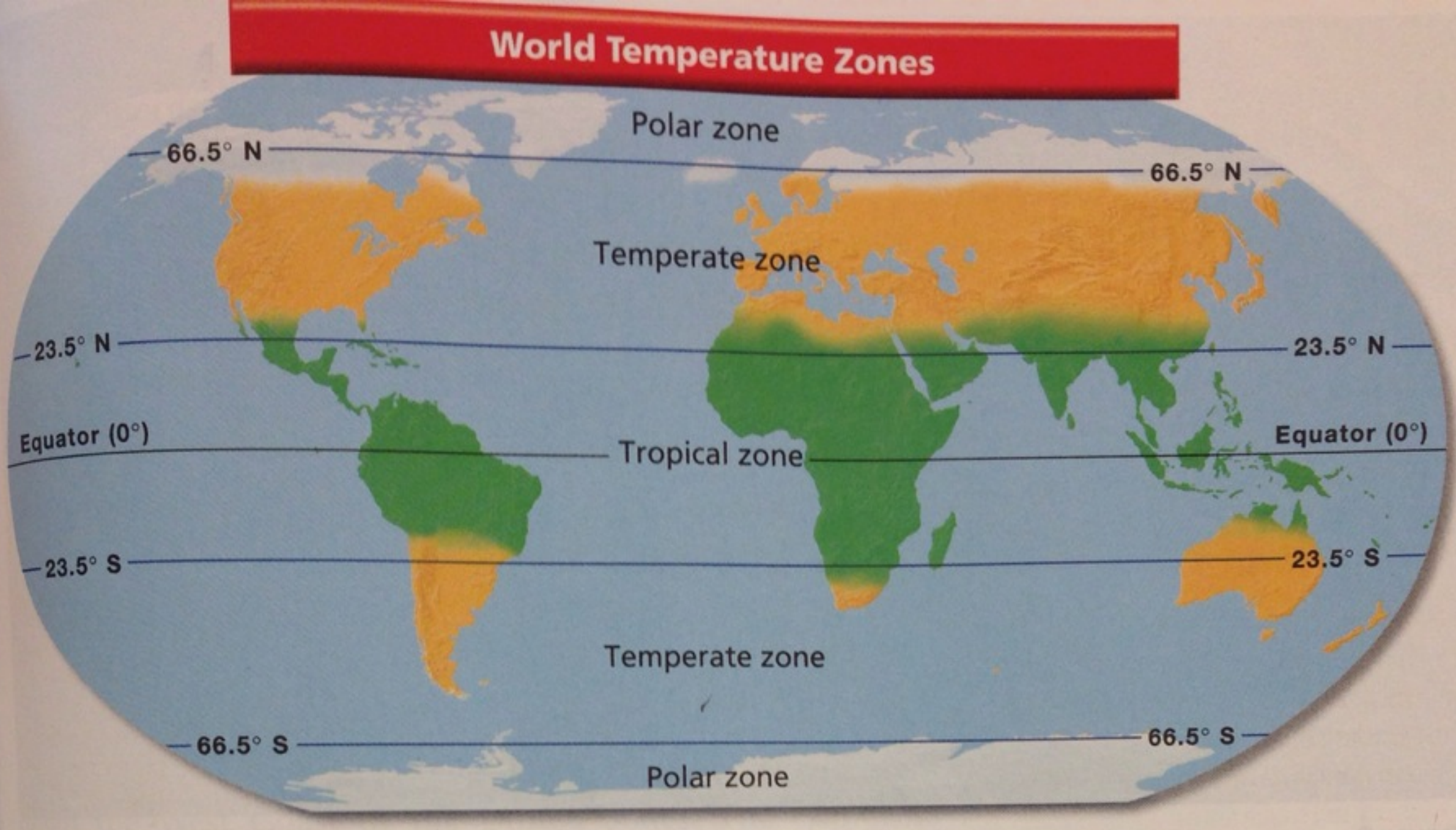



FIGURE 1
The tropical zone has the warmest climates. Cold climates occur in the polar zone. In between lies the temperate zone, where climates vary from warm to cool.
**Interpreting Maps** *In which temperature zone is most of the United States located?*

## Factors Affecting Temperature

Why are some places warm and others cold? **The main factors that influence temperature are latitude, altitude, distance from large bodies of water, and ocean currents.**

**Latitude** In general, climates of locations near the equator are warmer than climates of areas far from the equator. The reason is that the sun's rays hit Earth's surface most directly at the equator. At the poles, the same amount of solar radiation is spread over a larger area, and therefore brings less warmth.

Recall that latitude is the distance from the equator, measured in degrees. Based on latitude, Earth's surface can be divided into the three temperature zones shown in Figure 1. The **tropical zone** is the area near the equator, between about 23.5° north latitude and 23.5° south latitude. The tropical zone receives direct or nearly direct sunlight all year round, making climates there warm.

In contrast, the sun's rays always strike at a lower angle near the North and South poles. As a result, the areas near both poles have cold climates. These **polar zones** extend from about 66.5° to 90° north and 66.5° to 90° south latitudes.

Between the tropical zones and the polar zones are the **temperate zones**. In summer, the sun's rays strike the temperate zones more directly. In winter, the sun's rays strike at a lower angle. As a result, the weather in the temperate zones ranges from warm or hot in summer to cool or cold in winter.

FIGURE 2
**Effect of Altitude**
Mount Kilimanjaro, in Tanzania, is near the equator.
**Relating Cause and Effect** *What factor is responsible for the difference between the climate at the mountaintop and the climate at the base?*

**Altitude** The peak of Mount Kilimanjaro towers high above the plains of East Africa. Kilimanjaro is covered in snow all year round, as shown in Figure 2. Yet it is located near the equator, at 3° south latitude. Why is Mount Kilimanjaro so cold?

In the case of high mountains, altitude is a more important climate factor than latitude. In the troposphere, temperature decreases about 6.5 Celsius degrees for every 1-kilometer increase in altitude. As a result, highland areas everywhere have cool climates, no matter what their latitude. At nearly 6 kilometers, the air at the top of Kilimanjaro is about 39 Celsius degrees colder than the air at sea level at the same latitude.

**Distance From Large Bodies of Water** Oceans or large lakes can also affect temperatures. Oceans greatly moderate, or make less extreme, the temperatures of nearby land. Water heats up more slowly than land. It also cools down more slowly. Therefore, winds off the ocean often prevent extremes of hot and cold in coastal regions. Much of the west coasts of North America, South America, and Europe have mild **marine climates,** with relatively mild winters and cool summers.

The centers of North America and Asia are too far inland to be warmed or cooled by the ocean. Most of Canada and of Russia, as well as the central United States, have continental climates. **Continental climates** have more extreme temperatures than marine climates. Winters are cold, while summers are warm or hot.

**Ocean Currents** Marine climates are influenced by ocean currents, streams of water within the oceans that move in regular patterns. Some warm ocean currents move from the tropics towards the poles. This affects climate as the warm ocean water warms the air above it. The warmed air then moves over nearby land. In the same way, cold currents bring cold water from the polar zones toward the equator. A cold current brings cool air.

As you read about the following currents, trace their paths on the map in Figure 3. The best-known warm-water current is the Gulf Stream. The Gulf Stream begins in the Gulf of Mexico, then flows north along the east coast of the United States. When it crosses the North Atlantic, it becomes the North Atlantic Drift. This warm current brings mild, humid air to Ireland and southern England. As a result, these areas have a mild, wet climate despite their relatively high latitude.

In contrast, the cool California Current flows southward down the West Coast of the United States. The California Current makes climates along the West Coast cooler than you would expect at those latitudes.

Reading Checkpoint **What effect do oceans have on the temperatures of nearby land areas?**

Lab zone **Skills Activity**

### Inferring

Look at the currents in the South Pacific, South Atlantic, and Indian oceans. What pattern can you observe? Now compare currents in the South Atlantic to those in the North Atlantic. What might be responsible for differences in the current patterns?

**FIGURE 3**
On this map, warm currents are shown in red and cold currents in blue. Interpreting Maps *What type of current occurs around Antarctica?*

## Factors Affecting Precipitation

The air masses that pass over an area may bring rain or snow. The amount of precipitation varies from year to year. But over time, total precipitation tends toward a yearly average. What determines the amount of precipitation an area receives? **The main factors that affect precipitation are prevailing winds, the presence of mountains, and seasonal winds.**

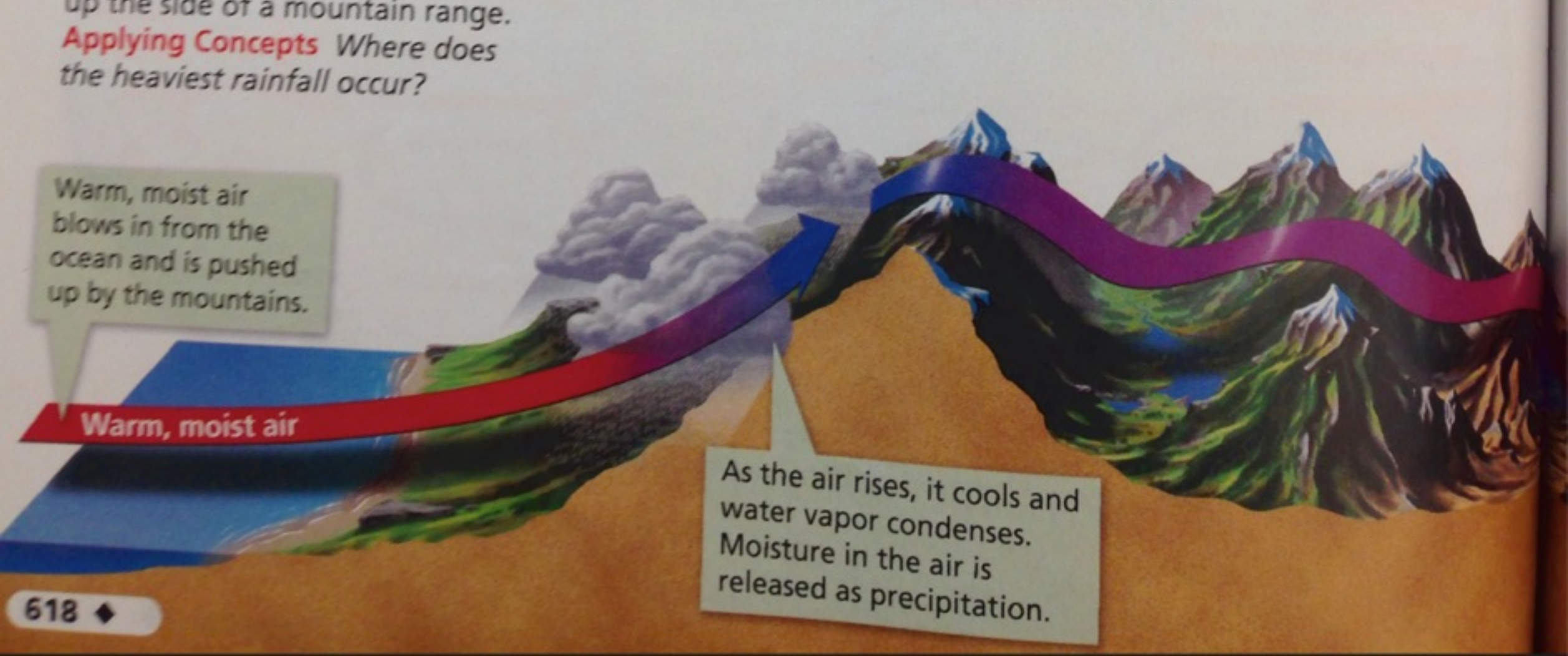
**Prevailing Winds** As you know, weather patterns depend on the movement of huge air masses. Air masses are moved from place to place by prevailing winds, the directional winds that usually blow in a region. Air masses can be warm or cool, dry or humid. The amount of water vapor in the air mass influences how much rain or snow will fall.

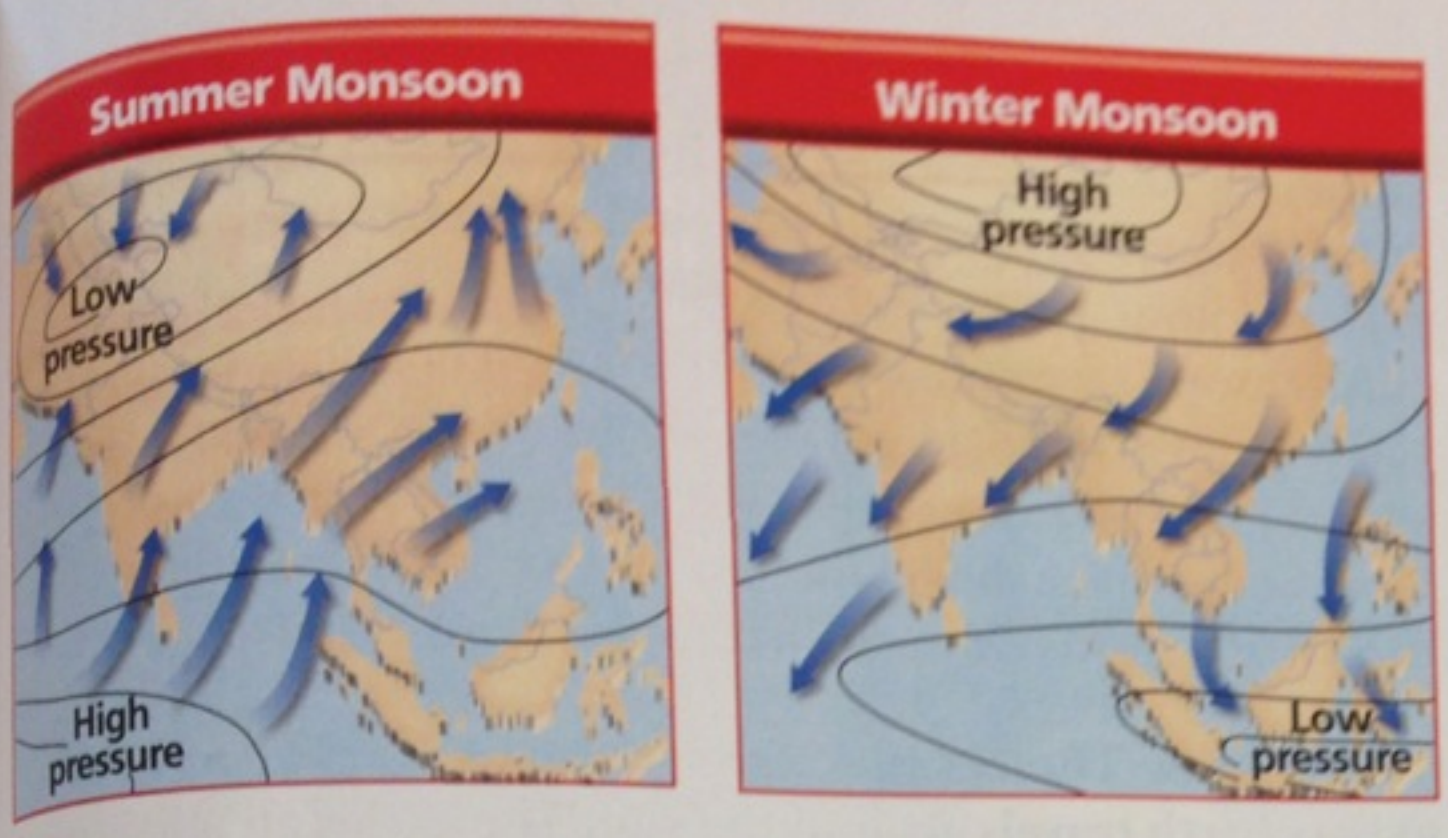
The amount of water vapor in prevailing winds also depends on where the winds come from. Winds that blow inland from oceans or large lakes carry more water vapor than winds that blow from over land. For example, winter winds generally blow from west to east across the Great Lakes. The winds pick up moisture that evaporates from the lakes. As a result, areas that are downwind can receive large amounts of snow.

**Mountain Ranges** A mountain range in the path of prevailing winds can also influence where precipitation falls. When humid winds blow from the ocean toward coastal mountains, they are forced to rise, as shown in Figure 4. The rising air cools and its water vapor condenses, forming clouds. Rain or snow falls on the **windward** side of the mountains, the side the wind hits.

By the time the air has moved over the mountains, it has lost much of its water vapor, so it is cool and dry. The land on the **leeward** side of the mountains—downwind—is in a rain shadow. Little precipitation falls there.

**FIGURE 4**
**Rain Shadow**
*A mountain range can form a barrier to the movement of humid air. Humid air cools as it is blown up the side of a mountain range.*
**Applying Concepts** *Where does the heaviest rainfall occur?*





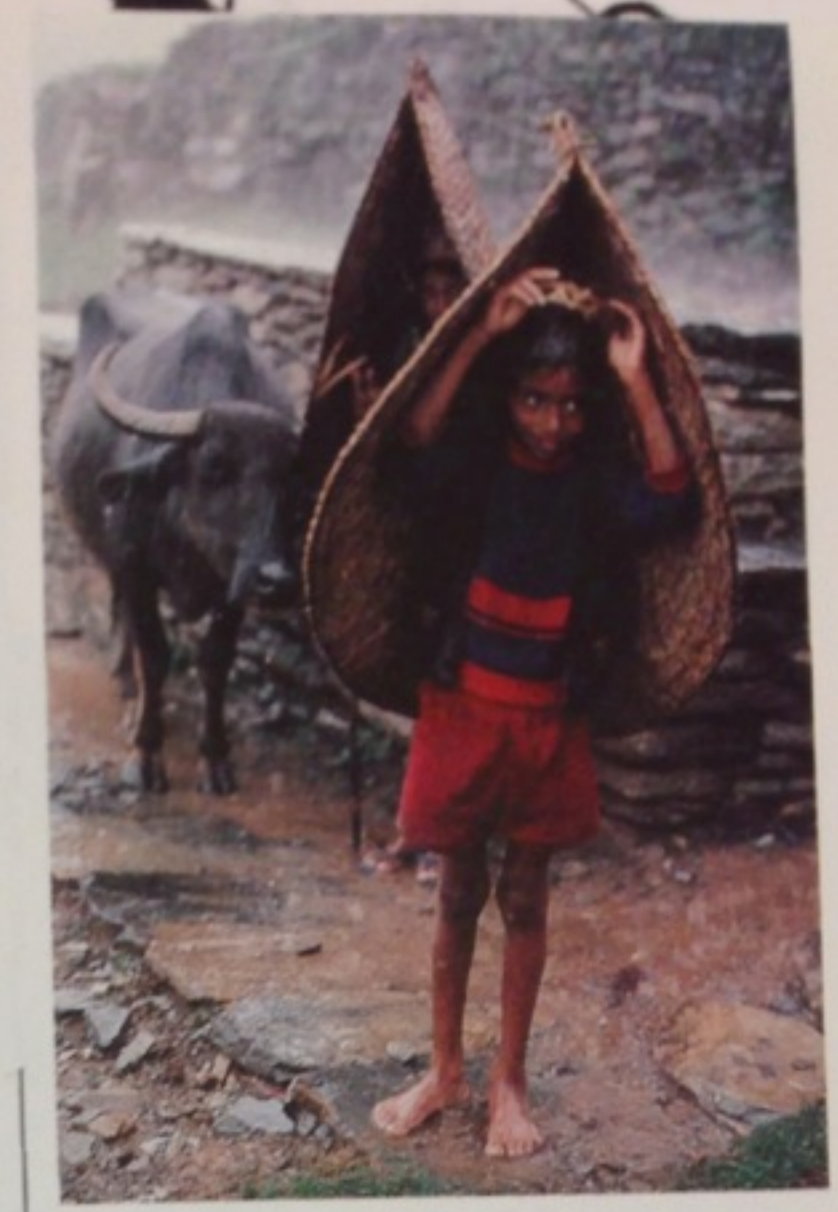



FIGURE 5
**Monsoons**
In a summer monsoon, wind blows from the ocean to the land. In the winter, the monsoon reverses and blows from the land to the ocean. Summer monsoons in Nepal cause heavy rain (above).

**Seasonal Winds** A seasonal change in wind patterns can affect precipitation. These seasonal winds are similar to land and sea breezes, but occur over a wider area. Sea and land breezes over a large region that change direction with the seasons are called **monsoons.** What produces a monsoon? In the summer in South and Southeast Asia, the land gradually gets warmer than the ocean. A "sea breeze" blows steadily inland from the ocean all summer, even at night. The air blowing from the ocean during this season is very warm and humid. As the humid air rises over the land, the air cools. This causes water vapor to condense into clouds, producing heavy rains.

Thailand and parts of India receive much of their rain from the summer monsoons. These rains supply the water needed by rice and other crops. Monsoon winds also bring rain to coastal areas in West Africa and northeastern South America.

Regions affected by monsoon winds receive very little rain in winter. In the winter, the land cools and becomes colder than the ocean. A "land breeze" blows steadily from the land to the ocean. These winds carry little moisture.

**Reading Checkpoint** **Why does precipitation fall mainly on the windward sides of mountains?**

## Math Skills

**Percentage** Light from the sun strikes Earth's surface at different angles. An angle is made up of two lines that meet at a point. Angles are measured in degrees. A full circle has 360 degrees.

When the sun is directly overhead near the equator, it is at an angle of 90° to Earth's surface. A 90° angle is called a right angle. What percentage of a circle is it?

$$\frac{90 \text{ degrees}}{360 \text{ degrees}} = \frac{d\%}{100\%}$$

$$90 \times 100 = 360 \times d$$

$$\frac{90 \times 100}{360} = d = 25$$

A 90° angle is 25 percent of a full circle.

**Practice Problem** Earth's axis is tilted at an angle of 23.5°. About what percentage of a right angle is this?

## The Seasons

Although you can describe the average weather conditions of a climate region, these conditions are not constant all year long. Instead, most places outside the tropics have four seasons: winter, spring, summer, and autumn. When it is summer in the Northern Hemisphere it is winter in the Southern Hemisphere. So the seasons are not a result of changes in the distance between Earth and the sun. In fact, Earth is farthest from the sun during the summer in the Northern Hemisphere.

**Tilted Axis** **The seasons are caused by the tilt of Earth's axis as Earth travels around the sun.** The axis is an imaginary line through Earth's center that passes through both poles. Earth rotates, or turns, around this axis once each day. Earth's axis is not straight up and down, but is tilted at an angle of 23.5°. As Earth travels around the sun, its axis always points in the same direction. So the north end of the axis is pointed away from the sun for one part of the year and toward the sun for another part of the year.

**Effect of the Tilted Axis** Look at Figure 7. Which way is the north end of Earth's axis tilted in June? Notice that the Northern Hemisphere receives more direct rays from the sun. Also, in June the days in the Northern Hemisphere are longer than the nights. The combination of more direct rays and longer days makes Earth's surface warmer in the Northern Hemisphere than at any other time of the year. It is summer in the Northern Hemisphere. At the same time, the Southern Hemisphere is experiencing winter.

In December, on the other hand, the north end of Earth's axis is tilted away from the sun. It is winter in the Northern Hemisphere and summer in the Southern Hemisphere.

**Reading Checkpoint** **In June, what season is it in the Southern Hemisphere?**

**FIGURE 6**
**Summer and Winter**
There can be a striking difference between summer and winter in the same location. Inferring *During which season does the area shown receive more solar energy?*

Section 4

Integrating Environmental Science

# Global Changes in the Atmosphere

## Reading Preview

### Key Concepts

- What events can cause short-term climate changes?
- How might human activities be affecting the temperature of Earth's atmosphere?
- How have human activities affected the ozone layer?

### Key Terms

- El Niño
- La Niña
- global warming
- greenhouse gas
- chlorofluorocarbon

### Target Reading Skill

**Asking Questions** Before you read, preview the red headings. Ask a *what* or *how* question for each heading, for example, "How does short-term climate change occur?" As you read, write the answers to your questions.

Lab zone **Discover Activity**

### What Is the Greenhouse Effect?

1. Cut two pieces of black construction paper to fit the bottoms of two shoe boxes.
2. Place a thermometer in each box. Record the temperatures on the thermometers. Cover one box with plastic wrap.
3. Place the boxes together where sunlight or a light bulb can shine on them equally. Make sure the thermometers are shaded by the sides of the boxes.
4. Wait 15 minutes and read the thermometers again. Record the temperatures.

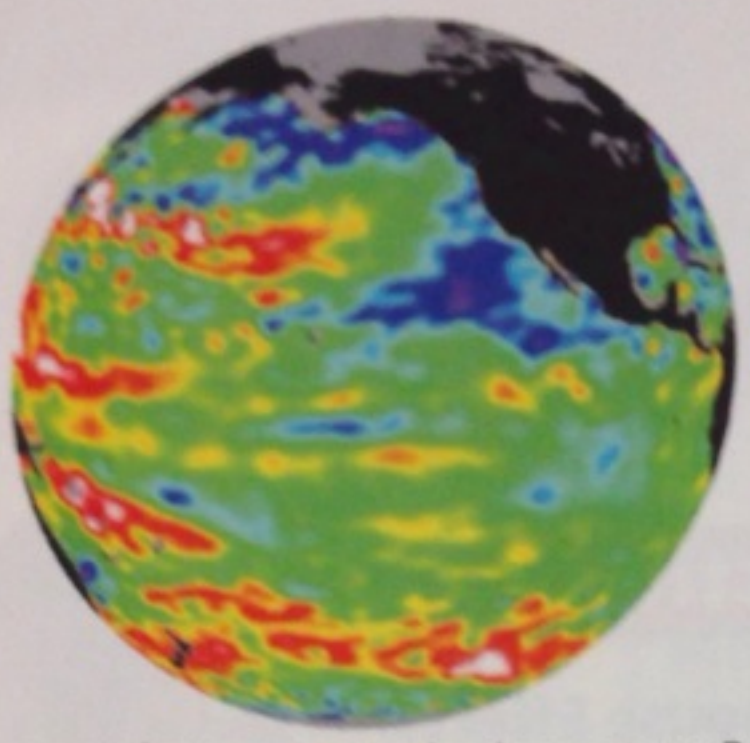
**Think It Over**

**Inferring** How can you explain any temperature difference between the two boxes?

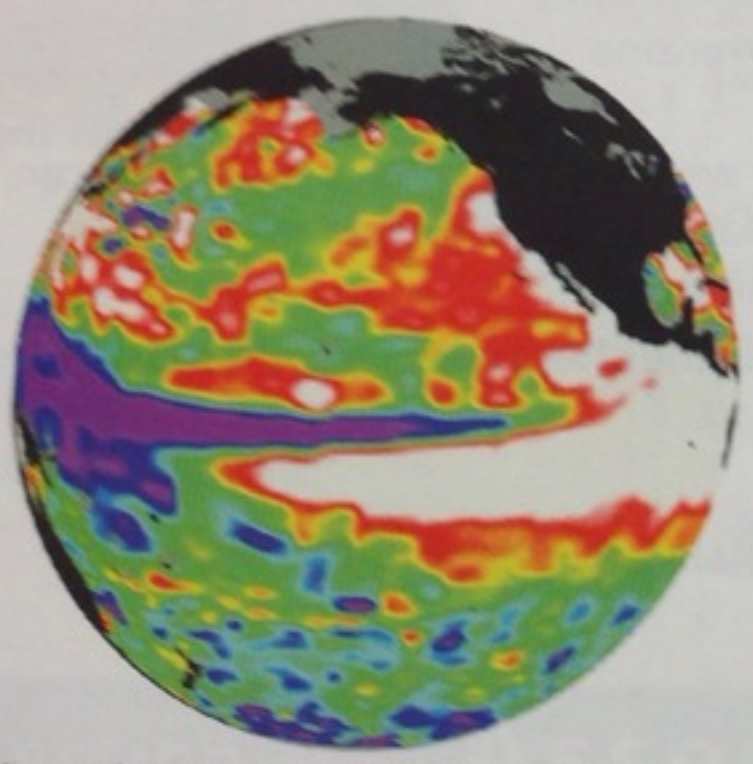
If you live in one area for several years, you get to know the area's climate. But in some years, the weather is so unusual that you might think the climate has changed. That's what happened in several different parts of the world during 1997–1998. Droughts occurred in parts of Africa, Asia, and Australia. Heavy rains struck parts of South America. In the United States, very heavy rains swept across California and the South.

What produced these global changes? During the droughts and floods of 1998, parts of the Pacific Ocean were much warmer than usual. Even the ocean's winds and currents changed. Scientists have evidence that these changes in the Pacific Ocean led to wild weather in other parts of the world.

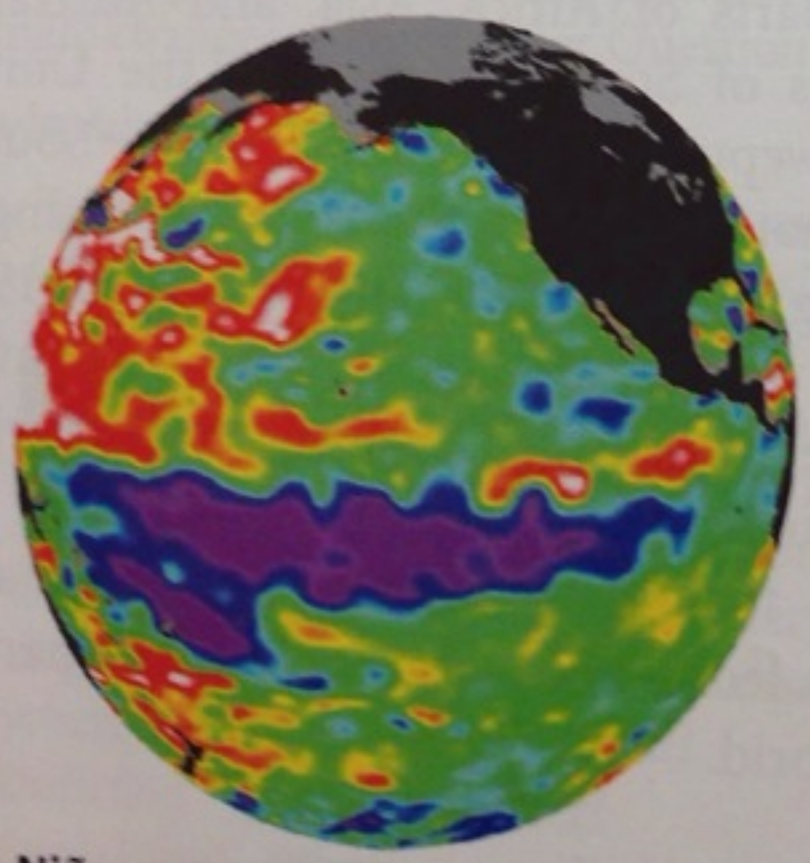
◀ **In 1998, mudslides from heavy rains caused severe damage in California.**



▲ In **normal years**, water in the eastern Pacific is kept relatively cool by currents along the coast of North and South America.



▲ When **El Niño** occurs, warm surface water from the western Pacific moves east toward the coast of South America.



▲ **La Niña** occurs when surface waters in the eastern Pacific Ocean are colder than normal.

FIGURE 21
**El Niño and La Niña**
In these satellite images, warmer water is red and white. Cooler water is blue and purple.

## Short-Term Climate Change

Changes in ocean currents and winds can greatly affect climate. **El Niño and La Niña are short-term changes in the tropical Pacific Ocean caused by changes in ocean surface currents and prevailing winds.** El Niño and La Niña both influence weather patterns all over the world.

**El Niño** The warm-water event known as **El Niño** begins when an unusual pattern of winds forms over the western Pacific. This causes a vast sheet of warm water to move eastward toward the South American coast, as shown in Figure 21. El Niño causes the surface of the ocean in the eastern Pacific to be unusually warm. El Niño typically occurs every two to seven years.

The arrival of El Niño's warm surface water disrupts the cold ocean currents along the western coast of South America and changes weather patterns there. El Niño also affects weather patterns around the world, often bringing severe conditions such as heavy rains or droughts. El Niño conditions can last for one to two years before normal winds and currents return.

**La Niña** When surface waters in the eastern Pacific are colder than normal, a climate event known as **La Niña** occurs. A La Niña event is the opposite of an El Niño event. La Niña events typically bring colder than normal winters and greater precipitation to the Pacific Northwest and the north central United States. Another major effect of La Niña is greater hurricane activity in the western Atlantic.

**Reading Checkpoint** **How often does El Niño typically occur?**

## Global Warming

Most changes in world climates are caused by natural factors. But recently scientists have observed climate changes that could be the result of human activities. For example, over the last 120 years, the average temperature of the troposphere has risen by about 0.5 Celsius degree. This gradual increase in the temperature of Earth's atmosphere is called **global warming.**

**The Greenhouse Hypothesis** Recall that gases in Earth's atmosphere hold in heat from the sun, keeping the atmosphere at a comfortable temperature for living things. The process by which gases in Earth's atmosphere trap this energy is called the greenhouse effect. Look at the greenhouse in Figure 22. Notice that sunlight does not heat the air in the greenhouse directly. Instead, sunlight first heats the soil, benches, and pots. Then infrared radiation from these surfaces heats the air in the greenhouse. The greenhouse effect in Earth's atmosphere is similar in some ways.

Gases in the atmosphere that trap energy are called **greenhouse gases.** Carbon dioxide, water vapor, and methane are some of the greenhouse gases. **Many scientists have hypothesized that human activities that add greenhouse gases to the atmosphere may be warming Earth's atmosphere.**

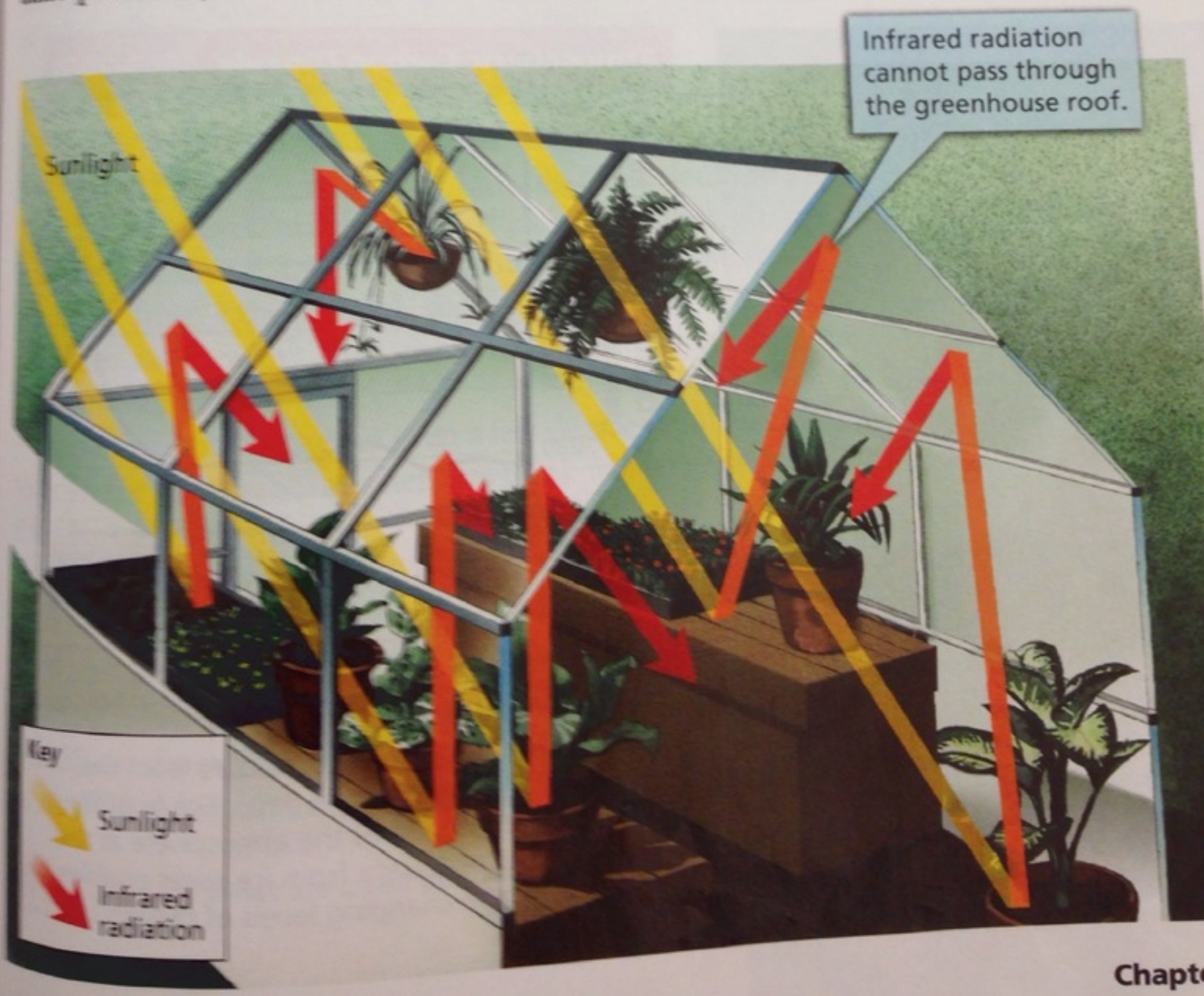
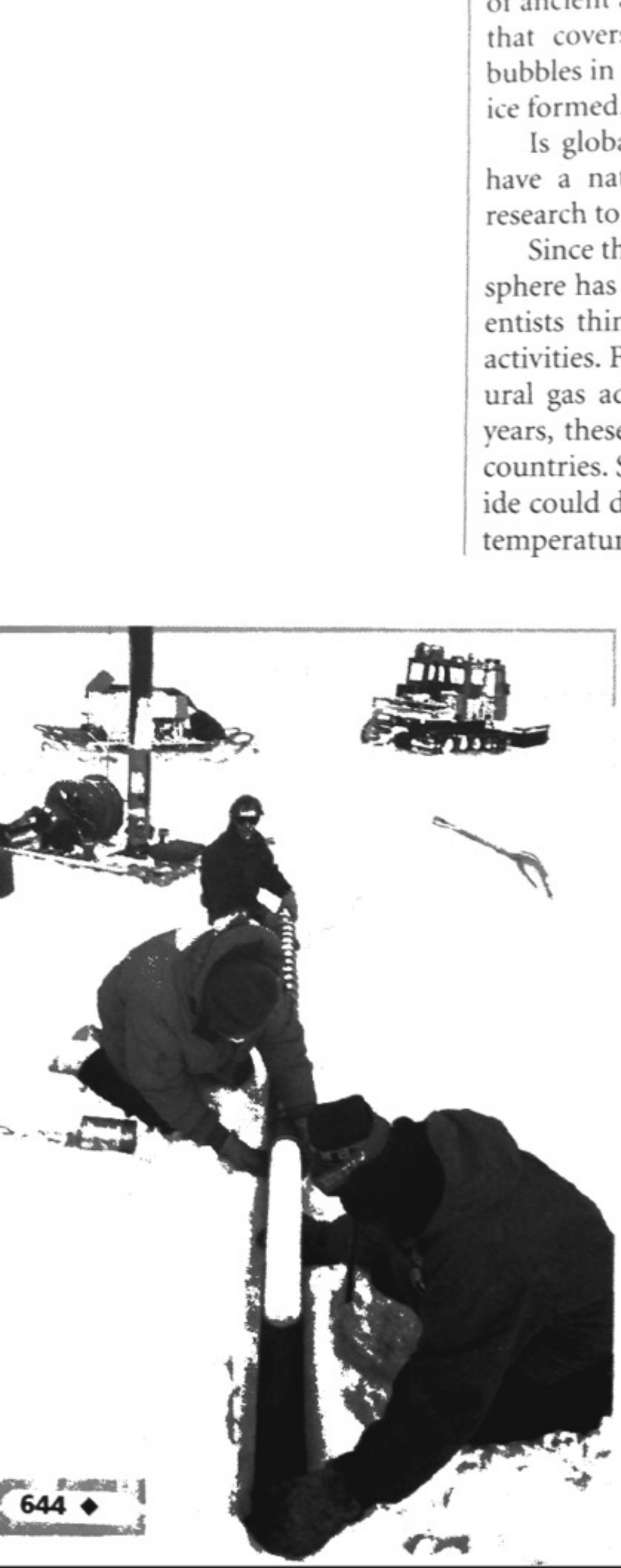



**FIGURE 22**
**Greenhouse Effect**
Sunlight enters a greenhouse and is absorbed. The interior of the greenhouse radiates back energy in the form of infrared radiation, or heat. Much of the heat is trapped and held inside the greenhouse, warming it.
**Applying Concepts** *What gases in Earth's atmosphere can trap heat like a greenhouse?*

**Changing Levels of Carbon Dioxide** Scientists think that an increase in carbon dioxide is a major factor in global warming. Until the late 1800s, the level of carbon dioxide in the atmosphere remained about the same. How did scientists determine this? They measured the amount of carbon dioxide in air bubbles trapped in Antarctic ice. They obtained these samples of ancient air from ice cores, as shown in Figure 23. The glacier that covers Antarctica formed over millions of years. Gas bubbles in the ice cores provide samples of air from the time the ice formed.

Is global warming caused by human activities, or does it have a natural cause? Scientists have done a great deal of research to try to answer this question.

Since the late 1800s, the level of carbon dioxide in the atmosphere has increased steadily, as shown in Figure 23. Many scientists think that this change is a result of increased human activities. For example, the burning of wood, coal, oil, and natural gas adds carbon dioxide to the air. During the last 100 years, these activities have increased greatly in many different countries. Some scientists predict that the level of carbon dioxide could double by the year 2100. If that happens, then global temperature could rise by 1.5 to 3.5 Celsius degrees.



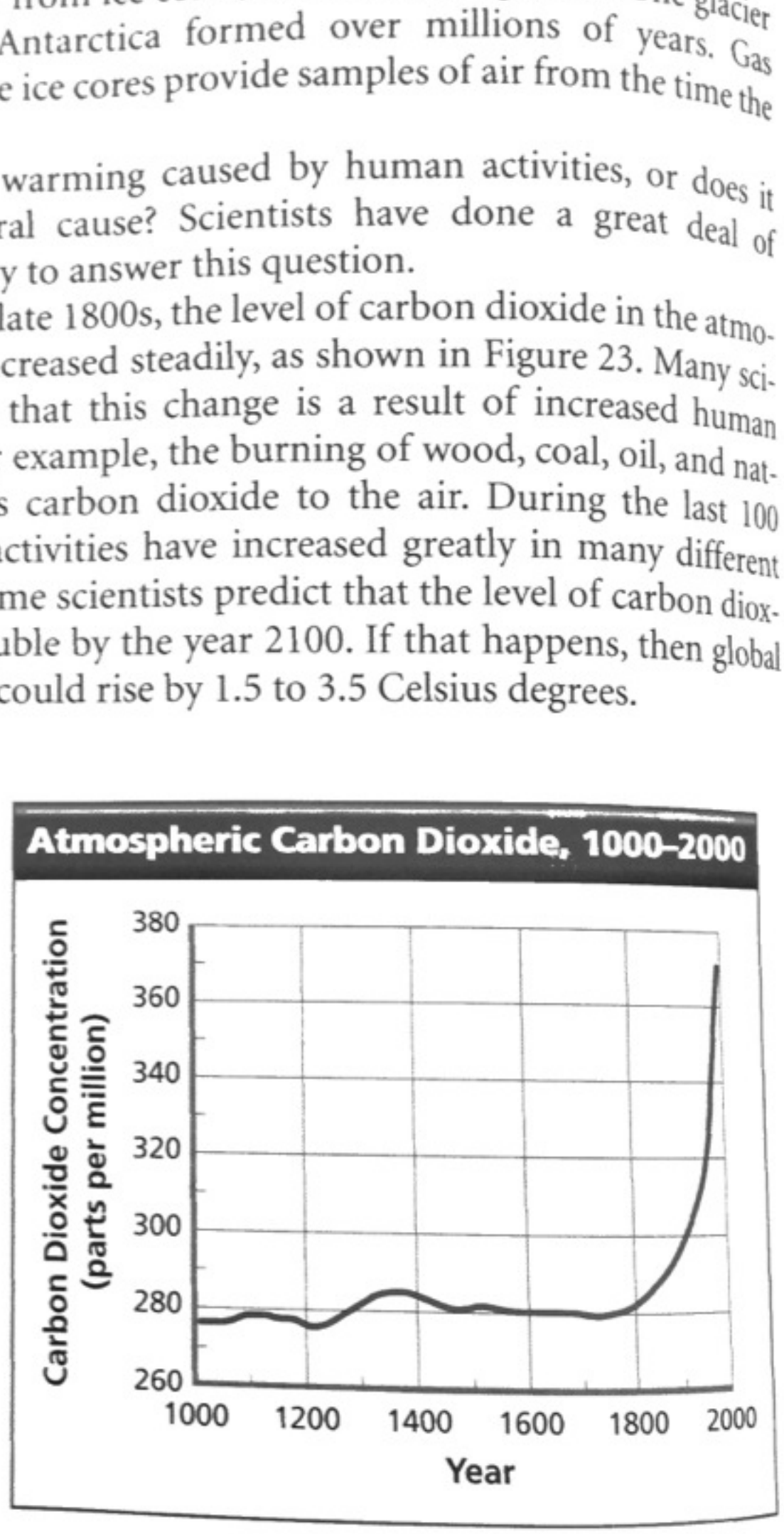



**FIGURE 23**
**Carbon Dioxide Levels**
These scientists are taking an ice core from the glacier that covers Antarctica (left). Gas bubbles in the ice provide samples of the atmosphere at the time the ice formed. Data from ice cores enables scientists to graph changing levels of carbon dioxide (above).

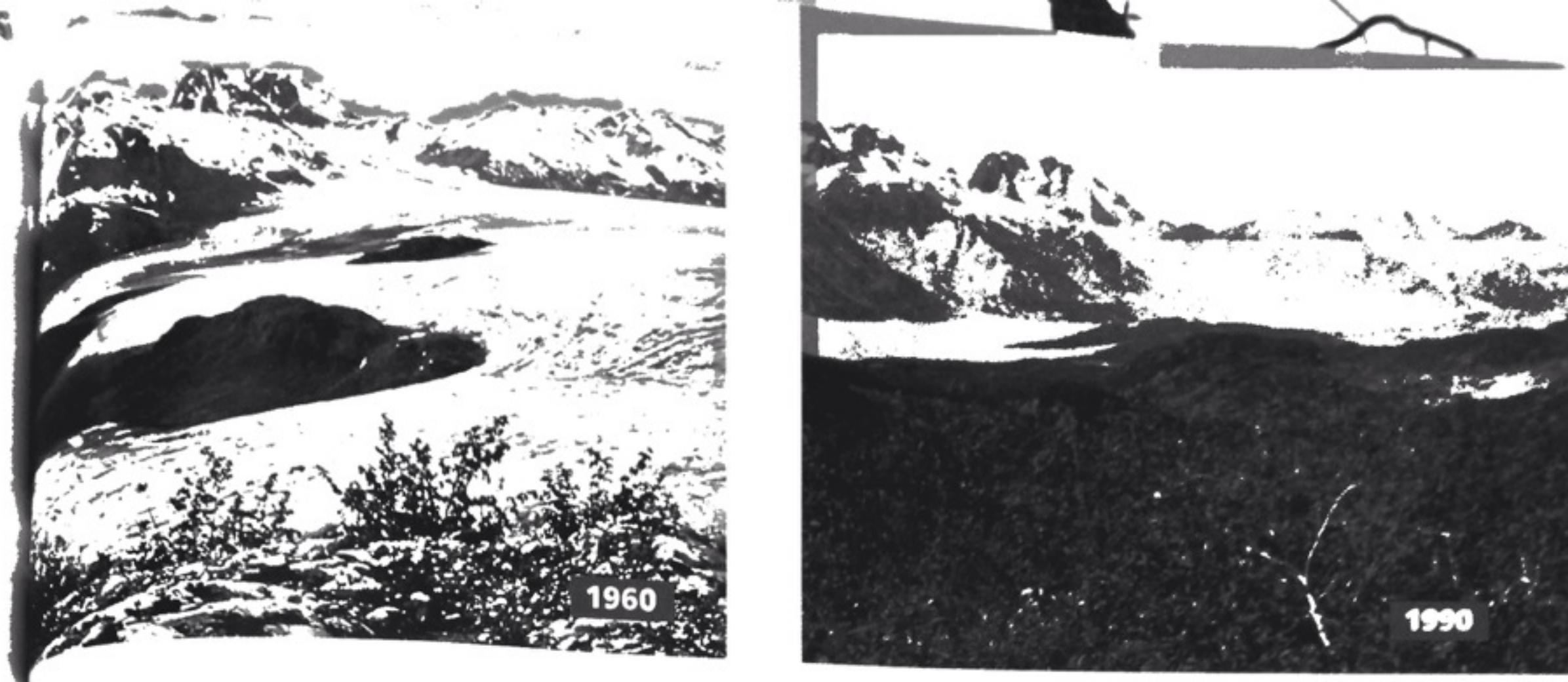



FIGURE 24
**Melting Glaciers**
The photos show the Burroughs glacier in Alaska. The photo on the left was taken in 1960. The photo on the right was taken in1990, and shows the large amount of melting that has taken place.

**Climate Variation Hypothesis** Not all scientists agree about the causes of global warming. Some scientists think that the 0.5 Celsius degree rise in global temperatures over the past 120 years may be part of natural variations in climate rather than a result of increases in carbon dioxide.

Satellite measurements have shown that the amount of energy the sun produces increases and decreases from year to year. These changes in solar energy could be causing periods of warmer and cooler climates. Or climate change could be a result of changes in both carbon dioxide levels and the amount of solar energy.

**Possible Effects** Global warming could have some positive effects. Farmers in some cool areas could plant two crops a year. Places that are too cold for farming today could become farmland. However, many effects of global warming are likely to be less positive. Higher temperatures would cause water to evaporate from exposed soil, such as plowed farmland. Dry soil blows away easily. Thus, some fertile fields might become "dust bowls."

A rise in temperatures of even a few degrees could warm up water in the oceans. Some scientists think warmer ocean water could increase the strength of hurricanes.

As the water warmed, it would expand, raising sea level around the world. The melting of glaciers and polar ice caps could also increase sea level. Sea level has already risen by 10 to 20 centimeters over the last 100 years, and could rise another 25 to 80 centimeters by the year 2100. Even such a small rise in sea level would flood low-lying coastal areas.

**Reading Checkpoint** **What are three possible effects of global warming?**

**Go Online**
PLANET DIARY

**For:** More on the greenhouse effect
**Visit:** PHSchool.com
**Web Code:** cfd-4044