CHAPTER 3

Weather and Climate

You have read about Earth in space and our planet's relationship to the Sun. In this chapter you will learn more about the Sun's energy and its effects on Earth. You will see how that energy affects atmospheric conditions and life on our planet.

Fog gathers over San Francisco Bay, California.

A tornado strikes Pampa, Texas.

Heavy snow blankets New York City.

Section 1

Factors Affecting Climate

READ TO DISCOVER

1. How does the Sun affect Earth's atmosphere?
2. How does atmospheric pressure distribute energy around the globe?
3. How do global wind belts affect weather and climate?
4. How do the oceans affect weather and climate?

Reading Strategy

READING ORGANIZER Draw a circle in the center of a sheet of paper. Label the circle Factors Affecting Climate. Draw four rays from the circle. Then, draw a small circle at the end of each ray. Label the four circles The Sun and Latitude, Atmospheric Pressure, Global Wind Belts, and Oceans and Currents. As you read this section, write information you learn about each factor by its circle. Include key terms and their definitions.

IDENTIFY

Gulf Stream

DEFINE

weather
climate
temperature
greenhouse effect
global warming
cyclones
prevailing winds
doldrums
front

The Sun and Latitude

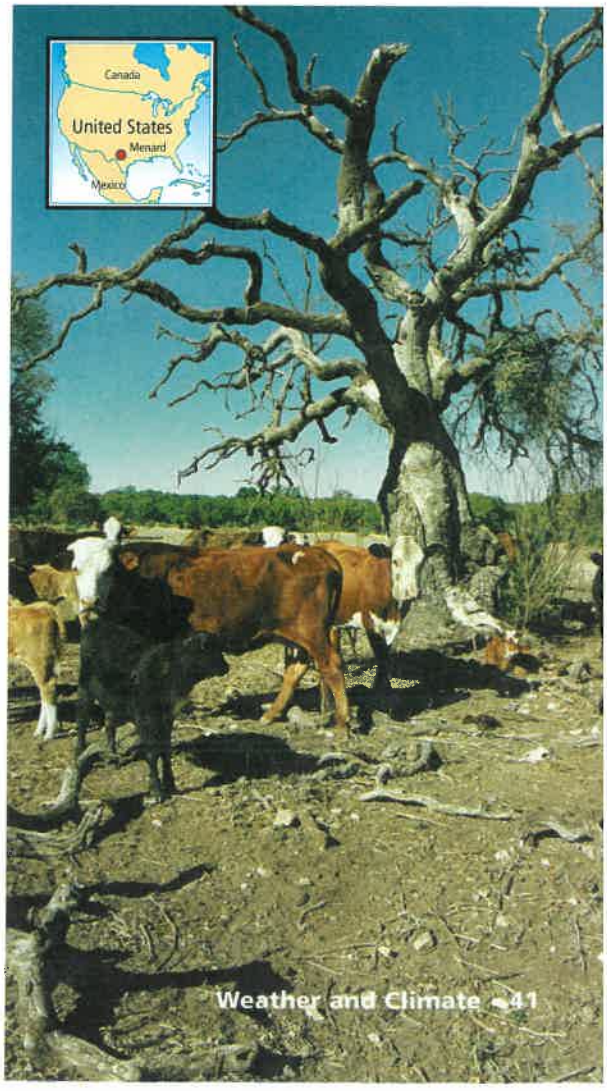
The Sun plays the major role in Earth's **weather** and **climate** patterns. Weather is the condition of the atmosphere at a given time and place. Weather conditions in a geographic region over a long time are called climate. As you read earlier, solar energy heats Earth unevenly. The tilt of Earth as the planet revolves around the Sun is important. It determines which hemisphere receives the Sun's most direct rays at a given time of year. This process causes the changing seasons. Areas in the middle and high latitudes have distinct seasons. On the other hand, tropical locations in lower latitudes receive the most direct rays year-round. Thus, they are warm all year. Polar areas receive the least amount of energy from the Sun and are very cold all year.

What happens to the Sun's energy when it reaches Earth? About half is reflected back into space or absorbed by the atmosphere. Earth's surface absorbs the other half. Once absorbed, solar energy is converted into heat. The measurement of heat is called **temperature**.

Earth's atmosphere traps heat energy in a process called the **greenhouse effect**. Like the clear glass of a greenhouse, the atmosphere allows much sunlight to pass through. Earth's air then slows the rate at which the heat escapes into space. The greenhouse effect helps keep the planet warm.

Evidence seems to show that Earth has gotten warmer in recent decades. Most scientists believe that this process, called **global warming**, is caused by human activities. They point out that burning coal, natural gas, and oil adds carbon dioxide to the lower atmosphere. Because carbon dioxide absorbs heat, increased amounts

INTERPRETING THE VISUAL RECORD *Much of Texas suffered terrible heat and drought during 2000.* ***How might harsh weather affect how people view a region? How might their views differ from those held by people who live elsewhere?***



During the Little Ice Age of the 1500s to 1800s, the average global temperature dropped about 1°C. Ice sheets advanced over Greenland farms, and the Baltic Sea and Thames River froze more often than they do now.

could enhance the greenhouse effect. These scientists urge us to reduce the production of carbon dioxide and other so-called greenhouse gases.

However, some people believe that global warming is part of a natural cycle. They believe the process may not be related entirely to human activities. This difference of opinion can affect public policies on the local, state, national, and international level. For example, citizens may convince a city council to ban gasoline-powered leaf blowers within city limits.

READING CHECK: ***Physical Systems*** How does Earth's atmosphere help keep the planet warm?

Atmospheric Pressure

Earth distributes the Sun's heat through a number of processes. These processes affect climate. Some of these effects occur in the atmosphere. Although you do not notice it, air in our atmosphere has weight. The air around you, extending to the top of the atmosphere, is always pushing on you. This force is called atmospheric pressure or air pressure. If you were climbing a mountain, as you moved higher there would be less air above you pushing down. The force pushing against you—the air pressure—would drop. At very high altitudes the air is too thin for humans to breathe. This is why high-flying aircraft are sealed and pressurized.

Air pressure also changes at different places on Earth's surface. Earth's unequal heating causes most of these changes. For example, when air is heated it expands, becomes less dense, and rises. This creates a low-pressure area. The rising air usually cools as it moves higher in the atmosphere. As the air rises and cools, the water vapor it carries may form clouds. These clouds may bring rain or even storms. For this reason, low pressure usually accompanies unstable weather conditions. All centers of low pressure are called **cyclones**. They can vary in intensity. Some might take the form of slight breezes and cloud cover. Others might become powerful storms with heavy rain and high winds.

These climbers use oxygen tanks as they scale Mount Everest in Nepal. Atmospheric pressure at the top of Mount Everest—at 29,035 feet, or 8,850 meters—is about one third what it is at sea level. Since the atmospheric pressure is so low at this altitude, about two-thirds less oxygen is available in each breath. As a result, climbers must force supplemental oxygen into their lungs.

On the other hand, cold air is dense and sinks toward Earth's surface. This process creates high-pressure areas. As air sinks, it heats and dries. Centers of high pressure usually bring stable, clear, and dry weather. However, they can also bring extreme heat in summer or bitter cold in winter.

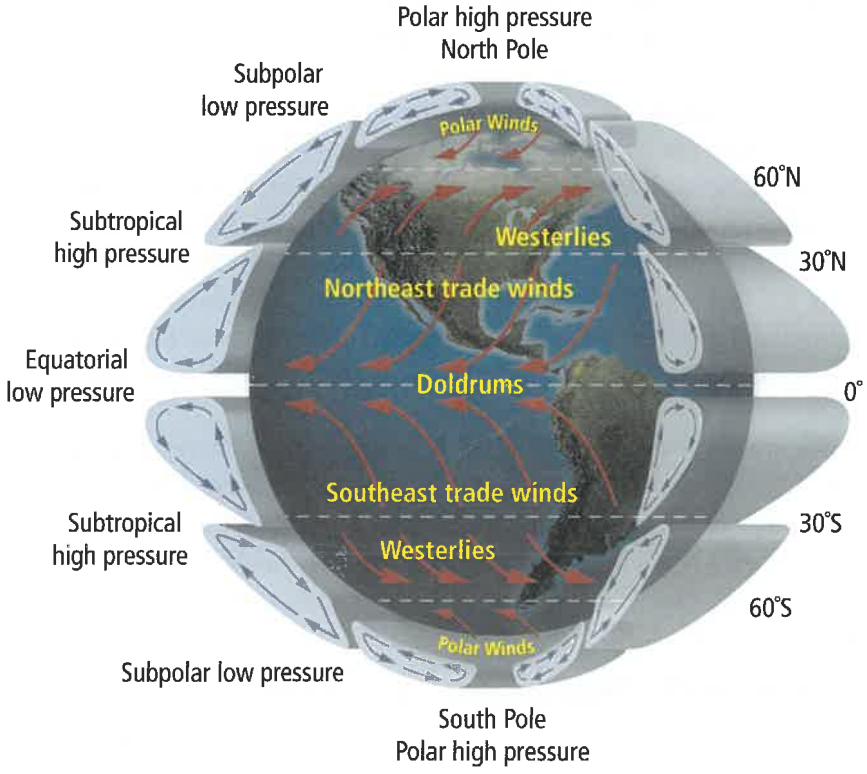
On a global scale there are four major air pressure zones. They are the equatorial low, the subtropical highs, the subpolar lows, and the polar highs. Together they carry air back and forth between the equator and the Poles and between Earth's atmosphere and its surface. How does this work? Along the equator, the direct rays of the Sun cause warm air to rise, forming the equatorial low. This rising air cools in the upper atmosphere and flows toward the Poles. At about 30° latitude the cooled air begins to sink to the surface. This sinking causes the subtropical highs in each hemisphere. At the Poles, dense cold air sinks to the surface, causing the polar highs. The cold air then flows along the surface away from the Poles. At about 60° latitude the cold air forces warmer air flowing toward the Poles higher. This rising air forms the subpolar lows. (See the diagram.)

READING CHECK: ***Physical Systems*** What kind of weather is usually associated with an area of low pressure?

Global Wind Belts

Air pressure affects global wind patterns. Wind is the horizontal flow of air. Wind always flows from high to low pressure areas. For example, when air is released from a tire—an area of high pressure—it flows outward. Air will not flow into the tire unless a high-pressure hose pumps it in.

Pressure and Wind Systems



INTERPRETING THE DIAGRAM

Earth's rotation deflects the trade winds. Otherwise, they would flow more directly north or south. ***How do you think the trade winds affected exploration by European sailors?***

A warm front heading northwest from the Gulf of Mexico brings rain to the plains of southern New Mexico. Cold fronts can lower the temperature rapidly—as much as 15°F within an hour.

Winds move heat and cold across the Earth's surface. This movement helps maintain a global energy balance. Some areas of the world have winds that blow from the same direction most of the time. These winds are known as **prevailing winds**. For example, the trade winds blow from the northeast and southeast toward the equator. They flow from the subtropical highs toward the equatorial low. These winds are so named because trading ships once used them to sail across the ocean.

Not all areas of the world lie in prevailing wind belts. The zone along the equator is calm, with no prevailing winds. This area is sometimes called the **doldrums**. Because the area has little wind, sailing ships could be caught there for long periods of time.

In the middle latitudes the prevailing winds are called westerlies. These winds flow generally from the west, from the subtropical highs toward the subpolar lows. Most of the contiguous United States is located in the westerlies. These winds carry most weather patterns and storms across the United States from west to east.

In the high latitudes the winds are more variable but come mainly from the east. These areas are subject to the cold polar easterlies. These strong winds blow from Arctic and Antarctic areas into the middle latitudes. In the United States, only Alaska is far enough north to be within this polar wind belt.

A **front** occurs when two air masses of widely different temperatures or moisture levels meet. Precipitation often occurs along these fronts. The warm westerlies meet the cold polar winds between about 40° and 60° latitude. This shifting zone where the cold and warm air masses meet is called the polar front.

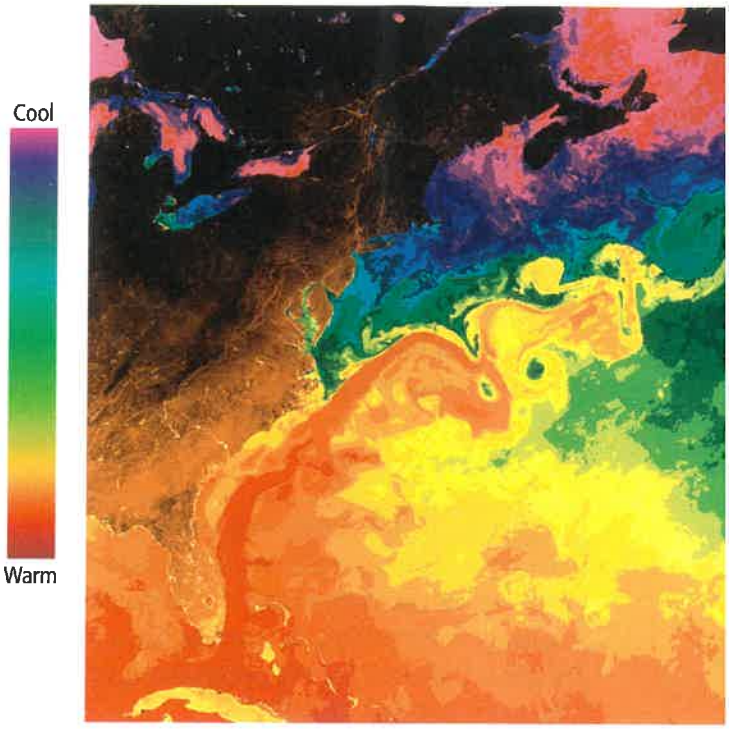
There are also prevailing winds in the upper atmosphere, miles above the ground. The fastest of these high-speed westerly winds are called the jet streams. Wind speeds within jet streams can reach more than 300 miles (480 km) per hour. Usually there are two or three jet streams flowing in each hemisphere. Although we do not feel them directly, the jet streams move heat and steer major weather patterns.

READING CHECK: ***Physical Systems*** How is wind direction related to differences of air pressure?

Oceans and Currents

Oceans also affect climate. Water heats and cools more slowly than land. Thus, land areas near oceans do not have such great temperature ranges as areas in the interior of continents. For example, Kansas City, Missouri, and San Francisco, California, are both located near the same latitude. However, Kansas City's winters are much colder and summers much warmer than those in San Francisco. This is because San Francisco lies on the Pacific coast. Kansas City is much farther from the ocean's moderating effects on temperatures.

Great rivers of seawater, called currents, are also important to climate. (See the map of world climate regions in Section 3.) Earth's winds and rotation as well as varying ocean temperatures create these ocean currents. The currents generally flow in circular paths. They move clockwise in the Northern Hemisphere and counterclockwise in the Southern Hemisphere.



This infrared satellite image shows the Gulf Stream moving warm water from lower latitudes to higher latitudes. The dark red shape alongside Florida's east coast is the Gulf Stream.

Ocean currents move heat back and forth between the tropics and the polar regions. This movement helps maintain Earth's energy balance. Warm currents carry heated water from the tropics toward the cooler middle latitudes. The northward-flowing **Gulf Stream**, along the U.S. East Coast, is a good example of a warm current. Cool currents return cooled water from the middle and high latitudes toward the equator where it becomes warmer again. The southward-flowing California Current off the West Coast is a cool current. Cold ocean currents cool nearby land areas. Warm ocean currents make nearby land areas warmer. For example, consider the British Isles, which lie in high latitudes. You might expect to find cold climates there. However, a warm ocean current moderates the islands' climate.

READING CHECK: ***Physical Systems*** What are the main forces that create the ocean currents?

Section 1 Review

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Keyword: SW3 HP3

Identify Gulf Stream

Define weather, climate, temperature, greenhouse effect, global warming, cyclones, prevailing winds, doldrums, front

Reading for the Main Idea

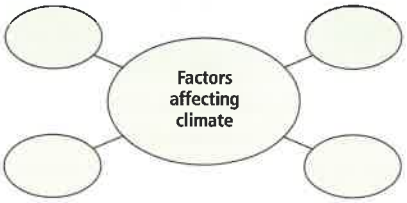
1. ***Physical Systems*** How do air pressure, global wind belts, and ocean currents affect Earth's energy balance?
2. ***Physical Systems*** How is air pressure affected when an area of Earth is heated?
3. ***Places and Regions*** Why are temperature ranges greater for places in the interior of continents than they are for places near oceans?

Critical Thinking

4. **Comparing** How do views on the causes of global warming differ among scientists and other people? Why is the issue important?

Organizing What You Know

5. Copy the word web shown below. Use it to identify major factors affecting climate discussed in this section.



Section 2

Weather Factors

READ TO DISCOVER

1. What are the common forms of precipitation, and how are they formed?
2. How do mountains and elevation affect weather and climate?
3. What are the different types of storms, and how do they form?

DEFINE

evaporation
humidity
condensation
orographic effect
rain shadow
tornadoes
hurricanes
typhoons

Reading Strategy

TAKING NOTES Taking notes while you read will help you understand and remember the information in this section. Your notes will be useful for reviewing the material. Write down the headings in the section. As you read, fill in notes under each heading. Underline the most important details you find. Include key terms and their definitions.

Precipitation

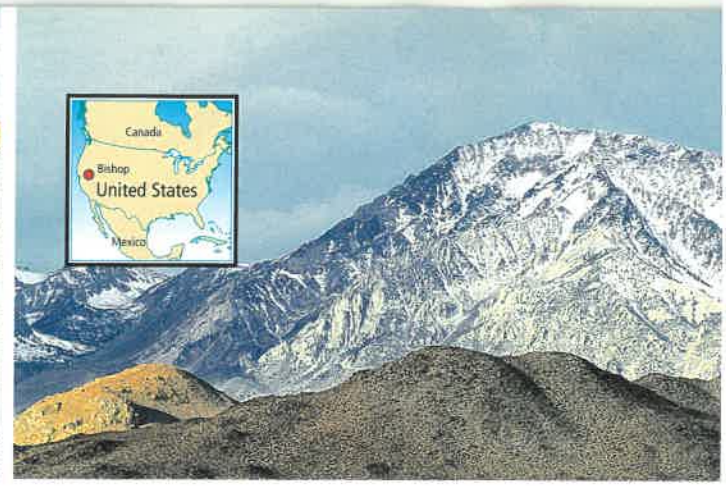
Water vapor plays an important role in many atmospheric processes. Without it, there would be no clouds, rain, or storms. The process by which water changes from a liquid to a gas is **evaporation.** Most water vapor that becomes rain is evaporated from the oceans. Some also evaporates from lakes, rivers, soils, and vegetation.

The amount of water vapor in the air is called **humidity**. The higher the temperature, the more water vapor the air can hold. When air cools, it will reach a temperature at which it cannot hold any more water vapor. At this point, **condensation** occurs. Condensation is the process by which water vapor changes from a gas into liquid droplets. Often you see condensation as clouds, dew, fog, or frost. If the condensed water droplets become large enough, they will fall as precipitation. There are four common forms of precipitation: rain, snow, sleet, and hail. Rain is, of course, a liquid. Snow is made up of generally six-sided ice crystals formed in the clouds. Sleet is rain that freezes as it falls. Hailstones are chunks of ice that form in storm clouds.

Precipitation is not evenly distributed around the world. It is generally highest in the persistent low-pressure zones. These zones are the equatorial low and the subpolar lows in the middle latitudes. Precipitation is generally lowest in the high-pressure zones. Those zones are the subtropical highs and the polar highs. Of course, precipitation also varies from season to season and from year to year in any given place.

READING CHECK: ***Physical Systems*** What are the four common forms of precipitation?

High humidity contributes to this Virginia gardener's discomfort. Perspiration evaporates very slowly when the air has a high water vapor content.



Elevation and Mountain Effects

High elevation affects weather and climate. An increase in elevation—height on Earth's surface above sea level—causes a drop in temperature. The temperature drops 3.5°F per 1,000 feet of elevation (1°C/100 m). Thus, it may be warm at the base of a mountain while the summit is covered with snow or glaciers.

Mountains influence climates through the **orographic effect**. This effect occurs when moist air pushes against a mountain. The barrier forces the air to rise. The rising air cools and condenses, forming clouds and causing precipitation. As a result, the side of the mountain facing the wind receives a great deal of moisture. This side is known as the windward side. The side of the mountain facing away from the wind is the leeward side. As the air moves down the leeward side, it warms and dries. This drier area is called a **rain shadow**. Deserts are often located in rain shadows.

READING CHECK: ***Physical Systems*** How do high elevations and mountains influence weather and climate?

INTERPRETING THE VISUAL RECORD

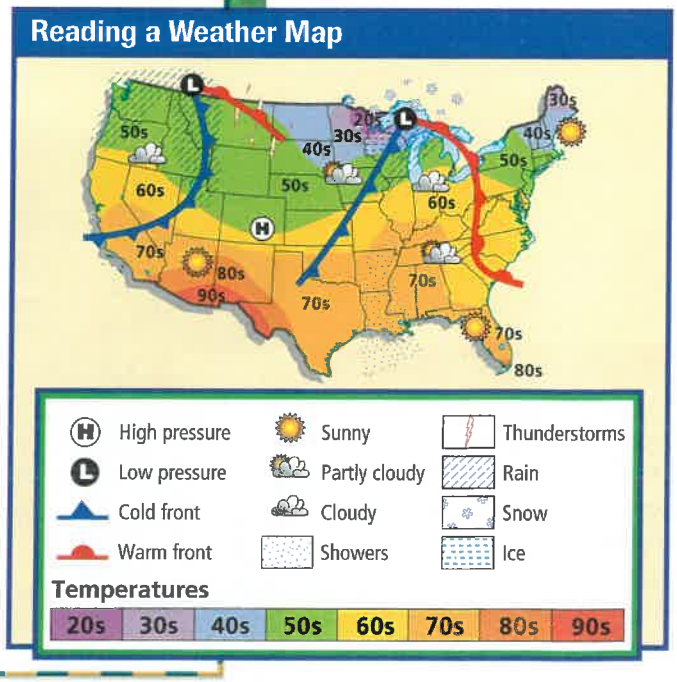
Pictured on the left are mountains in the western part of the Sierra Nevada, in Sequoia National Park. At the right is part of the eastern slope of the same range, near Bishop, California. ***How does the vegetation of these places differ? What accounts for the difference?***

Skill-Building Activity

Reading a Weather Map

You have probably seen weather maps like this one on television or in the newspaper. Weather maps show atmospheric conditions either as they currently exist or as they are predicted to be in the future. Most weather maps have legends that explain what the colors and symbols on the map mean. The map on this page shows two cold fronts sweeping through the United States. Low-pressure systems are at the center of storms bringing rain and snow to the Northwest and upper Midwest. Notice that temperatures behind the cold front are significantly cooler than temperatures ahead of the front.

Analyzing Maps What forms of precipitation does this map show?



In the United States, lightning strikes the ground an estimated 30 million times a year. In an average year lightning kills more Americans than do tornadoes or hurricanes.

Storms

Storms are sudden and violent weather events. They can cause high winds, flooding, blowing snow, lightning, and turbulent seas. As a result, they can be extremely dangerous to human life and property. They also cause major problems for transportation.

Some very low-pressure cyclones that have rising unstable air become very large storms. They usually move from west to east in the middle latitudes, pushed by the jet stream flow. They are known as middle-latitude storms or extratropical cyclones. They can be huge, up to 1,000 miles (1,600 km) in diameter. These storms can travel across an entire continent or ocean. Most middle-latitude storms occur along a polar front. They form when cold dry polar air mixes with moist warm air from the tropics.

Middle-latitude storms may produce thunderstorms and **tornadoes**. These twisting spirals of air affect fairly small areas, but they can destroy almost anything in their path. The United States experiences more tornadoes than any other country.

Storms in the tropics differ from middle-latitude storms. Tropical cyclones are usually much smaller. Because there is no cold air present, they lack fronts. Also, they mainly travel westward, pushed by the trade winds. **Hurricanes** are the most powerful and destructive tropical cyclones. These rotating storms can bring heavy rain and winds higher than 155 miles per hour (249 kph). They begin over warm tropical seas. Those that strike the United States usually form in the tropical Atlantic Ocean. They become stronger as they move westward.

Hurricanes, which are called **typhoons** in the western Pacific Ocean, can create dangerously high waves. They may also produce thunderstorms and tornadoes. High seas brought by the storms can erode and destroy beaches and coastal areas. Sometimes large stretches of beach are swept away. Flooding can threaten people, property, and plant and animal life. Fortunately, hurricanes weaken as they move inland.

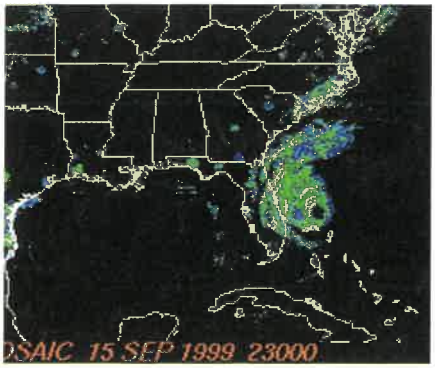
READING CHECK: ***Physical Systems*** What are examples of very violent middle-latitude and tropical storms?

INTERPRETING THE VISUAL RECORD

Hondurans look at a bridge destroyed during Hurricane Mitch in 1998. Hurricane Mitch has been labeled the deadliest Atlantic storm in two centuries. It caused massive damage throughout much of Central America and killed more than 9,000 people. ***How might continued rainfall affect the place in the photo?***

Visible light image

Radar image



Infrared image

Hurricane Floyd, pictured above in three types of images, battered the eastern United States in mid-September 1999.

FOCUS ON SCIENCE, TECHNOLOGY, AND SOCIETY

Weather Satellites At one time, hurricanes could strike coastal areas with little warning. For example, in 1900 a hurricane caught residents of Galveston, Texas, unprepared. The storm killed thousands of people. Today satellites orbiting Earth help weather forecasters track the development of storms and save lives.

Weather satellites carry instruments that collect information about the Earth's surface and atmosphere. For example, they carry special cameras that make use of both visible light and invisible infrared light. Infrared sensors detect heat given off by clouds, land, and water. Radar can also be used to gather atmospheric data. With the information from these instruments, scientists can predict the path of a hurricane. They can also identify areas that may flood. People who live in affected areas can then leave before conditions worsen.

As technology improves, scientists can gather data on storms earlier in their development. Two satellites now use microwaves to peer through heavy clouds. They gather information on young hurricanes while the storms are still far out at sea. One of the satellites measures the sea's roughness. The other measures the rainfall in a given area.

For centuries, people looked to the skies for information about the weather. Now, scientists can use satellites to look down on Earth from above.

READING CHECK: *Physical Systems* How do weather satellites help people live safely in places affected by hurricanes?

Section 2 Review

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Keyword: SW3 HP3

Define

evaporation
humidity
condensation
orographic effect
rain shadow
tornadoes
hurricanes
typhoons

Reading for the Main Idea

1. *Physical Systems* How is temperature change related to condensation and precipitation?
2. *Physical Systems* What determines the direction of storm movement?

Critical Thinking

3. **Contrasting** How do storms in the tropics differ from storms in the middle latitudes?
4. **Analyzing Information** In what places near the equator might you expect to see snow and ice all year? Why?

Organizing What You Know

5. Using the weather map in the chapter as a guide, create a sketch map of the United States showing imaginary weather events. Use the standard weather map symbols. Then write a short description of the weather patterns you have displayed.

Section 3

Climate and Vegetation Patterns

READ TO DISCOVER

1. How do the two tropical climates differ?
2. What conditions are common in dry climates?
3. What climates are found in the middle latitudes?
4. What characterizes high-latitude and highland climates?

DEFINE

ecosystems
monsoon
savannas
arid
deciduous forests
coniferous forests
permafrost

Reading Strategy

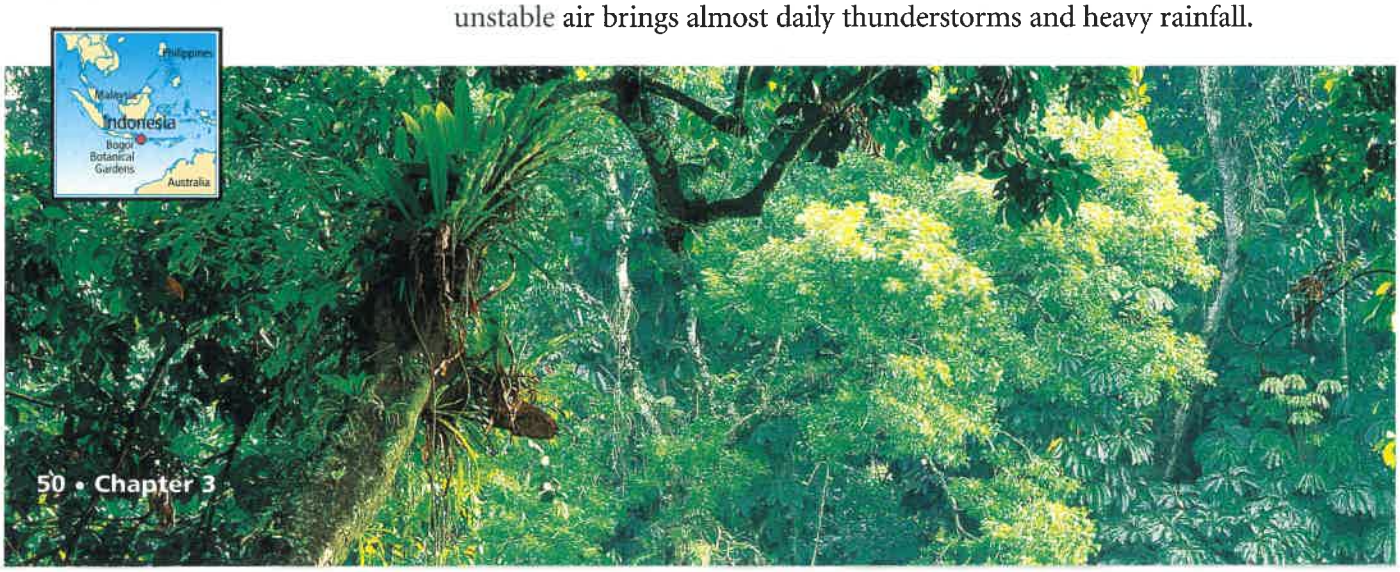
USING PRIOR KNOWLEDGE Use the headings to guide you in writing down what you know about weather and climate. Then write down what you want to know. After you read the section, write down what you learned.

Tropical Climates

All of the world's climates support a variety of **ecosystems**. An ecosystem is the community of plants and animals in an area. It also includes the nonliving parts of their environment, such as soil and climate. (See Geography for Life: World Ecosystems and Biomes in the next chapter.)

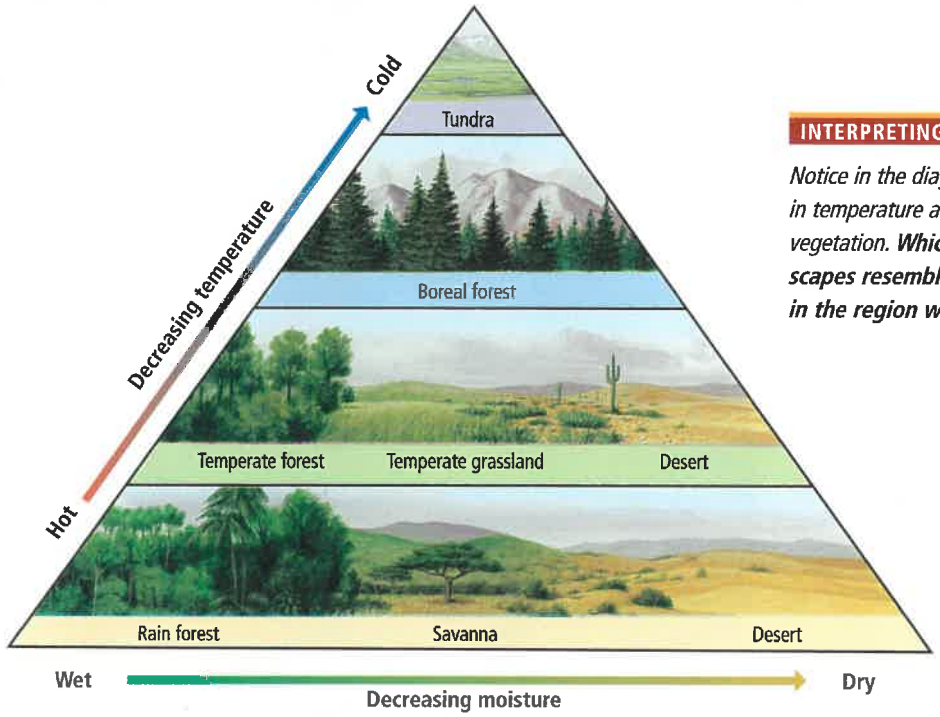
Among the world's most diverse ecosystems are those found in tropical climate regions. We will begin our discussion of world climate and vegetation patterns there. You can follow our discussion by studying the map and chart of world climate regions.

Western Java, in Indonesia, has a tropical humid climate. This scene is from the Bogor Botanical Gardens. Some tropical plants, like the one growing on the tree trunk, need no more moisture than what is in the warm humid air.



Tropical Humid Climate The tropical humid climate region is found in areas close to the equator. Those regions generally have warm temperatures and plentiful rainfall all year. They never have truly cold weather. Because the equator receives the Sun's direct rays all year, the area is always warm. As a result, warm air is always rising in the tropics. This continuous rising of warm unstable air brings almost daily thunderstorms and heavy rainfall.

Climate and Vegetation



INTERPRETING THE DIAGRAM

Notice in the diagram how changes in temperature and moisture affect vegetation. ***Which of these landscapes resemble natural areas in the region where you live?***

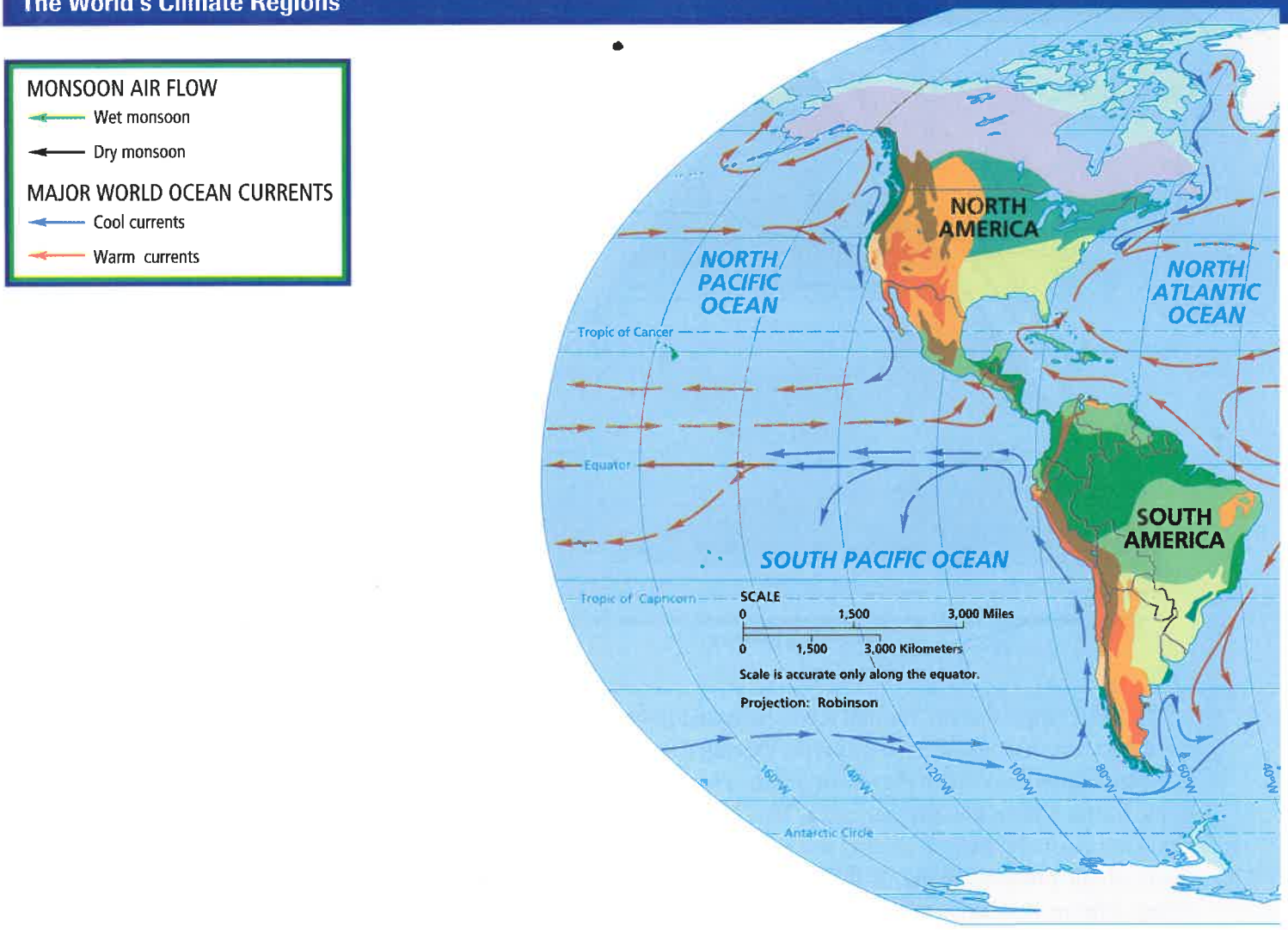
In some tropical areas, rainfall is concentrated in one wet season. India and Southeast Asia have seasons of this type. During the summer months moist air flows into these areas from the warm ocean, a high-pressure area. The air flows to the hotter land, a low-pressure area. This air flow brings heavy rains to areas along the coast and inland. During the winter, dry air flows off the cooling continent (high-pressure areas). It flows toward the warm oceans (low-pressure areas). The air flow causes dry conditions on the continent. This wind system, in which winds completely reverse direction and cause seasons of wet and dry weather, is called the **monsoon**.

Warm temperatures and heavy rainfall create ideal conditions for plant growth. Thus, dense tropical rain forests thrive in tropical humid areas. These forests are the most complex land ecosystems in the world. Thousands of kinds of plants and animals live there.

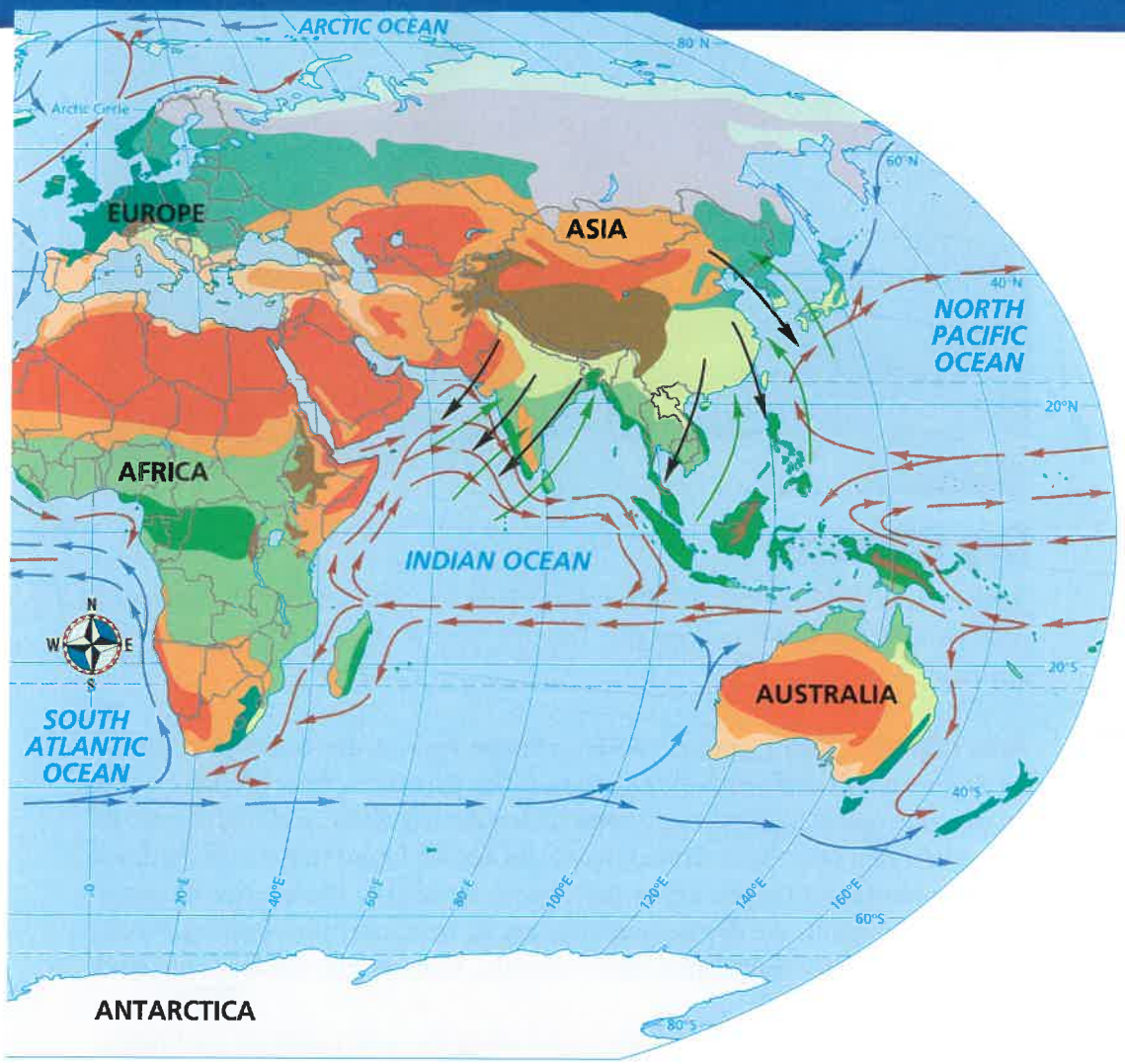
Tropical Wet and Dry Climate Just to the north and south of the tropical humid climate is the tropical wet and dry climate. It is sometimes called the tropical savanna climate. This climate results from the seasonal change in the way the Sun's rays strike areas just north and south of the equator. During summer in these areas, the Sun's rays strike most directly. As a result, temperatures rise, creating low pressure and unstable, rising air. This, in turn, leads to heavy rainfall. During the winter the Sun's direct rays move to the opposite hemisphere. High pressure replaces low pressure. The high pressure system brings stable, cool, sinking air and a dry season. This alternating pattern of wet and dry seasons supports **savannas**. Savannas are areas of tropical grasslands, scattered trees, and shrubs.

READING CHECK: ***Physical Systems*** How does the tropical wet and dry climate differ from the tropical humid climate?

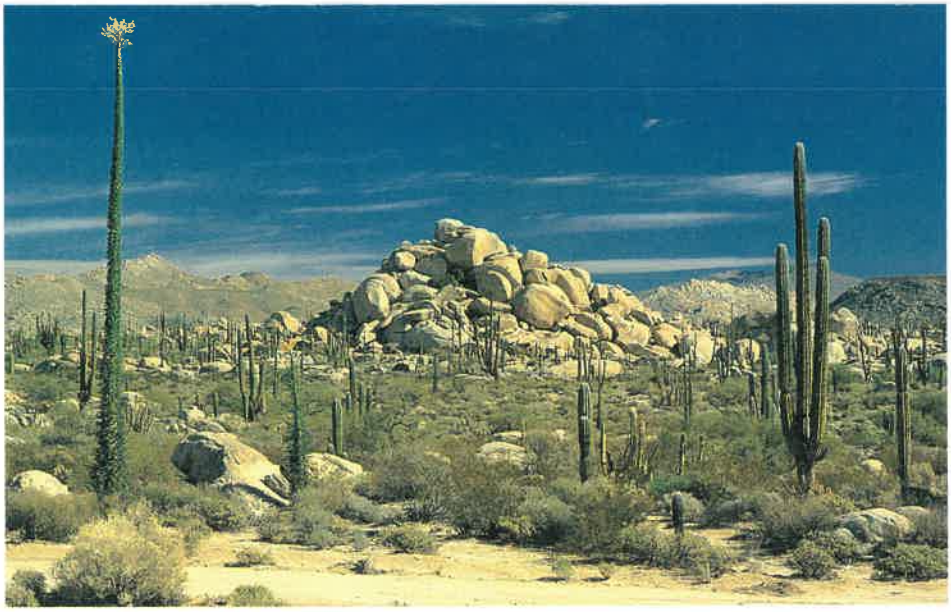
The World's Climate Regions



	Climate	Geographic Distribution	Major Weather Patterns	Vegetation
Tropical	TROPICAL HUMID	along equator; particularly equatorial South America, Congo Basin in Africa, Southeast Asia	warm and rainy year-round, with rain totaling anywhere from 65 to more than 450 in. (165–1,143 cm) annually; typical temperatures are 90°–95°F (32°–35°C) during the day and 65°–70°F (18°–21°C) at night	tropical rain forest
Tropical	TROPICAL WET AND DRY	between humid tropics and deserts; tropical regions of Africa, South and Central America, South and Southeast Asia, Australia	warm all year; distinct rainy and dry seasons; precipitation during the summer of at least 20 in. (51 cm); monsoon influences in some areas, such as South and Southeast Asia; summer temperatures average 90°F (32°C) during the day and 70°F (21°C) at night; typical winter temperatures are 75°–80°F (24°–27°C) during the day and 55°–60°F (13°–16°C) at night	tropical grassland with scattered trees
Dry	ARID	centered along 30° latitude; some middle-latitude deserts in interior of large continents and along western coasts; particularly Saharan Africa, Southwest Asia, central and western Australia, southwestern North America	arid; precipitation of less than 10 in. (25 cm) annually; sunny and hot in the tropics and sunny with great temperature ranges in middle latitudes; typical summer temperatures for lower-latitude deserts are 110°–115°F (43°–46°C) during the day and 60°–65°F (16°–18°C) at night, while winter temperatures average 80°F (27°C) during the day and 45°F (7°C) at night; in middle latitudes the hottest month averages 70°F (21°C)	sparse drought-resistant plants; many barren, rocky, or sandy areas
Dry	SEMIARID	generally bordering deserts and interiors of large continents; particularly northern and southern Africa, interior western North America, central and interior Asia and Australia, southern South America	semiarid; about 10–20 in. (25–51 cm) of precipitation annually; hot summers and cooler winters with wide temperature ranges similar to desert temperatures	grassland; few trees
Middle Latitudes	MEDITERRANEAN	west coasts in middle latitudes near cool ocean currents; particularly southern Europe, part of Southwest Asia, northwestern Africa, California, southwestern Australia, central Chile, south-western South Africa	dry sunny warm summers and mild wetter winters; precipitation averages 14–35 in. (35–90 cm) annually; typical temperatures are 75°–80°F (24–27°C) on summer days; the average winter temperature is 50°F (10°C)	scrub woodland and grassland
Middle Latitudes	HUMID SUBTROPICAL	east coasts in middle latitudes; particularly southeastern United States, eastern Asia, central southern Europe, southeastern parts of South America, South Africa, and Australia	hot humid summers and mild humid winters; precipitation year-round; coastal areas are in the paths of hurricanes and typhoons; precipitation averages 40 in. (102 cm) annually; typical temperatures are 75°–90°F (24°–32°C) in summer and 45°–50°F (7°–10°C) in winter	mixed forest



	Climate	Geographic Distribution	Major Weather Patterns	Vegetation
Middle Latitudes	MARINE WEST COAST	west coasts in upper-middle latitudes; particularly northwestern Europe and North America, southwestern South America, central southern South Africa, southeastern Australia, New Zealand	cloudy mild summers and cool rainy winters; strong ocean influence; precipitation averages 20–98 in. (51–250 cm) annually; westerlies bring storms, rain; average temperature in hottest month is usually between 60°F and 70°F (16°–21°C); average temperature in coolest month usually is above 32°F (0°C)	temperate evergreen forest
	HUMID CONTINENTAL	east coasts and interiors of upper-middle-latitude continents; particularly northeastern North America, northern and eastern Europe, northeastern Asia	four distinct seasons; long cold winters and short warm summers; precipitation amounts vary, usually 20–50 in. (51–127 cm) or more annually; average summer temperature is 75°F (24°C); average winter temperature is below freezing	mixed forest
High Latitudes	SUBARCTIC	higher latitudes of interior and east coasts of continents; particularly northern parts of North America, Europe, and Asia	extremes of temperature; long cold winters and short mild summers; low precipitation amounts all year; precipitation averages 5–15 in. (13–38 cm) in summer; temperatures in warmest month average 60°F (16°C) but can warm to 77°F (25°C); winter temperatures average below 0°F (–18°C)	northern evergreen forest
	TUNDRA	high-latitude coasts; particularly far northern parts of North America, Europe, and Asia, Antarctic Peninsula, subantarctic islands	cold all year; very long cold winters and very short cool summers; low precipitation amounts; precipitation average is 5–15 in. (13–38 cm) annually; warmest month averages less than 50°F (10°C); coolest month averages a little below 0°F (–18°C)	moss, lichens, low shrubs; permafrost bogs in summer
	ICE CAP	polar regions; particularly Antarctica, Greenland, Arctic Basin islands	freezing cold; snow and ice year-round; precipitation averages less than 10 in. (25 cm) annually; average temperatures in warmest month do not reach higher than freezing	no vegetation
	HIGHLAND	high mountain regions, particularly western parts of North and South America, eastern parts of Asia and Africa, southern and central Europe and Asia	greatly varied temperatures and precipitation amounts over short distances as elevation changes; prevailing wind patterns can affect rainfall on windward and leeward sides of highland areas	forest to tundra vegetation, depending on elevation



A boojum tree, at left, and saguaro cactus, at right, grow in the desert of Baja California, Mexico. Both of these unusual plants are well adapted to the desert's heat and lack of moisture. The boojum drops its leaves to save water, and the saguaro stores water in its fleshy trunk. Hurricanes sometimes sweep from the Pacific Ocean across Baja California. Then desert plants burst into bloom.

Dry Climates

Arid means "dry." All dry climate regions have low annual rainfall. However, their temperatures may vary greatly. The two types of dry climates are arid and semiarid.

Arid Climate Most arid, or desert, climate regions are centered at about 30 degrees north and south of the equator. The dryness in these areas is caused by the subtropical high-pressure zone. This zone has stable, sinking, dry air all year. Little rain falls there. Arid climates can also be found in the rain shadows of some mountain ranges. Other dry regions lie deep in the interior of continents. Such regions are dry because they are far from moisture-bearing winds. These areas experience temperature extremes. Winters may be very cold, and summers are very hot.

Small dry areas are sometimes found along the west coasts of continents. They lie where cool ocean currents create highly stable atmospheric conditions. Dry coastal deserts of this type are found along the west coasts of Australia, Mexico, South America, and southwestern Africa.

Plants and animals in these dry regions must be hardy. Most desert plants are small, and they may only sprout and flower after a rare rainfall. Soils tend to be thin and rocky.

Semiarid Climate The semiarid climate is a transition zone between the arid climate and the more humid climates. Semiarid climates receive more moisture than the deserts but less than the more humid areas. Where rainfall is heavy enough, grasses make up much of the plant life. Humans use many of these areas for growing grain. In the drier areas, plant life is more limited.

✓ **READING CHECK:** ***Physical Systems*** What are four factors that can create dry climates?

Middle-Latitude Climates

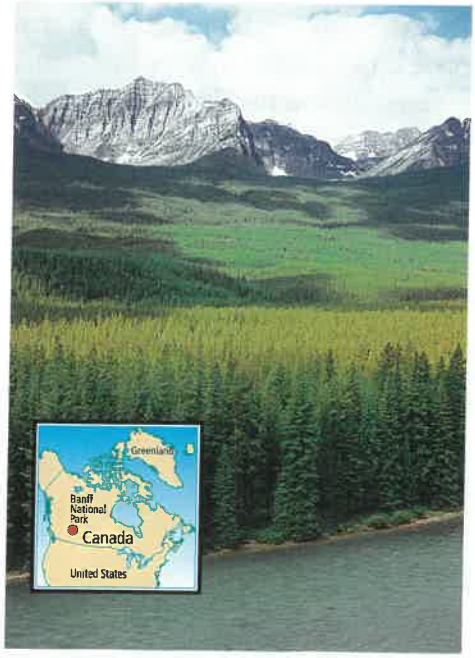
Several types of climates are found in the middle latitudes. These are generally temperate climates. For the most part, they do not experience the extreme conditions found in tropical and high-latitude climates.

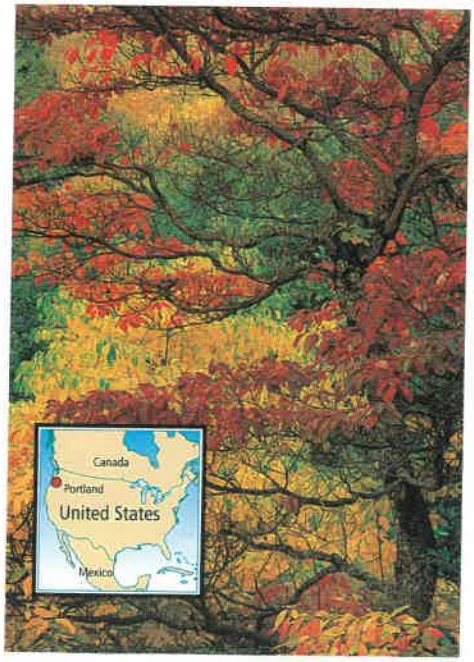
Mediterranean Climate The Mediterranean climate exists mainly in two kinds of areas. One is along coastal areas of southern Europe. The other is along west coasts of continents with cool ocean currents. Mediterranean climates do not usually extend far beyond inland mountain ranges. The stable sinking air of the subtropical high-pressure zone causes long, sunny, dry summers. During the mild winter, however, cool middle-latitude storms bring rain. The natural plant life of this climate is the Mediterranean scrub woodland. It includes short trees and shrubs with a few scattered large trees.

Like many other areas in southern Europe, Greece has a Mediterranean climate. This photo was taken on the island of Corfu.

Humid Subtropical Climate The humid subtropical climate is much more widespread than the Mediterranean climate. It is found on the eastern side of continents where there are warm ocean currents. The moist air flowing off the warm ocean waters greatly affects this climate area. Summers are hot and humid. Winters are mild, with occasional frost and some snow. Hurricanes or typhoons can be a danger here. The natural plant life of humid subtropical and other middle-latitude regions includes temperate forests. These forests can be divided into two main types. One type is **deciduous forests**. Trees there lose their leaves during part of the year. The other type is **coniferous forests**. Trees in those forests remain green all year.

Marine West Coast Climate The marine west coast climate is heavily influenced by oceans. This climate is generally found on the west coasts of continents in the upper middle latitudes. Temperatures in these areas are mild all year. Storms traveling across the oceans in the westerlies bring most of the rainfall. Winters are foggy, cloudy, and rainy. However, summers can be warm and sunny. This climate is widespread in northwestern Europe. Lowlands along the coast there allow cool moist ocean air to spread far inland. In some places, the rainy weather of this climate supports dense coniferous forests. These areas are called temperate rain forests.





Left: A coniferous forest grows in Banff National Park in the Canadian Rocky Mountains. Right: Deciduous trees in Portland, Oregon, change color in the fall before losing their leaves.

Humid Continental Climate The humid continental climate is found in the interiors and east coasts of upper-middle latitude continents. Invasions of both warm and cold air regularly affect these areas. The humid continental climate has the most changeable weather conditions. In fact, it experiences four distinct seasons. Because this climate type is situated along the polar front, storms bring rain throughout much of the year. Snow falls in winter. Precipitation is heavy enough to support forests.

✓ **READING CHECK:** ***Physical Systems*** In areas with a Mediterranean climate, which season brings most of the rainfall?

High-Latitude and Highland Climates

There are three main types of high-latitude climates. They are subarctic, tundra, and ice cap climates.

Subarctic Climate The subarctic climate is located generally above 50° north latitude. However, a warm ocean current moderates the climate in areas above this latitude in northern Europe. The subarctic climate has long cold winters. Temperatures stay well below freezing for half of the year. The short summers can be warm, however. This climate also has the greatest annual temperature ranges in the world. Although severe, the climate supports vast evergreen forests. These northern forests are also called boreal forests.

The subarctic climate region is very large. It stretches across far northern North America, Europe, and Asia. In the Southern Hemisphere there is practically no land at these latitudes.

Tundra Climate Coastal areas in high latitudes have a tundra climate. These areas also have long winters. Temperatures are above freezing only during the short summers. In some places, water and soil below the ground's surface remain frozen throughout the year. The permanently frozen soil is called **permafrost**. During summer the permafrost makes it difficult for water from melting snow to seep into the ground. As a result, swamps and bogs form on the surface.

The tundra climate takes its name from the only kinds of vegetation that can survive there. Tundra vegetation is made up of lichens, mosses, herbs, and low shrubs. Trees cannot grow there. However, during the short summer the area bursts into flower.

INTERPRETING THE VISUAL RECORD

Tundra vegetation grows near Hudson Bay, Canada. ***Why might growing low to the ground be an advantage for these plants?***

Guanaco feed on the plains of Torres del Paine National Park, Chile. Behind them rise the Andes. This long South American mountain range contains a variety of climates.

Ice Cap Climate Ice cap climates are found in Earth's polar regions. Those areas are always covered by huge flat masses of ice and snow. Most parts of Antarctica and Greenland are covered by ice caps. Few land plants and animals can survive in these climates. Hardy plant life may grow on exposed rocks. In contrast, the cold seas of the ice cap regions have rich marine ecosystems. Many birds, fish, and marine mammals live there. For example, seals and some whales feed on the fish of the Arctic Ocean. Polar bears feed on the seals.

Highland Climate Highland areas can have varying climates. This is partly because temperatures change with elevation. In addition, prevailing wind patterns can affect rainfall on windward and leeward sides of highland areas.

The lowest elevations of a mountain generally have a climate and vegetation similar to that of the surrounding area. Higher up the mountain, temperatures and air pressure are lower. The cooler temperatures limit the kinds of plants that can grow. No trees can grow above a certain level called the tree line. Climate conditions at the highest elevations are similar to those of the ice cap climate. Ice and snow are always present, and plant and animal life is scarce. Some mountains in the tropics have snow all year. For example, Africa's snowcapped Kilimanjaro lies only about 200 miles (322 km) south of the equator.

✓ **READING CHECK:** *Physical Systems* Which of the polar climates supports large forests?

Review

go.hrw.com **Homework Practice Online**
Keyword: SW3 HP3

Define

ecosystems, monsoon, savannas, arid, deciduous forests, coniferous forests, permafrost

Reading for the Main Idea

1. *Physical Systems* Why are there wet and dry seasons in some tropical areas?
2. *Places and Regions* What kinds of precipitation levels and temperatures would you expect in arid climates?

Critical Thinking

3. **Drawing Inferences and Conclusions** Why do you think Mediterranean climates do not extend far inland past mountain ranges?
4. **Comparing** How do conditions on high mountaintops within highland climate regions resemble the ice cap climate?

Organizing What You Know

5. Create a graphic organizer like the one below. Add as many rows as you need to describe the vegetation that is typical in each of Earth's climate types.

Climate type	Vegetation

CASE STUDY

The Poles

Environment and Society Earth's axis intersects its surface at the North and South Poles. The Poles are the same distance from the equator, and both have ice cap climates. However, the Poles also have varying geographic features. They and their surrounding regions offer unique opportunities for expanding human knowledge about our world.

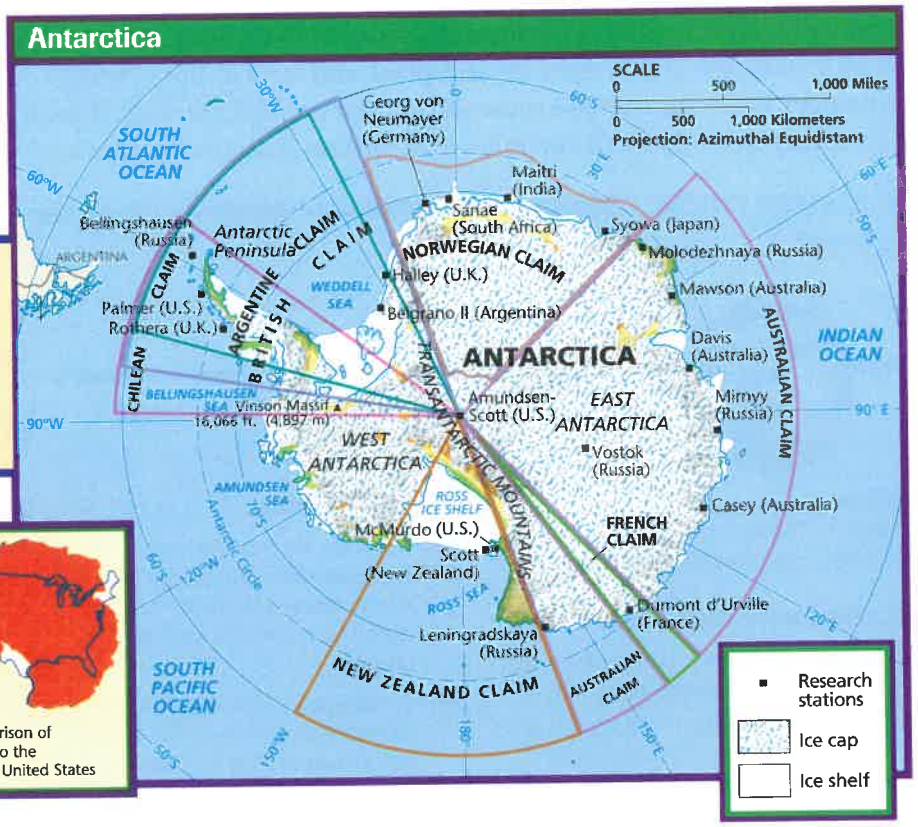
A Frozen Land

The South Pole is in the heart of Antarctica—a continent buried under snow and ice. It is the coldest, driest, windiest, and most isolated continent on Earth. Antarctica also has the highest average elevation of any continent. Russian scientists recorded the world's lowest temperature there, –128.6°F (–89.2°C). Even in the summer, the average temperature in Antarctica's interior stays far below freezing. The air is so cold that it cannot hold moisture. As a result, central Antarctica gets only 2 inches (5 cm) of precipitation per year. However, the ice has been building up for millions of years!

What does the bottom of the world look like? More than 95 percent of Antarctica's surface is ice. It is Earth's deep freeze, storing more than 90 percent of the planet's ice. Ice does not cover the Transantarctic Mountains, however. At 6,500 to 13,000 feet (2,000 to 4,000 m), these mountains break through the ice that blankets most of the continent. Mountains, plateaus, and valleys lie buried under the ice throughout the rest of the continent. Much of Antarctica's rock foundation lies under the frozen surface, some of it below sea level. If all of Antarctica's ice melted, parts of the continent would become island chains. In addition, without the weight of the ice pushing it downward, the underlying rock would rise.

A Frozen Sea

The North Pole lies in the middle of the Arctic Ocean instead of deep within a continent. Asia, Europe, and North America surround the Arctic Ocean. A permanent layer of sea ice covers the ocean's center. During the warmest months of the year, when the



INTERPRETING THE MAP *Each country's Antarctic claim forms a large pie-shaped wedge of the continent.* ***Why do you think three countries claim the Antarctic Peninsula? Which countries are involved?***

INTERPRETING THE VISUAL RECORD *Bottom: The polar bear is at home in the Arctic Ocean and on land or ice. Top: At the North Pole, passengers from a Russian ship walk through all the time zones.* ***Through which hemispheres could these people walk?***

temperature hovers near freezing, the edges of this frozen crust melt. When winter cold returns, so does the ice.

Compared to the stable and thick Antarctic ice cover, Arctic ice is very thin and loose. Antarctic ice is typically thousands of feet thick. In contrast, Arctic ice averages only 10 to 16 feet (3 to 5 m) in thickness. Arctic ice floats in large chunks on the ocean's surface. Currents, tides, and wind push and pull the ice. Cracks and ridges spread. Large sections of ice collide, combine, break up, and collide again.

Research at the Poles

Scientists have conducted research at both Poles for many decades. During the 1950s and 1960s American and Soviet scientists mapped the Arctic Ocean's floor from research stations on the ice. However, because Arctic ice is always changing, these stations were not permanent.

In contrast, Antarctic research stations have been more durable. Some 29 countries have sponsored research projects in Antarctica. These projects address a wide range of topics. Some scientists search the ice for meteorites that provide information about our solar system. Others have compared air trapped in ancient ice bubbles with today's air. They learned that the use of fossil fuels has raised the amount of carbon dioxide in the air to the highest levels in human history. Some researchers concentrate on how animals survive in the frigid climate of Antarctica and the waters surrounding it.

A Harsh but Fragile Place

Antarctica is not immune to damage or change. For some time, people at research stations piled up trash and sewage and pushed it into the ocean. In addition, some energy companies have hoped to extract the continent's store of oil and minerals. Oil spills have already caused environmental damage. In 1991, 32 countries forged an agreement to protect Antarctica. The agreement forbids most activities in Antarctica that do not have a scientific purpose. It bans mining and drilling and limits tourism.

Still, Antarctica is changing. Satellite images show that the continent's ice sheet is shrinking. In 2001, scientists found that since 1992 about 8 trillion gallons of water had melted from a glacier in western Antarctica. That is enough to cover about 23 million acres of land with about 1 foot of water. Scientists believe this finding is further evidence of global warming.

Applying What You Know

1. **Summarizing** What are some of the important differences in the physical geography of the North and South Poles?
2. **Identifying Cause and Effect** How have humans modified the physical environment of Antarctica? How may global warming be affecting Antarctica?

CHAPTER 3 Review

HOLT

Geography's Impact Video Series

Review the video to answer the closing question: *How are climate and weather different, and how does the influence they have differ?*

Building Vocabulary

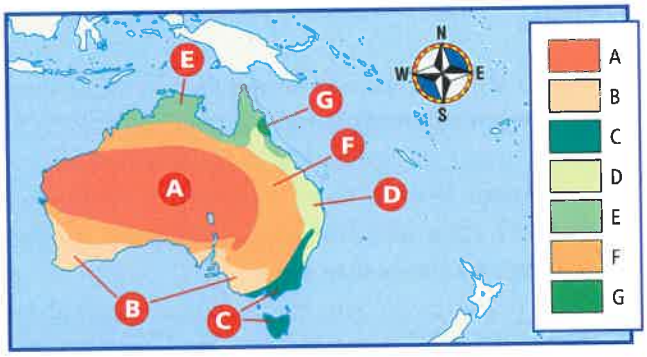
On a separate sheet of paper, explain the following terms by using them correctly in sentences.

weather
condensation
doldrums
temperature
hurricanes
evaporation
cyclones
arid
prevailing winds
climate
rain shadow
front
greenhouse effect
monsoon
humidity

Locating Key Places

On a separate sheet of paper, match the letters on the map of Australia with their correct labels.

tropical humid climate
marine west coast climate
semiarid climate
arid climate
tropical wet and dry climate
humid subtropical climate
Mediterranean climate



Understanding the Main Ideas

Section 1

1. *Physical Systems* How does latitude relate to climate?
2. *Physical Systems* How do atmospheric pressure zones and ocean currents affect Earth's energy balance?

Section 2

3. *Places and Regions* On a global scale, where is precipitation most common?
4. *Physical Systems* What effects can hurricanes have on local environments?

Section 3

5. *Places and Regions* Where will you find climates that are generally warm and wet all year? What creates dry weather conditions in arid regions?

Thinking Critically

1. **Identifying Cause and Effect** Why is precipitation heavier in the persistent low-pressure zones of the world?
2. **Drawing Inferences and Conclusions** What climate factors do you think keep trees from growing in tundra regions?
3. **Analyzing Information** Around what lines of latitude are most arid regions centered? Why?

Using the Geographer's Tools

1. **Analyzing Diagrams** Study the diagram of Earth's pressure and wind systems. Then identify Earth's main prevailing wind patterns.
2. **Summarizing** Review the map and chart of Earth's climate regions. Create a word web for each climate type. Use the webs to describe the distribution and precipitation, temperature, and wind patterns of each climate. Then describe the factors that influence climate.
3. **Preparing Diagrams** Create two diagrams to show how the seasonal change in the way the Sun's rays strike the areas north and south of the equator helps create the tropical wet and dry climate. Draw one diagram to show how the climate is affected in the summer. The other diagram should show how the climate is affected in the winter.

Writing about Geography

Conduct research on the latest scientific studies of global warming. You may want to concentrate on evidence from the polar regions. Pay particular attention to differences of opinion. Write a short newspaper article about your findings. When you are finished with your article, proofread it to make sure you have used standard grammar, spelling, sentence structure, and punctuation.

SKILL BUILDING

Geography for Life

Using Research Skills

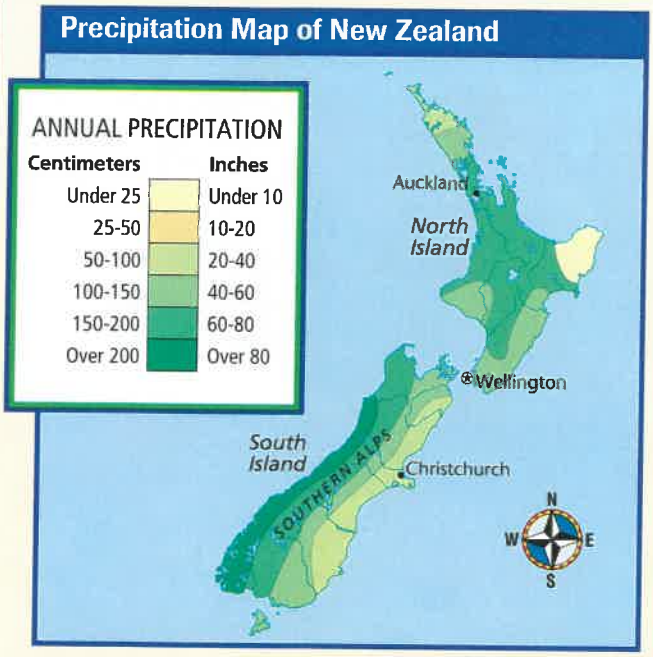
Physical Systems Conduct research on three desert regions on different continents or at different latitudes. Use the climate and precipitation maps in this textbook's unit atlases to help you locate the deserts. Then write a report comparing and contrasting the three areas. Discuss the factors that create each arid climate and the range of temperatures and rainfall in each location. In addition, describe the plants and animals that live in each region.

Building Social Studies Skills

Interpreting Maps

Study the precipitation map below. Then use the information from the map to help you answer the questions that follow. Mark your answers on a separate sheet of paper.

Precipitation Map of New Zealand



1. Of the following amounts of precipitation, which is the amount that falls in Wellington, according to the precipitation map?
   a. 19 cm
   b. 27 cm
   c. 88 cm
   d. 120 cm
2. Describe the difference in precipitation levels of the western and eastern coasts of New Zealand's South Island.

Using Language

The following passage contains mistakes in grammar, punctuation, or usage. Read the passage and then answer the following questions on a separate sheet of paper.

"[1] A humid tropical climate is warm all year. [2] A humid tropical climate is rainy all year. [3] People living in this climate do not see a change from summer to winter. [4] The heat in the tropics cause almost daily rainstorms."

3. Which word group contains an error in subject-verb agreement?
   a. 1
   b. 2
   c. 3
   d. 4
4. Write a sentence that effectively combines word groups 1 and 2.

Alternative Assessment

PORTFOLIO ACTIVITY

Learning about Your Local Geography

Group Project: Field Work

Within a group, use a barometer, rain gauge, and thermometer to keep a daily record of air pressure, rainfall, and temperature at your school. Track these values over several weeks. If possible, note how these factors change with the seasons. Then conduct research on weather records for your area and compare your observations to the official records. Write several generalizations about changes or lack of change in weather patterns.

internet connect

Internet Activity: go.hrw.com
KEYWORD: SW3 GT3

Choose a topic on weather and climate to:

- use satellite maps to learn about weather conditions, fronts, and surface conditions around the world.
- create a poster to display research on hurricanes and the technology of hurricane tracking.
- investigate global warming.