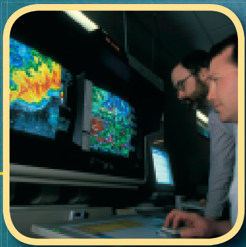
Chapter 21

Weather

Chapter Outline



Why It Matters

Weather—both mild and severe—affects our daily lives. Scientists use weather data and weather patterns to help predict and forecast the weather.

Inquiry Lab

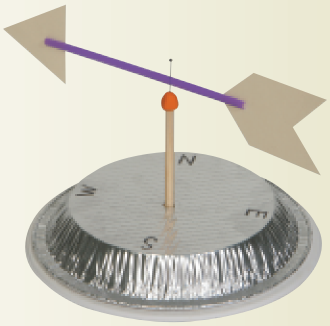
20 min

Build a Wind Vane

Use **scissors** to cut a piece of **thin cardboard** or **manila paper** into a triangular arrowhead, 5 cm long, and a rectangular tail, 7 cm long. Make parallel cuts at both ends of a **drinking straw** about 2 cm long, and slide in the arrowhead and the tail. Push a **straight pin** through the balance point of the straw and into the eraser end of a **pencil.** Then push the pointed end of the pencil vertically through the center of an **aluminum pie plate** and into a lump of **modeling clay.** Place the clay in center of a heavy **paper plate** and press down, forming a sandwich of clay between the two plates. (You may also want to steady the pin with a small piece of clay.) Mark the directions N, S, E, and W around the edges of the pie plate with a **marker.** Place your wind vane in front of a **fan** and turn the fan on low speed. Observe what happens.

Questions to Get You Started

1. What does a wind vane measure?
2. How does the design of your wind vane make the arrow point upwind?
3. How is wind direction described? Is it described as the direction from which the wind blows or the direction in which the wind is blowing?



READING TOOLBOX

These reading tools will help you learn the material in this chapter.

Word Parts

Prefixes, Suffixes, and Root Words The prefix *iso-* is from the Greek word *isos,* meaning "equal." When added to the root word *therm,* which means "heat," you have the word *isotherm,* which means "a line on a weather map that connects points of equal temperature."

Your Turn On a separate sheet of paper, complete a table like the one below with key terms or italicized words from this chapter that contain prefixes, suffixes, or word roots. Use a dictionary or the Internet to find the meanings of the word parts.

Word	Definition	Root	Prefix	Suffix
isobar	a line on a weather map that connects points of equal atmospheric pressure	bar: from the Greek word baros, meaning "weight"	iso: from the Greek word isos, meaning "equal"	

Generalizations

Properties of Severe Weather When you make a generalization, you make a statement that applies to a large group of things or people. If you say, "Most students studied for the test," you are saying that most, but not all, students studied for the test. Words such as *most, usually, typically, commonly,* and *generally,* and phrases such as *in general* and *for the most part,* signal generalizations. Some generalizations do not have a word or phrase signal.

Your Turn As you read Section 2, complete a table like the one below to list the generalizations that you find.

Sentence	Word or phrase that signals generalization	Explanation of why sentence is a generalization
Tornadoes generally cover paths not more than 100 m wide.	generally	The statement applies to most, but not all, tornadoes.

Note Taking

Two-Column Notes Two-column notes can help you learn the key terms, italicized words, and main ideas as you read.

Your Turn Complete two-column notes for Sections 1 and 4.

1. Write one key term, italicized word, or main idea in each row of the left-hand column.
2. Add definitions, details, and examples in the right-hand column.

Key term, italicized word, or main idea	Definitions, details, and examples
maritime	• on or near the ocean
maritime air masses	• air masses that form over the ocean • take on the characteristics of the water over which they form (moist, humid) • usually bring precipitation and fog

For more information on how to use these and other tools, see **Appendix A.**

SECTION 1

Air Masses

Key Ideas	Key Terms	Why It Matters
❯ Explain how an air mass forms. ❯ List the four main types of air masses. ❯ Describe how air masses affect the weather of North America.	**air mass**	You may not think about air masses very often, but they influence weather across North America every day.

Differences in air pressure are caused by unequal heating of Earth's surface. The region along the equator receives more solar energy than the regions at the poles do. The heated equatorial air rises and creates a low-pressure center. Conversely, cold air near the poles sinks and creates high-pressure centers. Differences in air pressure at different locations on Earth create wind patterns.

How Air Moves

Air moves from areas of high pressure to areas of low pressure. Therefore, there is a general, worldwide movement of surface air from the poles toward the equator. At high altitudes, the warmed air flows from the equator toward the poles. Temperature and pressure differences on Earth's surface create three wind belts in the Northern Hemisphere and three wind belts in the Southern Hemisphere. These wind belts are influenced by the *Coriolis effect*, which occurs when winds are deflected by Earth's rotation. The processes that affect air movement also influence storms, such as the one shown in **Figure 1.**

air mass a large body of air throughout which temperature and moisture content are similar

Formation of Air Masses

When air pressure differences are small, the air remains relatively stationary. If the air remains stationary or moves slowly over a uniform region, it takes on the characteristic temperature and humidity of that region. A large body of air throughout which temperature and moisture are similar is called an **air mass.** Air masses that form over frozen polar regions are very cold and dry. Air masses that form over tropical oceans are warm and moist.

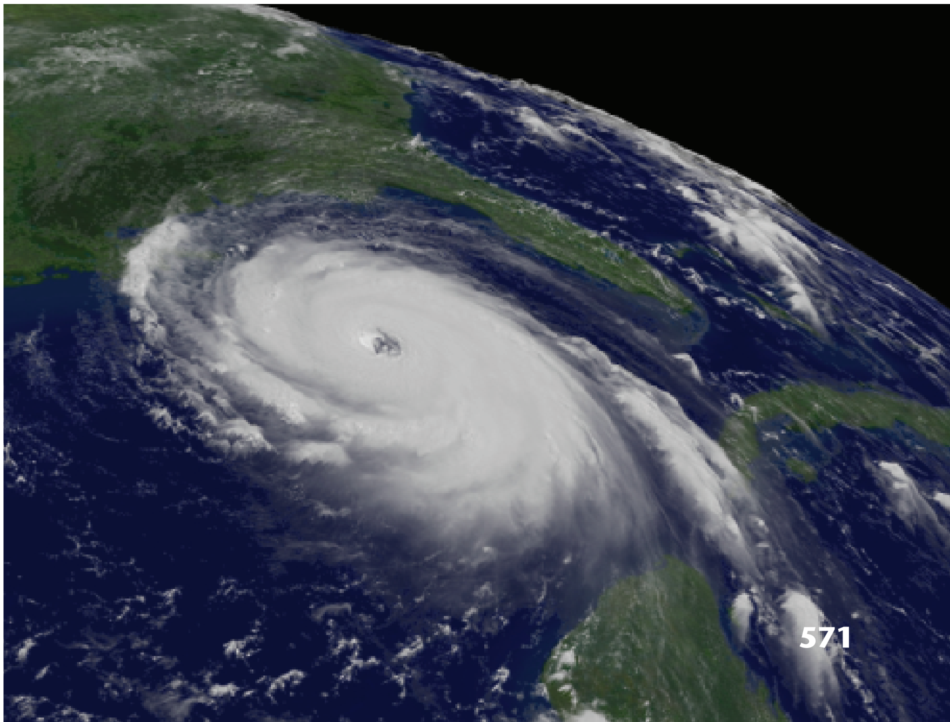


Figure 1 The motion of Earth's atmosphere can lead to the formation of powerful storms, such as Hurricane Katrina.

Table 1 Air Masses

Source region	Type of air	Symbol
Continental	dry	c
Maritime	moist	m
Tropical	warm	T
Polar	cold	P

Types of Air Masses

Air masses are classified according to their source regions. The source regions determine the temperature and the humidity of the air masses. The source regions for cold air masses are polar areas. The source regions for warm air masses are tropical areas. Air masses that form over oceans are called *maritime*. Air masses that form over land are called *continental*. Maritime air masses are moist, and continental air masses are dry. Air masses and the symbols used to designate them are listed in **Table 1.** The combination of tropical or polar air and continental or maritime air results in air masses that have distinct characteristics.

Continental Air Masses

Continental air masses form over large landmasses, such as northern Canada, northern Asia, and the southwestern United States. Because these air masses form over land, the level of humidity is very low. An air mass may remain over its source region for days or weeks. However, the air mass will eventually move into other regions because of global wind patterns. In general, continental air masses bring dry weather conditions when they move into another region. There are two types of continental air masses: *continental polar* (cP) and *continental tropical* (cT). Continental polar air masses are cold and dry. Continental tropical air masses are warm and dry.

READING TOOLBOX

Generalizations
As you read Section 1, look for sentences that contain generalizations. List them in a table like the one shown at the beginning of this chapter. Remember that some generalizations are not signaled by a word or phrase.

Maritime Air Masses

Maritime air masses form over oceans and other large bodies of water. These air masses take on the characteristics of the water over which they form. The humidity in these air masses tends to be higher than that of continental air masses. When these very moist air masses travel to a new location, they commonly bring precipitation and fog, as shown in **Figure 2.**

The two types of maritime air masses are *maritime polar* (mP) and *maritime tropical* (mT). Maritime polar air masses are moist and cold. Maritime tropical air masses are moist and warm.

Figure 2 A maritime air mass brings fog that rolls in off the coast of California.

North American Air Masses

The four types of air masses that affect the weather of North America come from six locations. These air masses, their source locations, their movements, and the weather they bring are summarized in **Table 2.** The general directions of the air masses' movements are shown in **Figure 3.** An air mass usually brings the weather of its source location, but an air mass may change as it moves away from its source location. For example, cold, dry air may become warmer and more moist as it moves from land to a warm ocean. As the lower layers of the air are warmed, the air rises. This warmed air may then create clouds and precipitation.

Table 2 Air Masses of North America

Air mass	Source location	Movement	Weather
cP	polar regions in Canada	south-southeast	cold and dry
mP	polar Pacific; polar Atlantic	southeast; southwest-south	cold and moist
cT	U.S. southwest	north-northeast	warm and dry
mT	tropical Pacific; tropical Atlantic	northeast; north-northwest	warm and moist

Academic Vocabulary

summarize (SUHM uh RIEZ) explain in a brief way

Tropical Air Masses

Continental tropical air masses form over the deserts of the southwestern United States. These air masses bring dry, hot weather in the summer. They do not form in the winter. Maritime tropical air masses form over the warm water of the tropical Atlantic Ocean, the Caribbean Sea, and the Gulf of Mexico. They bring mild, often cloudy weather to the eastern United States in the winter. In the summer, they bring hot, humid weather and thunderstorms. Maritime tropical air masses also form over warm areas of the Pacific Ocean. But these air masses do not usually reach the Pacific coast. In the winter, maritime tropical air masses bring moderate precipitation to the coast and the southwestern deserts.

SCILINKS.
www.scilinks.org
Topic: Air Masses
Code: HQX0031

Reading Check **Which air mass brings dry, hot weather in the summer?** (See Appendix G for answers to Reading Checks.)

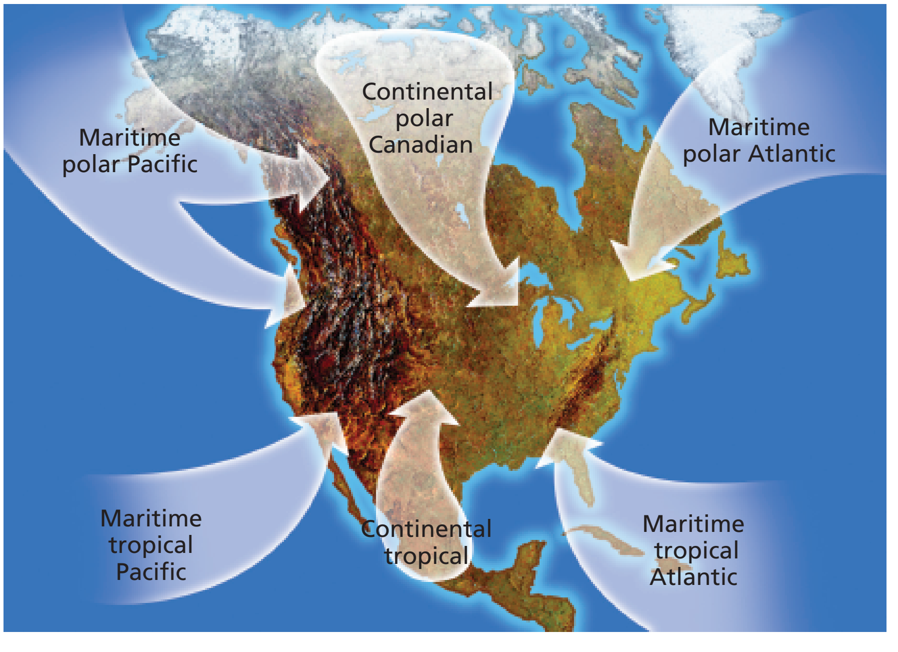


Figure 3 The four types of air masses that influence the weather in North America come from six locations and are named according to their source locations.

Figure 4 Maritime polar Atlantic air masses can bring heavy snowfall, such as this snowstorm that hit New York City in 2003.

Polar Air Masses

Polar air masses from three regions—northern Canada and the northern Pacific and Atlantic Oceans—influence weather in North America. Continental polar air masses form over ice- and snow-covered land. These air masses move into the northern United States and can occasionally reach as far south as the Gulf Coast of the United States. In summer, these air masses usually bring cool, dry weather. In winter, they bring very cold weather to the northern United States.

Maritime polar air masses form over the North Pacific Ocean and are very moist, but they are not as cold as continental polar Canadian air masses. In winter, maritime polar Pacific air masses bring rain and snow to the Pacific Coast. In summer, they bring cool, often foggy weather. As they move inland and eastward over the Cascades, the Sierra Nevada, and the Rocky Mountains, these cold air masses lose much of their moisture and warm slightly. Thus, they may bring cool and dry weather by the time they reach the central United States.

Maritime polar Atlantic air masses generally move eastward toward Europe, but they sometimes move westward over New England and eastern Canada. In winter, they can bring cold, cloudy weather and snow, as shown in **Figure 4.** In summer, these air masses can produce cool weather, low clouds, and fog.

Section 1 Review

Key Ideas

1. **Define** *air mass.*
2. **Explain** how an air mass forms.
3. **Identify** the location where a cold, dry air mass would form.
4. **List** the four main types of air masses.
5. **Describe** how the four main types of air masses affect the weather of North America.
6. **Describe** the air mass that forms over the warm water of the Atlantic Ocean. What letters designate the source region of this air mass?

Critical Thinking

7. **Making Predictions** How do temperature and humidity change when a maritime tropical air mass is replaced by a continental polar air mass?
8. **Recognizing Relationships** In which direction would you expect a tropical air mass near the coast of Europe to travel? Explain your answer.

Concept Mapping

9. Use the following terms to create a concept map: *maritime polar Pacific, maritime polar, continental polar Canadian, air mass, continental polar,* and *maritime polar Atlantic.*

SECTION 2

Fronts

Key Ideas

- Compare the characteristic weather patterns of cold fronts with those of warm fronts.
- Describe how a midlatitude cyclone forms.
- Describe the development of hurricanes, thunderstorms, and tornadoes.

Key Terms

cold front
warm front
stationary front
occluded front
midlatitude cyclone
thunderstorm
hurricane
tornado

Why It Matters

You've probably heard a weather forecaster use the term *front* and perhaps say that a cold front would pass through your area. Tracking the movement of fronts helps us forecast the weather.

When two unlike air masses meet, density differences usually keep the air masses separate. A cool air mass is dense and does not mix with the less-dense air of a warm air mass. Thus, a boundary, called a *front,* forms between air masses. A typical front is several hundred kilometers long. However, some fronts may be several thousand kilometers long. Changes in middle-latitude weather usually take place along the various types of fronts. Fronts do not exist in the tropics because no air masses that have significant temperature differences exist there.

Types of Fronts

For a front to form, one air mass must collide with another air mass. The kind of front that forms is determined by how the air masses move in relationship to each other.

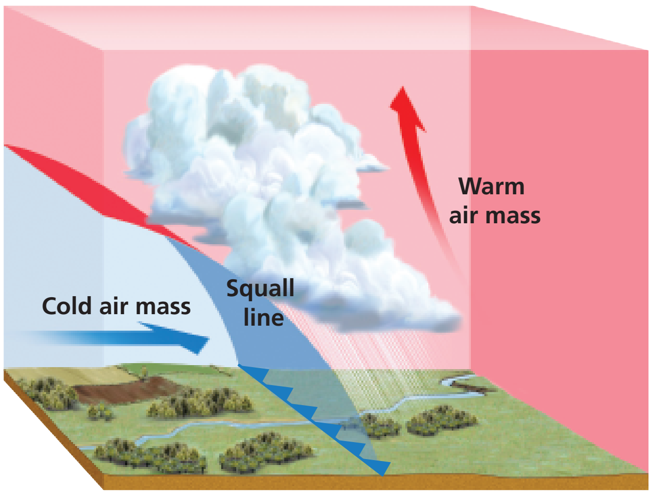
cold front the front edge of a moving mass of cold air that pushes beneath a warmer air mass like a wedge

Cold Fronts

When a cold air mass overtakes a warm air mass, a **cold front** forms. The moving cold air lifts the warm air. If the warm air is moist, clouds will form. Large cumulus and cumulonimbus clouds typically form along fast-moving cold fronts, as shown in **Figure 1.** Storms that form along cold fronts are usually short-lived and are sometimes violent. A long line of heavy thunderstorms, called a *squall line,* may occur in the warm, moist air just ahead of a fast-moving cold front. A slow-moving cold front lifts the warm air ahead of it more slowly than a fast-moving cold front does. A slow-moving cold front typically produces weaker storms and lighter precipitation than a fast-moving cold front does.

Figure 1 As a cold air mass overtakes a warm air mass, a line of thunderstorms called a *squall line* forms.

Cold Front



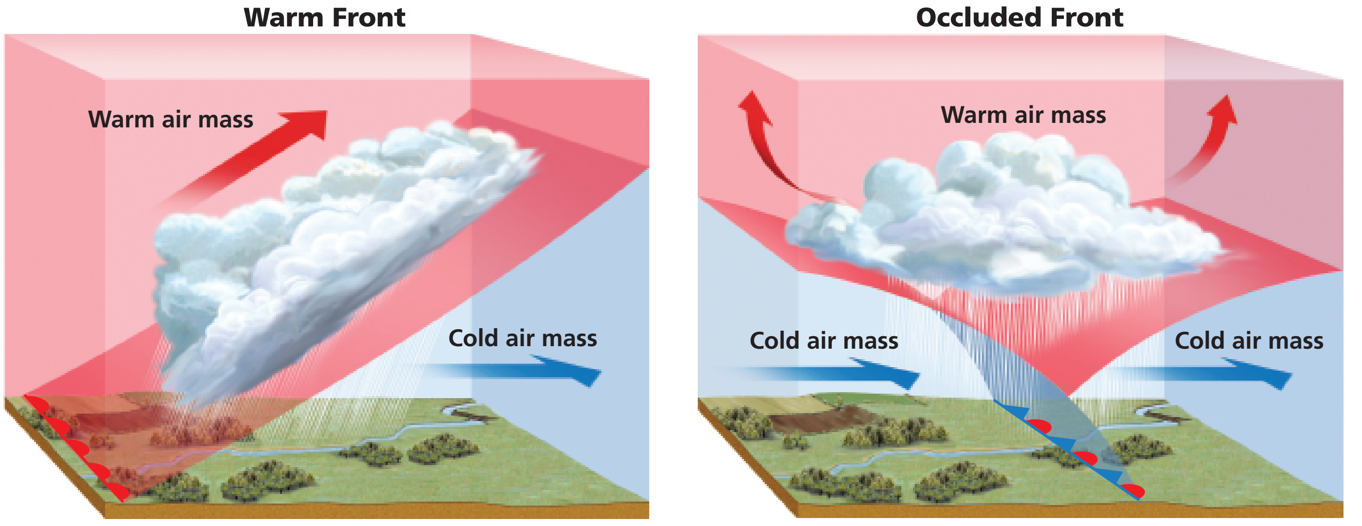


Figure 2 As a warm air mass rises over a cold air mass (left), a warm front forms at the boundary of the two air masses. An occluded front (right) forms when a cold air mass lifts a warm air mass off the ground.

Warm Fronts

When a warm air mass overtakes a cold air mass, a **warm front** forms. The less dense warm air rises over the cooler air. The slope of a warm front is gradual, as shown in **Figure 2.** Because of this gentle slope, clouds may extend far ahead of the surface location, or *base,* of the front. A warm front generally produces precipitation over a large area and may occasionally cause violent weather.

warm front the front edge of an advancing warm air mass that replaces colder air with warmer air

stationary front a front of air masses that moves either very slowly or not at all

occluded front a front that forms when a cold air mass overtakes a warm air mass and lifts the warm air mass off the ground and over another air mass

midlatitude cyclone an area of low pressure that is characterized by rotating wind that moves toward the rising air of the central low-pressure region

Stationary and Occluded Fronts

Sometimes, when two air masses meet, the air moves parallel to the front and neither air mass is displaced. A front at which air masses move either very slowly or not at all is called a **stationary front.** The weather produced by a stationary front is similar to the weather produced by a warm front. An **occluded front** usually forms when a fast-moving cold front overtakes a warm front and lifts the warm air off the ground completely, as shown in **Figure 2.**

Polar Fronts and Midlatitude Cyclones

Over each of Earth's polar regions is a dome of cold air that may extend as far as 60° latitude. The boundary where this cold polar air meets the tropical air mass of the middle latitudes, especially over the ocean, is called the *polar front*. Waves commonly develop along the polar front. A *wave* is a bend that forms in a cold front or a stationary front. This wave is similar to the waves that moving air produces when it passes over a body of water. However, the waves that form in a cold front or stationary front are much larger. They are the beginnings of low-pressure storm centers called midlatitude cyclones or *wave cyclones*. **Midlatitude cyclones** are areas of low pressure that are characterized by rotating wind, which moves toward the rising air of the central, low-pressure region. These cyclones strongly influence weather patterns in the middle latitudes.

READING TOOLBOX

Two-Column Notes
Use the two-column table that you started at the beginning of the chapter as a model to review the main ideas about fronts in this section.

Stages of a Midlatitude Cyclone

A midlatitude cyclone usually lasts several days. The stages of formation and dissipation of a midlatitude cyclone are shown in **Figure 3.** In North America, midlatitude cyclones generally travel about 45 km/h in an easterly direction as they spin counterclockwise. They follow several storm tracks, or routes, as they move from the Pacific coast to the Atlantic coast. As they pass over the western mountains, they may lose their moisture and energy.

SCILINKS.
www.scilinks.org
Topic: Fronts and Severe Weather
Code: **HQX0624**

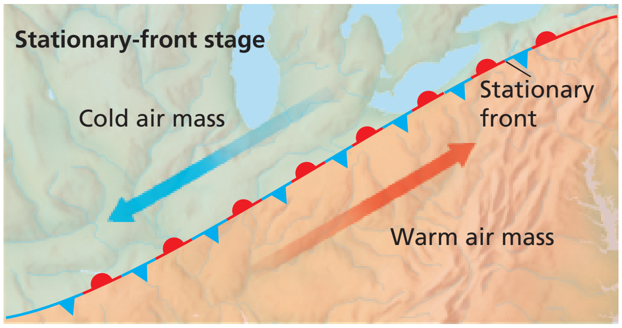
Anticyclones

Unlike the air in a midlatitude cyclone, the air in an *anticyclone* sinks and flows outward from a center of high pressure. Because of the Coriolis effect, the circulation of air around an anticyclone is clockwise in the Northern Hemisphere. Anticyclones bring dry weather, because their sinking air does not promote cloud formation. If an anticyclone stagnates over a region for a few days, it may cause air pollution problems. After being stationary for a few weeks, an anticyclone may cause a drought.

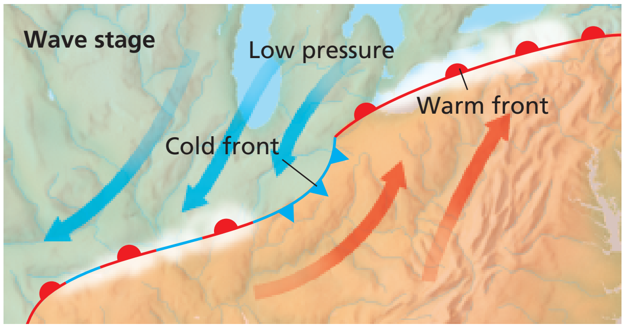
Reading Check **How is the air of an anticyclone different from the air of a midlatitude cyclone?**

THINK central
INTERACT ONLINE
Keyword: HQXWTHF3

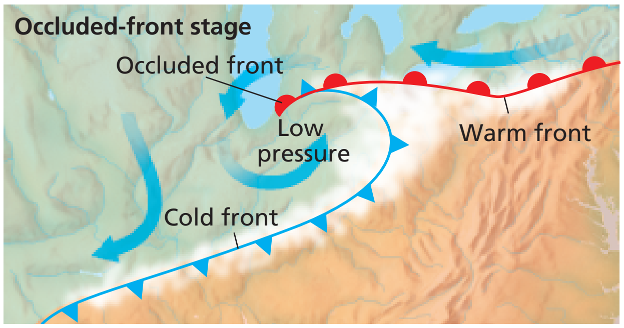
Figure 3 Stages of a Midlatitude Cyclone



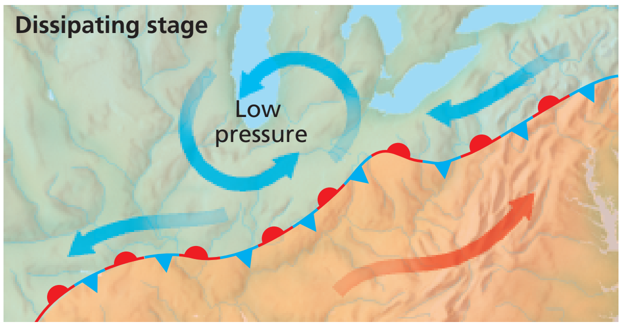
1 Midlatitude cyclones occur along a stationary front. Winds move parallel to the front but in opposite directions on the two sides of the front.



2 A wave forms when a bulge of cold air develops and advances slightly ahead of the rest of the front.



3 As the fast-moving part of the cold front overtakes the warm front, an occluded front forms and the storm reaches its highest intensity.



4 Eventually, the system loses most of its energy and the midlatitude cyclone dissipates.

Severe Weather

Severe weather is weather that may cause property damage or loss of life. Severe weather may include large quantities of rain, lightning, hail, strong winds, or tornadoes. This type of weather causes billions of dollars in damage each year.

Thunderstorms

thunderstorm a usually brief, heavy storm that consists of rain, strong winds, lightning, and thunder

A heavy storm that is accompanied by rain, thunder, lightning, and strong winds is called a **thunderstorm.** Thunderstorms develop in three distinct stages. In the first stage, or *cumulus stage,* warm, moist air rises, and the water vapor within the air condenses to form a cumulus cloud. In the next stage, called the *mature stage,* condensation continues as the cloud rises and becomes a dark cumulonimbus cloud. Heavy, torrential rain and hailstones may fall from the cloud. While strong updrafts continue to rise, downdrafts form as the air is dragged downward by the falling precipitation. During the final stage, or *dissipating stage,* the strong downdrafts stop air currents from rising. The thunderstorm dissipates as the supply of water vapor decreases.

Math Skills

Thunderstorm Distance The time between when you see a lightning strike and when you hear thunder indicates how far away the lightning bolt was from you. Sound travels approximately 1 km in 3 s. The lapse time in seconds divided by 3 is roughly the number of kilometers between you and the lightning. If 27 s pass between a flash of lightning and the sound of thunder, how far away was the lightning strike from you?

Lightning

During a thunderstorm, clouds discharge electricity in the form of *lightning*. The released electricity heats the air, and the air expands rapidly and produces the loud noise known as *thunder*. For lightning to occur, the clouds must have areas that carry distinct electrical charges. The upper part of a cloud usually carries a positive charge, while the lower part usually carries a negative charge. Lightning is a huge spark that travels within the cloud, or between the cloud and the ground, to equalize the electrical charges. **Figure 4** shows an example of lightning.

Figure 4 The average lightning flash lasts only about a quarter of a second, but lightning causes more than $330,000,000 in damage per year in the United States.

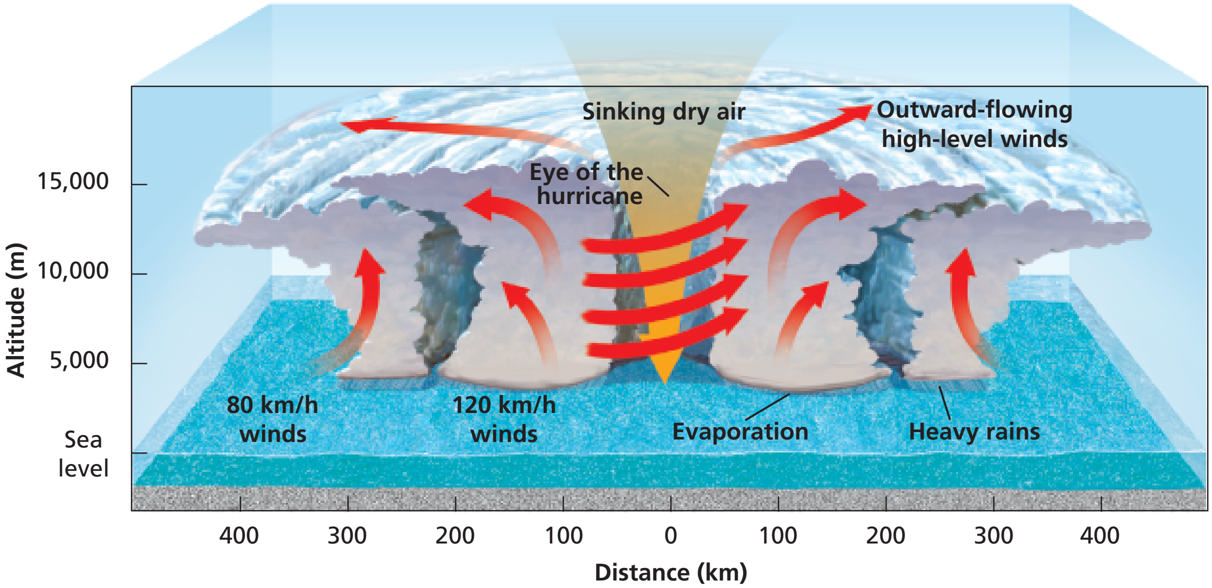


Figure 5 Although hurricanes are the most destructive storms, the eye at the center of a hurricane is relatively calm.

Hurricanes

Tropical storms differ from midlatitude cyclones in several ways. Tropical storms are concentrated over a smaller area. They lack warm and cold fronts. Also, they are usually much more violent and destructive than midlatitude cyclones. A tropical storm with wind speeds of 120 km/h or more that spiral in toward an intense low-pressure center is called a **hurricane.**

hurricane a severe storm that develops over tropical oceans and whose strong winds of more than 120 km/h spiral in toward the intensely low-pressure storm center

Hurricanes develop over warm, tropical oceans. A hurricane begins when warm, moist air over the ocean rises rapidly. When moisture in the rising warm air condenses, a large amount of energy in the form of latent heat is released. *Latent heat* is heat energy that is absorbed or released during a phase change. This heat increases the strength of the rising air.

A fully developed hurricane consists of a series of thick cumulonimbus cloud bands that spiral upward around the center of the storm, as shown in **Figure 5.** Winds increase toward the center, or eye, of the storm and reach speeds of up to 275 km/h along the eyewall. The eye itself, however, is a region of calm, clear, sinking air.

With a range in diameter of 400 to 800 km, hurricanes are the most destructive storms that occur on Earth. The most dangerous aspect of a hurricane is a rising sea level with large waves, called a *storm surge*. A storm surge can flood vast low-lying coastal areas. This flooding is the reason why most deaths during hurricanes are caused by drowning.

Every hurricane is categorized on the *Saffir-Simpson scale* by using several factors. These factors include central pressure, wind speed, and storm surge. The Saffir-Simpson scale has five categories. Category 1 storms cause the least damage. Category 5 storms can result in catastrophic damage.

Reading Check **Where do hurricanes develop?**

Why It Matters

Hurricane Katrina

Hurricane Katrina came marching in to New Orleans, Louisiana, on August 28, 2005. She was accompanied by torrential rain, sustained winds of 282 km/h, and storm surges of up to 8.5 meters. This event taught Americans many lessons about storm preparedness.

Katrina Approaches

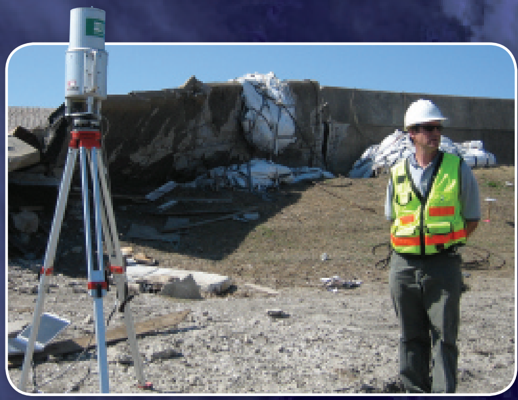
Large areas of New Orleans are below sea level. Therefore, city officials were concerned when the hurricane's path turned northward and the storm intensified as it moved toward the coast.

Thousands Homeless

Although a mandatory evacuation order was issued the day before the storm made landfall, many New Orleans residents were unable to leave the city until after the storm. Many of the people who remained sought refuge at the Superdome both before and after the hurricane.

HISTORY IN SCIENCE

Preventing Future Disasters



In the aftermath of the storm, teams of engineers and scientists reviewed the performance of the city's levees. These teams recommended ways to construct more storm-resistant levees.

Because of Hurricane Katrina, Hurricane Rita—which followed Hurricane Katrina by less than a month—was tracked very carefully, and evacuation orders were issued days in advance.

YOUR TURN

UNDERSTANDING CONCEPTS
Why did Hurricane Katrina particularly endanger New Orleans?

CRITICAL THINKING
What did scientists and government officials learn from Hurricane Katrina?

Figure 6 A powerful tornado in Texas embedded this bucket in a wooden door (inset).

tornado a destructive, rotating column of air that has very high wind speeds and that may be visible as a funnel-shaped cloud

Tornadoes

The smallest, most violent, and shortest-lived severe storm is a tornado. A **tornado** is a destructive, rotating column of air that has very high wind speeds and that is visible as a funnel-shaped cloud, as shown in **Figure 6.**

A tornado forms when a thunderstorm meets high-altitude, horizontal winds. These winds cause the rising air in the thunderstorm to rotate. A storm cloud may develop a narrow, funnel-shaped, rapidly spinning extension that reaches downward and may or may not touch the ground. If the funnel does touch the ground, it generally moves in a wandering, haphazard path. Frequently, the funnel rises and touches down again a short distance away. Tornadoes generally cover paths not more than 100 m wide. Usually, however, everything in that path is destroyed. Tornadoes occur in many locations, but they are most common in *Tornado Alley* in the late spring or early summer. Tornado Alley stretches from Texas up through the midwestern United States.

The destructive power of a tornado is due to mainly the speed of the wind in the funnel. This wind may reach speeds of more than 400 km/h. Most injuries and deaths caused by tornadoes occur when people are trapped in collapsing buildings or are struck by objects blown by the wind.

Section 2 Review

Key Ideas

1. **Describe** the four main types of fronts.
2. **Compare** the characteristic weather patterns of cold fronts with those of warm fronts.
3. **Identify** the type of front that may form a squall line.
4. **Summarize** how a midlatitude cyclone forms.
5. **Describe** the stages in the development of a thunderstorm.
6. **Describe** the stages in the development of a hurricane.
7. **Explain** why tornadoes are so destructive.

Critical Thinking

8. **Evaluating Methods** What areas of Earth should meteorologists monitor to detect developing hurricanes? Explain your answer.
9. **Making Comparisons** Compare the destructive power of midlatitude cyclones, hurricanes, and tornadoes in terms of size, wind speed, and duration.

Concept Mapping

10. Use the following terms to create a concept map: *tornado, hurricane, warm front, squall line, cold front, severe weather, stationary front, front, midlatitude cyclone,* and *occluded front.*

SECTION 3

Weather Instruments

Key Ideas	Key Terms	Why It Matters
❯ Identify four instruments that measure lower-atmospheric weather conditions. ❯ Describe how scientists measure conditions in the upper atmosphere. ❯ Explain how computers help scientists understand weather.	**thermometer** **barometer** **anemometer** **wind vane** **radiosonde** **radar**	When you look at a weather forecast, you see lots of numbers, including temperature, air pressure, and humidity data. These measurements help meteorologists track weather.

Weather observations are based on a variety of measurements, including atmospheric pressure, humidity, temperature, wind speed, and precipitation. These measurements are made with special instruments. Meteorologists then use these measurements to forecast weather patterns.

Measuring Lower-Atmospheric Conditions

During the course of a day, the lower-atmospheric conditions at a given location can change drastically. Meteorologists use the magnitude and speed of these changes to predict future weather events. To obtain accurate data from the lower atmosphere, scientists use instruments such as those shown in **Figure 1.**

Air Temperature

An instrument that measures and indicates temperature is called a **thermometer.** A common type of thermometer uses a liquid—usually mercury or alcohol—sealed in a glass tube to indicate temperature. A rise in temperature causes the liquid to expand and fill more of the tube. A drop in temperature causes the liquid to contract and fill less of the tube. A scale marked on the glass tube indicates the temperature.

thermometer an instrument that measures and indicates temperature

Another type of thermometer is an *electrical thermometer*. As the temperature rises, the electric current that flows through the material of the electrical thermometer increases and is translated into temperature readings. A *thermistor*, or thermal resistor, is a type of electrical thermometer that responds very quickly to temperature changes. For this reason, thermistors are extremely useful where temperature change occurs rapidly.

Figure 1 Weather instruments, such as these at Elk Mountain weather research facility in Wyoming, indicate wind speed and direction.

Figure 2 A meteorologist uses an anemometer during Hurricane Luis to measure wind speed.

Air Pressure

Changes in air pressure affect air masses at certain locations. The approach of a front is usually indicated by a drop in air pressure. Scientists use instruments called **barometers** to measure atmospheric pressure.

Wind Speed

An instrument called an **anemometer** (AN uh MAHM uht uhr) measures wind speed. A typical anemometer consists of small cups that are attached by spokes to a shaft that rotates freely. The wind pushes against the cups and causes them to rotate, as shown in **Figure 2.** This rotation triggers an electrical signal that registers the wind speed in meters per second or in miles per hour.

barometer an instrument that measures atmospheric pressure

anemometer an instrument used to measure wind speed

wind vane an instrument used to determine the direction of the wind

Wind Direction

The direction of the wind is determined by using an instrument called a **wind vane.** The wind vane is commonly an arrow-shaped device that turns freely on a pole as the tail catches the wind. Wind direction may be described by using one of 16 compass directions, such as north-northeast. Wind direction also may be described in degrees by moving clockwise, beginning with 0° at the north. Thus, east is 90°, south is 180°, and west is 270°.

Reading Check **Which instrument is used to measure air pressure?**

Quick Lab — Wind Chill

15 min

Procedure

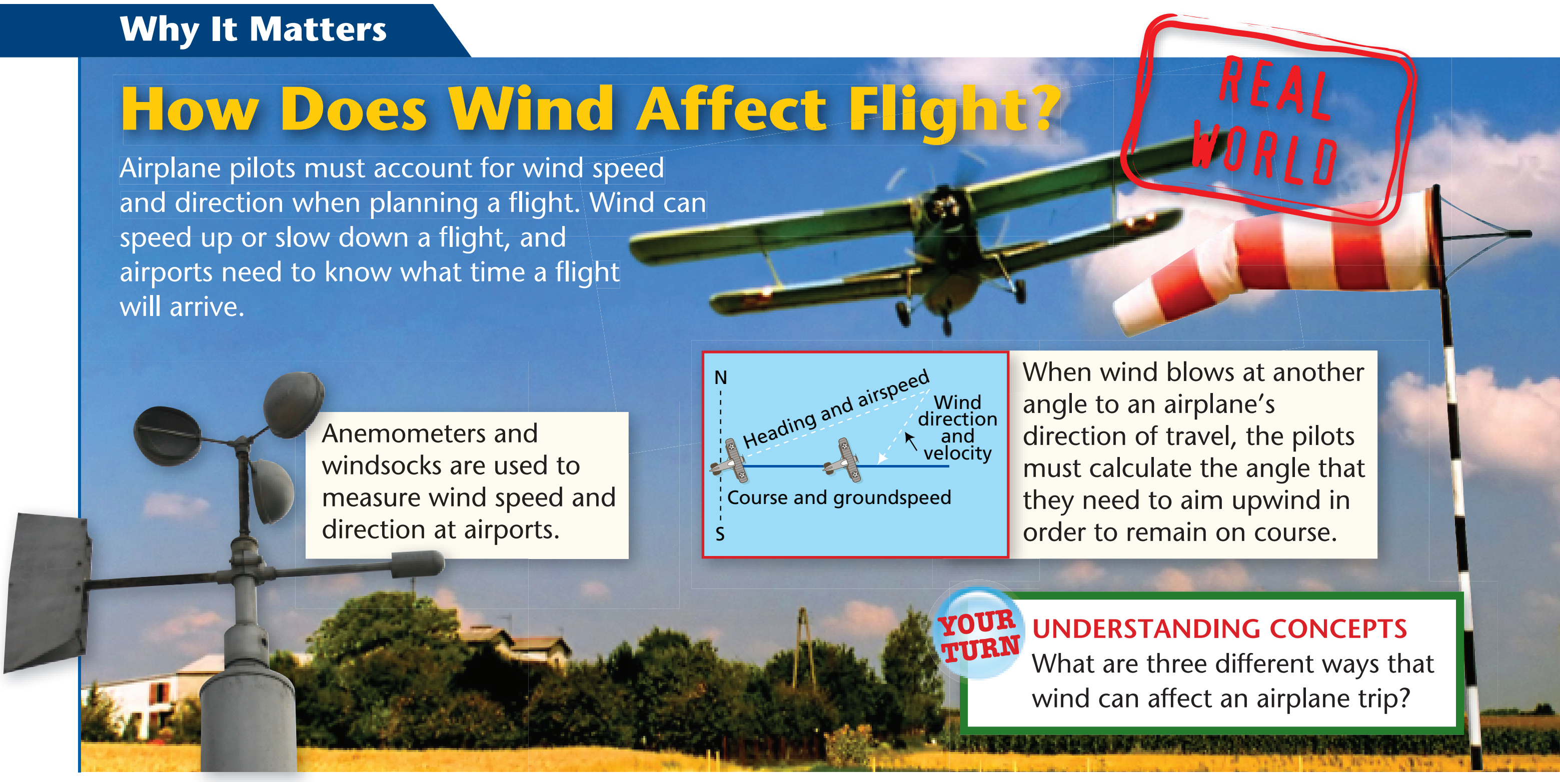
1. Place a 23 cm × 33 cm pan on a level table. Fill the pan to a depth of 1 cm with room-temperature water.
2. Lay a thermometer in the center of the pan, with the bulb submerged. After 5 min, record the water temperature. Do not touch the thermometer.
3. Place an electric fan facing the pan and a few centimeters from the pan. Turn on the fan at a low speed. **CAUTION** Do not get the fan or cord wet.
4. Record the water temperature every minute until the temperature remains constant.

Analysis

1. How does the moving air affect the temperature of the water?
2. If the moving air is the same temperature as the still air in the room, what causes the water temperature to change?
3. How would you dress on a cool, windy day to stay comfortable? Explain your answer.

Why It Matters

How Does Wind Affect Flight?



Airplane pilots must account for wind speed and direction when planning a flight. Wind can speed up or slow down a flight, and airports need to know what time a flight will arrive.

Anemometers and windsocks are used to measure wind speed and direction at airports.

When wind blows at another angle to an airplane's direction of travel, the pilots must calculate the angle that they need to aim upwind in order to remain on course.

YOUR TURN

UNDERSTANDING CONCEPTS
What are three different ways that wind can affect an airplane trip?

Measuring Upper-Atmospheric Conditions

Conditions of the atmosphere near Earth's surface are only part of the complete weather picture. Scientists use several instruments to measure conditions in the upper atmosphere, to obtain a better understanding of local and global weather patterns.

Radiosonde

An instrument package that is carried high into the atmosphere by a helium-filled weather balloon to measure relative humidity, air pressure, and air temperature is called a **radiosonde.** A radiosonde sends measurements as radio waves to a receiver that records the information. The path of the balloon is tracked to determine the direction and speed of high-altitude winds. When the balloon reaches a very high altitude, the balloon expands and bursts, and the radiosonde parachutes back to Earth.

Radar

Another instrument for determining weather conditions in the atmosphere is radar. **Radar,** which stands for **ra**dio **d**etection **a**nd **r**anging, is a system that uses reflected radio waves to determine the velocity and location of objects. For example, large particles of water in the atmosphere reflect radar pulses. Thus, precipitation and storms, such as thunderstorms, tornadoes, and hurricanes, are visible on a radar screen. The newest Doppler radar can indicate the precise location, movement, and extent of a storm. It can also indicate the intensity of precipitation and wind patterns within a storm.

radiosonde a package of instruments that is carried aloft by a balloon to measure upper atmospheric conditions, including temperature, dew point, and wind velocity

radar a system that uses reflected radio waves to determine the velocity and location of objects

READING TOOLBOX

Two-Column Notes
Create two-column notes to review the main ideas about weather instruments in this section. Put the main ideas in the left column. Add details and examples, in your own words, in the right column.

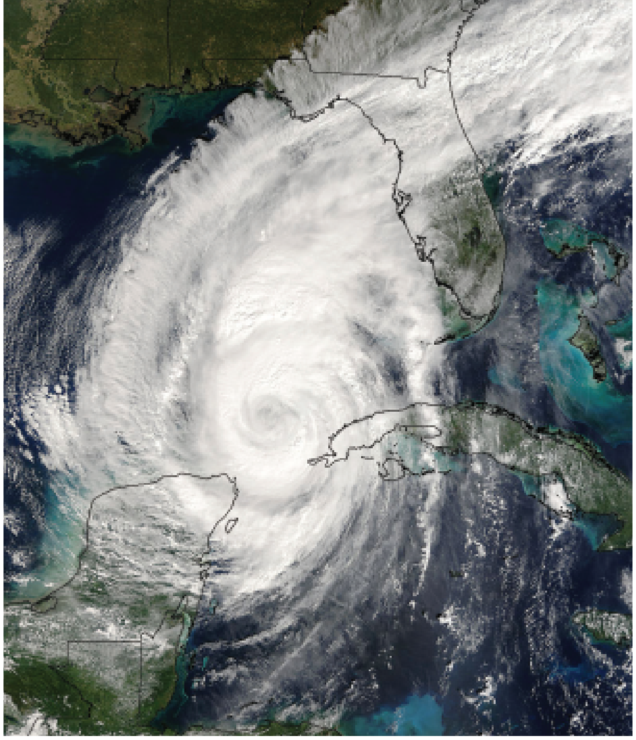


Figure 3 This satellite image captured Hurricane Wilma in 2005 as it approached Florida.

Weather Satellites

Instruments carried by weather satellites also collect important information about the atmosphere. Satellite images, such as the one shown in **Figure 3,** provide weather information for regions where observations cannot be made from the ground.

The direction and speed of the wind at the level of the clouds can be measured by examining a continuous sequence of cloud images. For night monitoring, satellite images made by using infrared energy reveal temperatures at the tops of clouds, at the surface of the land, and at the surface of the ocean. Satellite instruments can also measure marine conditions. For example, the instruments on satellites can measure the temperature and flow of ocean currents and the height of ocean waves. In addition, satellites can measure land temperatures and soil moisture conditions at remote locations on Earth.

SCILINKS.
www.scilinks.org
Topic: Weather Instruments
Code: **HQX1646**

Computers

Meteorologists use supercomputers to understand the weather. Before computers were available, solving the mathematical equations that describe the behavior of the atmosphere was very difficult, and sometimes impossible. In addition to solving many of these equations, computers can store weather data from around the world. These data can provide information that is useful in forecasting weather changes. Computers can also store weather records for quick retrieval. In the future, powerful computers may greatly improve weather forecasts and provide a much better understanding of the atmosphere.

Section 3 Review

Key Ideas

1. **Identify** four instruments that scientists use to measure lower-atmospheric conditions.
2. **Explain** why scientists are interested in weather conditions in the upper atmosphere.
3. **Describe** the instruments used to measure conditions in the upper atmosphere.
4. **Explain** how meteorologists send weather instruments into the upper atmosphere.
5. **Summarize** how satellites help meteorologists study weather.
6. **Summarize** how computers help scientists study weather.

Critical Thinking

7. **Recognizing Relationships** Wind is named according to the direction from which it blows. Why would a meteorologist need to know the direction that wind is blowing from?
8. **Making Inferences** If weather instruments were moved from a valley to the top of a hill, what changes would you expect in the data? Explain your answer.

Concept Mapping

9. Use the following terms to create a concept map: *thermometer, barometer, anemometer, radar, radio-sonde, satellite, upper atmosphere, lower atmosphere,* and *weather instruments.*

SECTION 4

Forecasting the Weather

Key Ideas	Key Terms	Why It Matters
❯ Explain how weather stations communicate weather data. ❯ Explain how a weather map is created. ❯ Explain how computer models help meteorologists forecast weather. ❯ List three types of weather that meteorologists have attempted to control.	**station model**	Early warnings of severe weather can reduce damage and save lives. Understanding weather information will help you take warnings seriously.

Predicting the weather has challenged people for thousands of years. People in many early civilizations attributed control of weather conditions, such as wind, rain, and thunder, to gods. Some people attempted to forecast the weather by using the positions of the stars and the moon as the basis for their predictions.

Scientific weather forecasting began with the invention of basic weather instruments, such as the thermometer and the barometer. The invention of the telegraph in 1844 enabled meteorologists to share information about weather conditions quickly and led to the creation of national weather services.

Global Weather Monitoring

Weather observers at stations around the world report weather conditions frequently, often several times per hour. They record the barometric pressure and how it has changed, as well as the speed and direction of surface wind. They measure precipitation, temperature, and humidity. They note the type, amount, and height of cloud cover. Weather observers also record visibility and general weather conditions. Similar data are gathered continuously by automated observing systems. Each station in the system sends its data to a collection center. Weather centers around the world exchange the weather information they have collected.

The World Meteorological Organization (WMO) sponsors a program called *World Weather Watch* to promote the rapid exchange of weather information. This organization helps developing countries establish or improve their meteorological services, as shown in **Figure 1.** It also offers advice on the effect of weather on natural resources and on human activities, such as farming and transportation.

Figure 1 One major role of the World Meteorological Organization is to train professionals to use weather instruments, such as this Dobson spectrophotometer installed at Maun, Botswana.

Weather Maps

The data that weather stations collect are transferred onto weather maps. Weather maps allow meteorologists to understand the current weather and to predict future weather events. To communicate weather data on a weather map, meteorologists use symbols and colors. These symbols and colors are understood and used by meteorologists around the world.

Academic Vocabulary
communicate (kuh MYOO ni KAYT) make known; tell

Weather Symbols

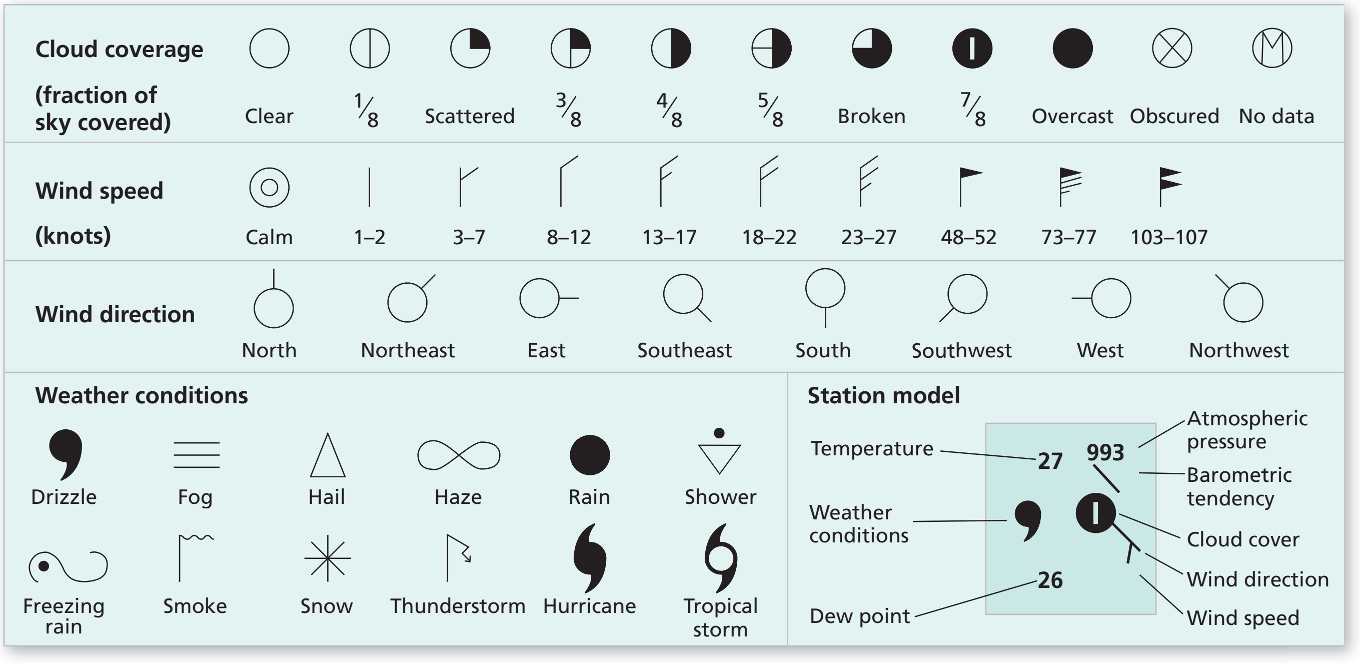
On some weather maps, clusters of meteorological symbols show weather conditions at the locations of weather stations. Such a cluster of symbols is called a **station model.** Common weather symbols describe cloud cover, wind speed, wind direction, and weather conditions, such as type of precipitation and storm activity. These symbols and a station model are shown in **Figure 2.** Notice that the symbols for cloud cover, wind speed, and wind direction are combined in one symbol in the station model.

station model a pattern of meteorological symbols that represents the weather at a particular observing station and that is recorded on a weather map

Other information included in the station model are the air temperature and the dew point. The *dew point* is the temperature at which the rate of condensation equals the rate of evaporation. The dew point indicates how high the humidity of the air is.

The station model also includes the atmospheric pressure, indicated by a three-digit number in the upper right-hand corner. The digits show pressure to the nearest tenth of a millibar (mb). Therefore you would add a 9 or a 10 to the beginning of the three-digit number to get the number nearest 1,000. For example, a value of 021 would be understood as 1,002.1 mb. A value of 987 would be understood as 998.7 mb. The position of a straight line under this figure—horizontal or angled up or down—shows whether the atmospheric pressure is steady or is rising or falling.

Figure 2 Meteorologists use symbols to indicate weather conditions. The station model (lower right) shows an example of conditions around a weather station.



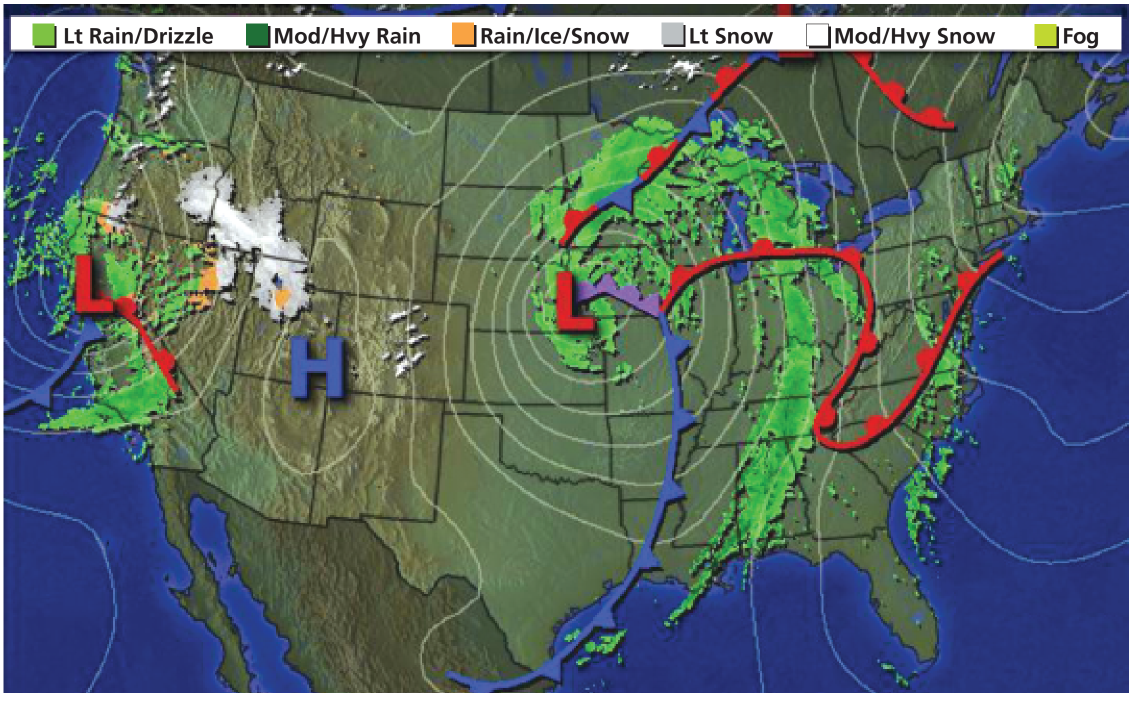


Figure 3 A typical weather map shows isobars, highs and lows, fronts, and precipitation. ***In what parts of the United States are low-pressure areas located?***

Plotting Temperature and Pressure

Scientists use lines on weather maps to connect points of equal measurement. Lines that connect points of equal temperature are called *isotherms*. Lines that connect points of equal atmospheric pressure are called *isobars*. The spacing and shape of the isobars help meteorologists interpret their observations about the speed and direction of the wind. Closely spaced isobars indicate a rapid change in pressure and high wind speeds. Widely spaced isobars generally indicate a gradual change in pressure and low wind speeds. Isobars that form circles indicate centers of high or low air pressure. Centers that are marked with an *H* represent high pressure, as you can see in **Figure 3.** Centers that are marked with an *L* represent low pressure.

Plotting Fronts and Precipitation

Most weather maps mark the locations of fronts and areas of precipitation. The weather map in **Figure 3** shows examples of a warm front, a cold front, an occluded front, and a stationary front. Fronts are identified by sharp changes in wind speed and direction, temperature, or humidity.

Areas of precipitation are commonly marked with colors or symbols. Different forms of precipitation are represented by different colors or symbols. For example, the weather map in **Figure 3** indicates light rain by using light green, and snow by using gray and white. Some weather maps use colors to represent different amounts of precipitation so the amounts of precipitation that fall in different areas can be compared.

Reading Check **How do meteorologists mark precipitation on a weather map?**

SCILINKS.
www.scilinks.org
Topic: Weather Maps
Code: **HQX1647**
Topic: Weather Forecasting
Code: **HQX1645**

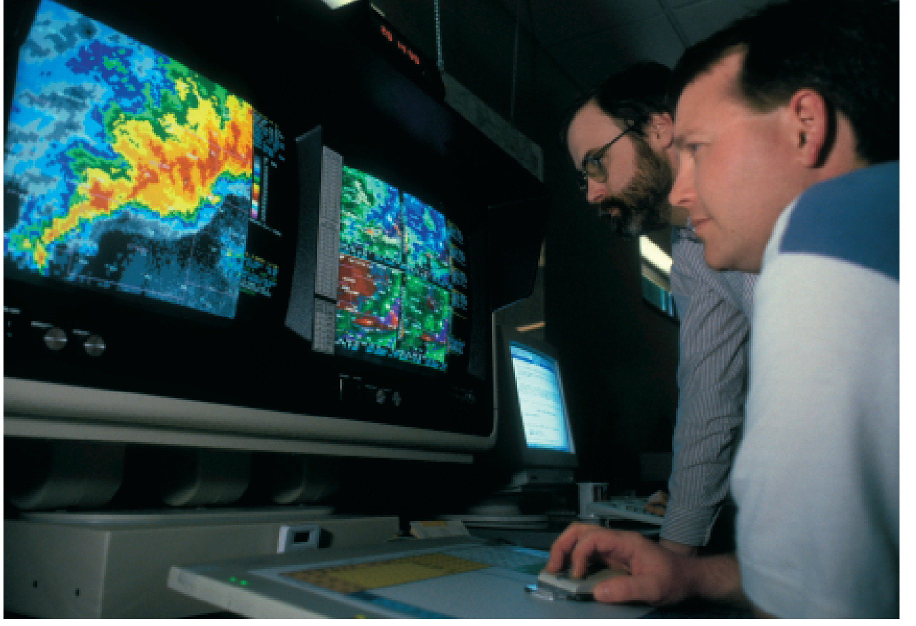


Figure 4 With the help of Doppler radar, meteorologists can track severe storms from radar stations, such as this one in Kansas.

Weather Forecasts

To forecast the weather, meteorologists use computers to plot the intensity and path of weather systems on maps. Meteorologists then study the most recent weather map and compare it with maps from previous hours. This comparison allows them to follow the progress of large weather systems. By following the progress of weather systems, meteorologists can forecast the weather.

Weather Data

Doppler radar, shown in **Figure 4,** and satellite images supply important information, such as intensity of precipitation. Meteorologists input these data into computers to create weather models. Computer models can show the possible weather conditions for several days. However, meteorologists must carefully interpret these models because computer predictions are based on generalized descriptions.

Some computer models may be better at predicting precipitation for a particular area, while other computer models may be better at predicting temperature and pressure. Comparing models helps meteorologists better predict weather. If weather information on two or more models is similar, a meteorologist will be more confident about a weather prediction. By using all the weather data available, meteorologists can issue an accurate forecast of the weather.

Temperature, wind direction, wind speed, cloudiness, and precipitation can usually be forecast accurately. But it is often difficult to predict precisely the time when precipitation will occur or the exact amount. By using computers, scientists can manipulate data on temperature and pressure to simulate errors in measuring these data. Forecasts are then compared to see if slight data changes cause substantial differences in forecasts. From what they learn, meteorologists can make more accurate forecasts.

Reading Check **Why do meteorologists compare models?**

Quick Lab

10 min

Gathering Weather Data

Procedure

1. Select an area that is outside your school building, in the shade and away from buildings and pavement.
2. Use a **thermometer** to measure the air temperature.
3. Estimate the percentage of cloud cover.
4. Estimate the wind speed. Use a **magnetic compass** to estimate the wind direction.

Analysis

1. What are the current weather conditions outside your school?
2. Using the data you collected, create a station model that describes the weather at your school.

Types of Forecasts

Meteorologists make four types of forecasts. *Nowcasts* mainly use radar and enable forecasters to focus on timing precipitation and tracking severe weather. *Daily forecasts* predict weather conditions for a 48-h period. *Extended forecasts* look ahead 3 to 5 days. *Medium-range forecasts* look ahead 3 to 7 days. *Long-range forecasts* look ahead at least 7 days and may cover monthly and seasonal periods.

Accurate weather forecasts can be made for 0 to 5 days. However, accuracy decreases with each day. Extended forecasts are made by computer analysis of slowly changing large-scale movements of air. These changes help meteorologists predict the general weather pattern. For example, the changes indicate if temperature will be warmer or cooler than normal or if conditions will be dry or wet.

READING TOOLBOX

Prefixes, Suffixes, and Root Words

The word *forecast* is part of several italicized terms on this page. It contains the prefix *fore-* and the root word *cast*. Use print or online sources to find the meanings of these word parts, and add the meanings to the table you started at the beginning of the chapter.

Severe Weather Watches and Warnings

One main goal of meteorology is to reduce the amount of destruction caused by severe weather by forecasting severe weather early. When meteorologists forecast severe weather, they issue warnings and watches. A *watch* is issued when the conditions are ideal for severe weather. A *warning* is given when severe weather has been spotted (thunderstorms or tornadoes) or is expected within 24 h (snowstorms or hurricanes). Meteorologists use these alerts to provide people in areas facing severe weather with instructions on how to be safer during the event. **Table 1** lists some safety tips to follow for different types of severe weather.

Table 1 Severe Weather Safety Tips

Type of weather	How to prepare	Safety during the event
Thunderstorm	Have a storm preparedness kit that includes a portable radio, fresh batteries, flashlights, rain gear, blankets, bottled water, canned food, and medicines.	Listen to weather updates. Stay or go indoors. Avoid electrical appliances, running water, metal pipes, and phone lines. If outside, avoid tall objects, stay away from bodies of water, and get into a car, if possible.
Tornado	Have a storm preparedness kit as described above. Plan and practice a safety route.	Listen to weather updates. Stay or go indoors. Go to a basement, storm cellar, or small, inner room, closet, or hallway that has no windows. Stay away from areas that are likely to have flying debris or other dangers. If outside, lie in a low-lying area. Protect your head and neck.
Hurricane	Have a storm preparedness kit as described above. Secure loose objects, doors, and windows. Plan and practice an evacuation route.	Listen to weather updates. Be prepared to follow instructions and planned evacuation routes. Stay indoors and away from areas that are likely to have flying debris or other dangers.
Blizzard	Have a storm preparedness kit as described above. Make sure that you have a way to make heat safely, in the event of power outages.	Listen to weather updates. Stay or go indoors. Dress warmly. Avoid walking or driving in icy conditions.

Figure 5 An outdoor ultra-high-voltage laboratory generates artificial lightning to test its effects on electrical utility equipment.

Controlling the Weather

Some meteorologists are investigating methods of controlling rain, hail, and lightning. Currently, the most researched method for producing rain has been *cloud seeding*. In this process, particles are added to clouds to cause the clouds to precipitate. Cloud seeding can also be used to prevent more-severe precipitation. Scientists in Russia have used cloud seeding, with some success, on potential hail clouds by causing rain, rather than hail, to fall.

Hurricane Control

Hurricanes have also been seeded with freezing nuclei in an effort to reduce their intensity. During Project Stormfury, which took place from 1962 to 1983, four hurricanes were seeded, and the project had mixed results. Scientists have, for the most part, abandoned storm and hurricane control because it is not an attainable goal with existing technology. They do, however, continue to seed clouds to cause precipitation.

Lightning Control

Attempts have also been made to control lightning. Seeding of potential lightning storms with silver-iodide nuclei has seemed to modify the occurrence of lightning. However, no conclusive results have been obtained. Researchers have generated artificial lightning at research facilities to learn more about lightning and how it affects objects it strikes. An example of one of these facilities is shown in **Figure 5.**

Section 4 Review

Key Ideas

1. **Summarize** how global weather is monitored.
2. **Explain** how a weather map is made.
3. **Explain** which would show stronger winds: widely spaced isobars or closely spaced isobars.
4. **List** six different pieces of information that you can obtain from a station model.
5. **Explain** why meteorologists compare new weather maps with weather maps that are 24 h old.
6. **Describe** how computer models help meteorologists forecast weather.
7. **List** three types of weather that meteorologists have tried to control.

Critical Thinking

8. **Making Inferences** Why might cloud seeding reduce the amount of hail from a storm?
9. **Making Reasoned Judgment** Seeding hurricanes may or may not yield positive results. Each attempt costs a lot of money. If you were in charge of deciding whether to seed a potentially dangerous hurricane, what factors would you consider when deciding what to do? Explain your answer.

Concept Mapping

10. Use the following terms to create a concept map: *isobar, isotherm, weather map, forecast, watch, warning, station model,* and *meteorological symbol.*

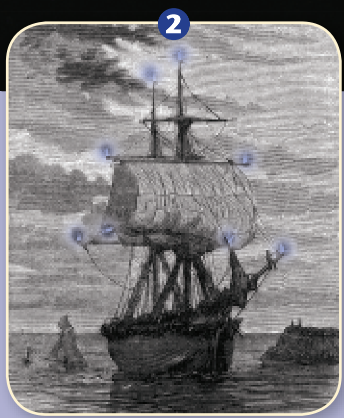
Why It Matters

When Lightning Strikes!

HISTORY IN SCIENCE

For thousands of years, most people believed that lightning was caused by the activities of various gods. American inventor Benjamin Franklin was the first person to propose that lightning was actually a giant electrical spark. In the 1750s, Franklin conducted several famous experiments, which involved flying kites in thunderstorms, to test his hypothesis.

1


2


3


1. In the mythology of the Aboriginals of northern Australia, Namarrgon the Lightning Man is a Creation Ancestor. The band from Namarrgon's head to his ankles represents the lightning he creates. **2.** Early sailors noticed a bluish glow, which they called St. Elmo's Fire, coming from the masts on their boats. The glow appeared before or after lightning storms. **3.** Franklin invented the first U.S. lightning rod. Placed on tall buildings, lightning rods channel electricity into the ground, keeping the building and the people inside safe.

YOUR TURN

UNDERSTANDING CONCEPTS

Who was the first person to relate lightning to electricity?

ONLINE RESEARCH

What is St. Elmo's Fire, and what causes it to form?

Skills Practice Lab

45 min

What You'll Do

- **Construct** a pressure and temperature map.
- **Interpret** a weather map.
- **Explain** how weather patterns are related to pressure systems.

What You'll Need

paper
pencil
pencils, red and blue

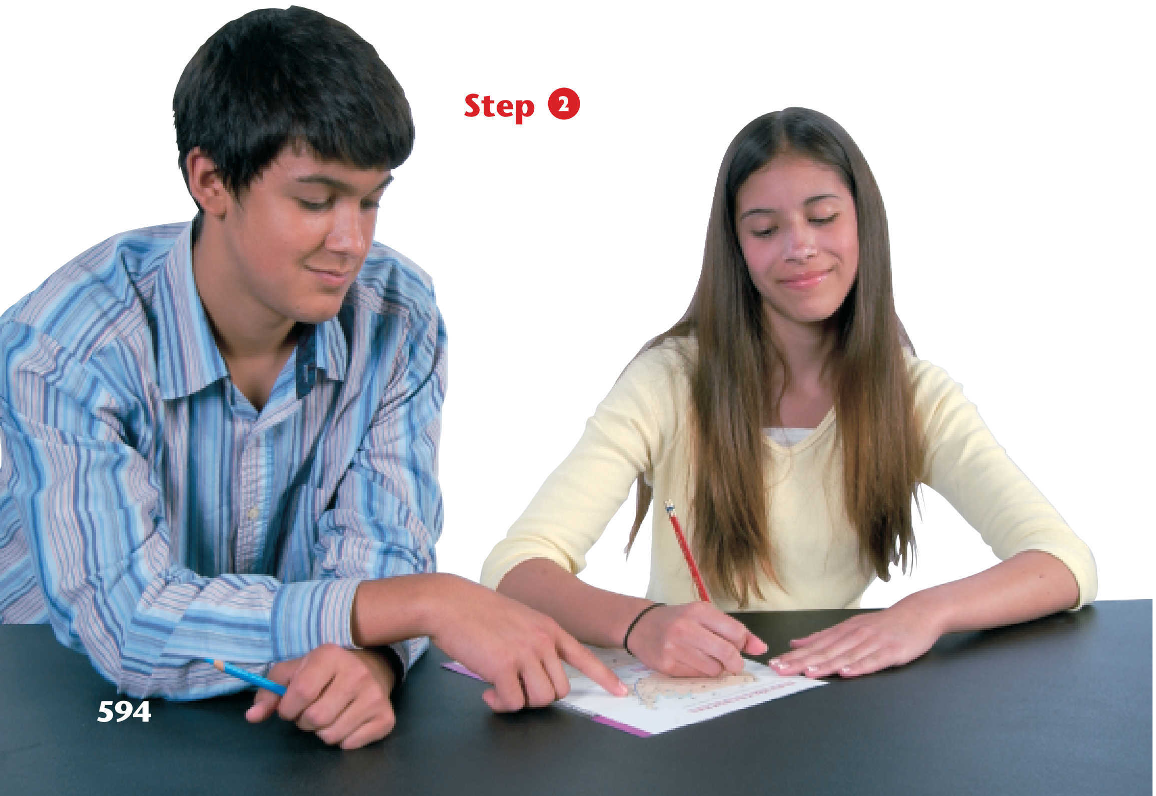
Weather Map Interpretation

Weather maps use various map symbols and lines to illustrate the weather conditions in an area at a given time. In this lab, you will study the symbols used on a weather map to gain an understanding of the relationships between temperature, pressure, and winds.

Procedure

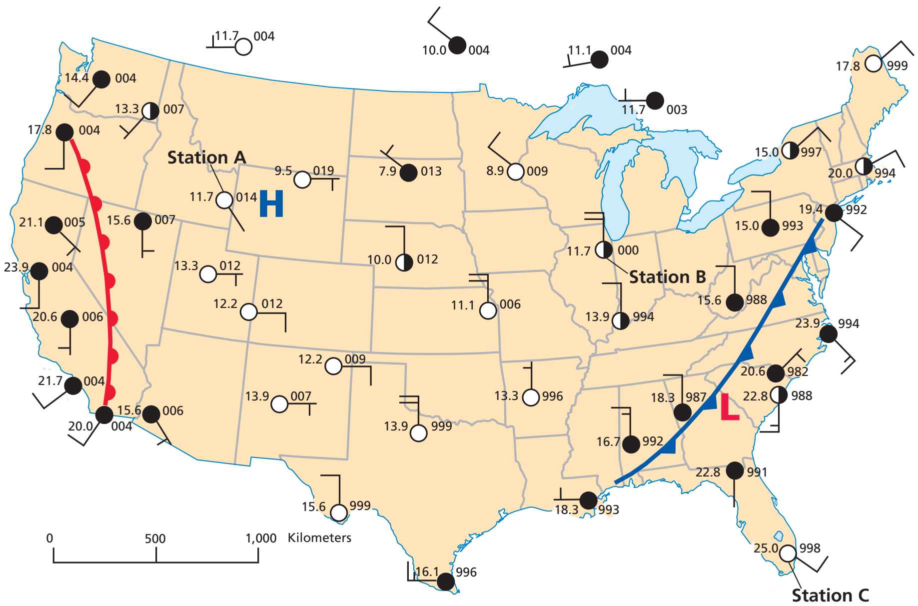
1. Make a copy of the weather map on the following page. You may want to copy a larger version of this map, which can be found in Appendix E. You will use the map symbols on the same page of the Appendix to interpret the weather map. The number on the right of each station on the map represents atmospheric pressure. The number on the left represents temperature.
2. On your copy of the weather map, find stations that have a temperature of 10.0 °C. Use a red pencil to draw a light line through these stations. If two adjacent stations have temperatures above and below 10 °C, there is an estimated point between them that is 10.0 °C. Draw a line through these estimated points to connect the stations that have temperatures of 10.0 °C with an isotherm. Label the isotherm 10 °C.
3. Using the same method as in step 2, draw isotherms for every two degrees of temperature. Examples are isotherms of 12.0 °C, 14.0 °C, and 16.0 °C. Label each isotherm with the temperature it represents.

Step 2



4 Find a station that has a barometric pressure of 1,001.2 mb (millibars), marked 012. Use a blue pencil, and follow the same method that you used in step 2 to create a 1,001.2 mb isobar.

5 Using the same method as in step 3, lightly draw isobars for every few millibars of pressure. Examples are isobars of 1,000.6 mb, 1,000.4 mb, and 994 mb. Label each isobar with the pressure it represents.



Analysis

1. **Identifying Trends** What is the lowest temperature for which you have drawn an isotherm? What is the highest temperature for which you have drawn an isotherm? Is either isotherm a closed loop? If so, which one?

2. **Making Inferences** Is the air mass that is identified by the closed isotherm a cold air mass or a warm air mass? Explain your answer.

3. **Analyzing Data** Is there a shift in wind direction associated with either front shown on your map? Describe the shift.

4. **Identifying Trends** What is the value of the lowest-pressure isobar that you drew? What is the value of the highest-pressure isobar that you drew? Is either isobar a closed loop? If so, which one?

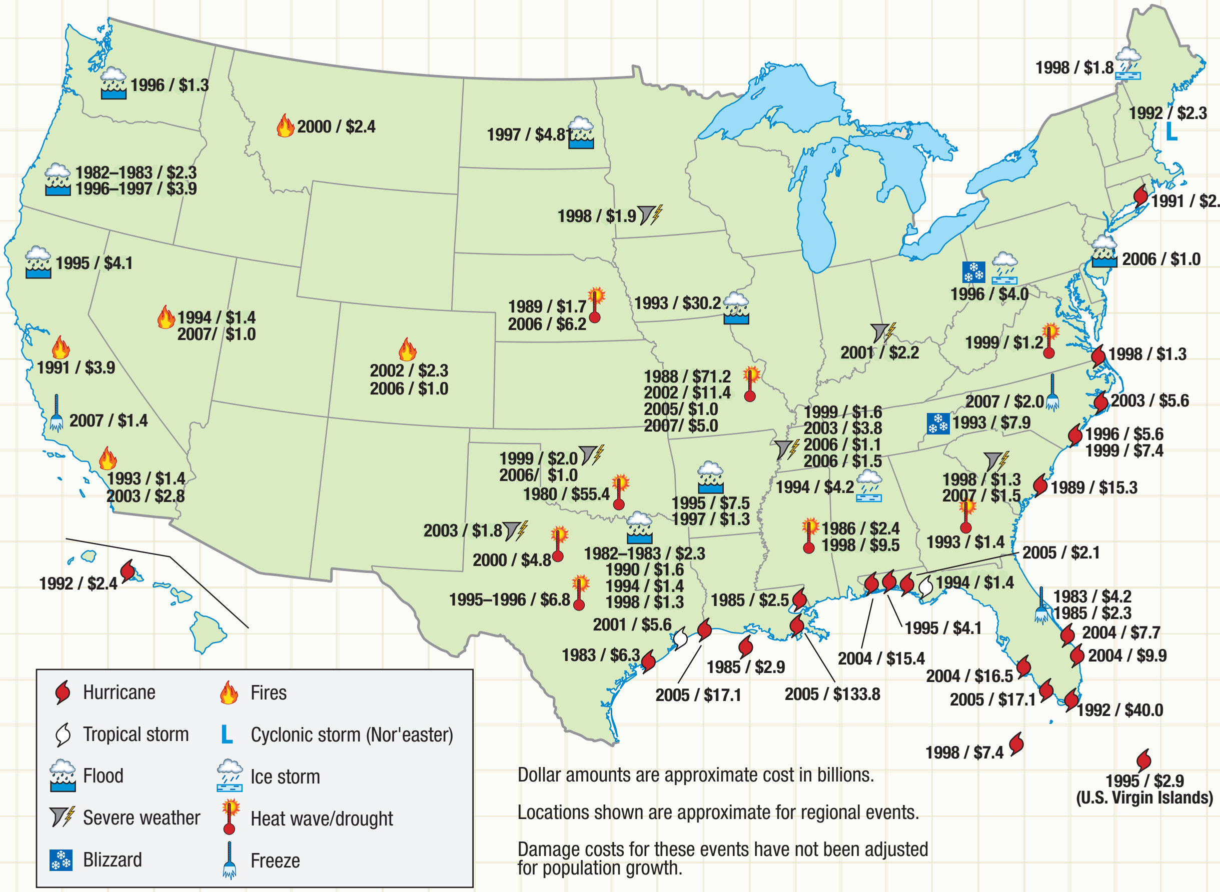
5. **Drawing Conclusions** At the time that the map represents, were there any areas of low pressure? Were there any areas of high pressure? Identify these areas. What weather conditions would you expect to find in these areas?

Extension

Making Predictions Predict the weather conditions at Station A 24 h after the observations for your map were made. Record your predictions in a table with columns for pressure, wind direction, wind speed, temperature, and sky condition. Also, make and record predictions for Station B and Station C.

MAPS in Action

Weather-Related Disasters



Map Skills Activity

This map shows the types and locations of weather disasters that caused at least $1 billion in damage in the United States. Use the map to answer the questions below.

1. **Using a Key** According to the map, how many severe weather events caused more than $10 billion in damage?
2. **Analyzing Data** Which type of weather disaster is more common: floods or fires?
3. **Making Comparisons** How do the types of disasters that happen in the western United States differ from the types of disasters that happen in the eastern United States? Explain why this difference exists.
4. **Inferring Relationships** Why might an ice storm in Alabama cause more damage than an ice storm in Maine?
5. **Identifying Trends** Almost all hurricane damage during this period happened along the coasts of the Atlantic Ocean and the Gulf of Mexico. Explain why.
6. **Analyzing Relationships** In 1996, a blizzard and floods caused $4.0 billion in damage in Ohio, Pennsylvania, and West Virginia. How might these events be related? Explain your answer.
7. **Analyzing Processes** Explain why fires are included in this map of weather-related disasters.

Chapter 21 Summary

THINK central
SUPER SUMMARY
Keyword: HQXWTHS

Section 1

Air Masses

Key Ideas

- An air mass forms when air remains stationary or moves slowly over a uniform region, taking on the characteristic temperature and humidity of that region.
- The four main types of air masses are polar, tropical, continental, and maritime.
- Air masses affect the weather by bringing air that is warm or cold, and dry or moist, to a region. Tropical air masses bring mild weather in the winter, and polar air masses bring cool weather in the summer.

Key Terms

air mass, p. 571

Section 2

Fronts

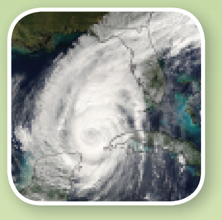
Key Ideas

- Cold fronts usually produce short-lived storms. Warm fronts usually produce precipitation over a large area.
- A midlatitude cyclone forms along a cold or stationary front, in which rotating wind moves toward a low-pressure center.
- Thunderstorms and tornadoes are caused by the interaction of air masses that have different properties. Hurricanes develop when warm, moist air over the ocean rises rapidly.

Key Terms

cold front, p. 575
warm front, p. 576
stationary front, p. 576
occluded front, p. 576
midlatitude cyclone, p. 576
thunderstorm, p. 578
hurricane, p. 579
tornado, p. 582

Section 3



Weather Instruments

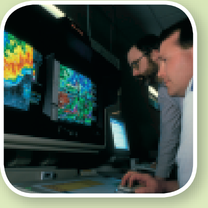
Key Ideas

- Thermometers, barometers, anemometers, and wind vanes measure lower-atmospheric weather conditions.
- Radiosondes, radar, and satellite equipment measure upper-atmospheric weather conditions.
- Computers are used to solve complicated mathematical equations that describe weather.

Key Terms

thermometer, p. 583
barometer, p. 584
anemometer, p. 584
wind vane, p. 584
radiosonde, p. 585
radar, p. 585

Section 4



Forecasting the Weather

Key Ideas

- Each weather station sends data to a collection center.
- Meteorologists prepare weather maps that are based on information from weather stations around the world.
- Computer models predict weather conditions for several days.
- Meteorologists have attempted to control rain, hurricanes, and lightning with only limited success.

Key Terms

station model, p. 588

Chapter 21 Review

1. **Prefixes, Suffixes, and Root Words** Look over the table of prefixes, suffixes, and root words that you made while reading this chapter. Identify the word parts that were used most often. Why were these word parts used so often in this chapter?

READING TOOLBOX

USING KEY TERMS

Use each of the following terms in a separate sentence.

2. *air mass*
3. *stationary front*
4. *station model*

For each pair of terms, explain how the meanings of the terms differ.

5. *midlatitude cyclone* and *hurricane*
6. *wind vane* and *anemometer*
7. *radiosonde* and *radar*
8. *cold front* and *warm front*
9. *thermometer* and *barometer*

UNDERSTANDING KEY IDEAS

10. Which of the following is information you would not find in a station model?
    a. precipitation
    b. cloud cover
    c. front
    d. wind speed
11. Continental polar Canadian air masses generally move
    a. southeasterly.
    b. northerly.
    c. northeasterly.
    d. westerly.
12. The type of front that forms when two air masses move parallel to the front between them is called
    a. stationary.
    b. occluded.
    c. polar.
    d. warm.
13. The type of front that forms when warm air is completely lifted off the ground by cold air is called
    a. cold.
    b. occluded.
    c. polar.
    d. warm.
14. The eye of a hurricane is a region of
    a. hailstorms.
    b. torrential rainfall.
    c. calm, clear air.
    d. strong winds.
15. The wind of a midlatitude cyclone blows in a circular path around a
    a. front.
    b. low-pressure center.
    c. high-pressure center.
    d. jet stream.
16. In the mature stage of a thunderstorm, a cumulus cloud grows until it becomes a
    a. stratocumulus cloud.
    b. altocumulus cloud.
    c. cumulonimbus cloud.
    d. cirrocumulus cloud.
17. An instrument package attached to a weather balloon is
    a. an anemometer.
    b. a wind vane.
    c. a thermograph.
    d. a radiosonde.
18. The lines that connect points of equal atmospheric pressure on a weather map are called
    a. isobars.
    b. isotherms.
    c. highs.
    d. lows.

SHORT ANSWER

19. Describe the weather before and after an occluded front.
20. What causes lightning?
21. What is the most likely location for hurricane development? Explain your answer.
22. How could a meteorologist use a station model to determine whether a cold front is approaching?
23. Identify the wind direction of wind given as 315°. What direction would a wind vane point in this case?
24. Identify the type of air mass that is most likely responsible if the air in your area is warm and dry. What letters designate this air mass?

CRITICAL THINKING

25. Making Predictions Suppose that people on Vancouver Island, off the west coast of Canada, hear reports of a midlatitude cyclone in the Gulf of Alaska. Is it likely that this midlatitude cyclone will reach their area? Explain why.

26. Making Inferences Suppose that a hurricane is passing over a Caribbean island. Suddenly, the rain and wind stop and the air becomes calm and clear. Can a person living on that island safely go outside? Explain your answer.

27. Applying Ideas Is it safe to be in an automobile during a tornado? Explain your answer.

28. Making Inferences An air traffic controller is monitoring nearby airplanes by radar. The controller warns an incoming pilot of a storm that is a few miles away. How did radar help the controller detect the storm?

CONCEPT MAPPING

29. Use the following terms to create a concept map: *air mass, front, warm front, cold front, cyclone, thunderstorm, thermometer, hurricane, barometer,* and *anemometer.*

MATH SKILLS

Math Skills

30. Making Calculations The temperature at a weather station is given as 47°F. Using the equation °C = 5/9 × (°F − 32), find the temperature in degrees Celsius.

31. Making Calculations An average of 124 tornadoes occur each year in Texas. If this is equivalent to 4.7 tornadoes per 10,000 square miles, what is the area of Texas in square miles?

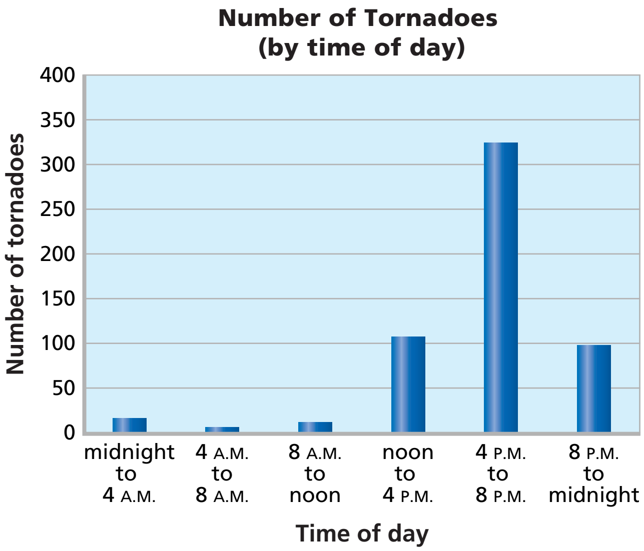
WRITING SKILLS

32. Creative Writing Imagine that you are traveling with friends through the desert in the southwestern United States and a thunderstorm occurs. You tell your friends about the type of front that may have brought the storm. Describe what the stages might look like by types of clouds formed, types of precipitation, and sky color.

33. Communicating Main Ideas Explain how cP and mT air masses travel across the United States, and explain why this information helps meteorologists make forecasts.

INTERPRETING GRAPHICS

The graph below shows the average number of tornadoes that generally occur at different times of day. Use this graph to answer the questions that follow.



34. During which time of day do the least tornadoes occur?

35. Would students be more likely to experience a tornado while they are at school or while they are at home?

36. During which time of day do most tornadoes occur? Why would most tornadoes occur at this time of day?

Chapter 21

Standardized Test Prep

Understanding Concepts

Directions (1–5): For each question, write on a separate sheet of paper the letter of the correct answer.

1. What tool do meteorologists use to analyze particle movements within storms?
- **A.** an anemometer
- **B.** a radiosonde
- **C.** doppler radar
- **D.** satellite imaging

2. What kind of front forms when two air masses move parallel to the boundary located between them?
- **F.** an occluded front
- **G.** a polar front
- **H.** a warm front
- **I.** a stationary front

3. Which of the following weather systems commonly forms over warm tropical oceans?
- **A.** midlatitude cyclones
- **B.** hurricanes
- **C.** tornadoes
- **D.** anticyclones

4. What often happens to maritime air masses as they move inland over mountainous country?
- **F.** They bring warm, dry weather conditions.
- **G.** They produce clouds and hurricanes.
- **H.** They bring cold, dry weather conditions.
- **I.** They lose moisture passing over mountains.

5. What type of air mass originates over the southwestern desert of the United States in summer?
- **A.** continental polar air mass
- **B.** continental tropical air mass
- **C.** maritime polar air mass
- **D.** maritime tropical air mass

Directions (6–7): For each question, write a short response.

6. What type of front is formed when a warm air mass is overtaken by a cold air mass, which causes the warm air to lift above the cold air?

7. What do closely spaced isobars indicate about the wind on a weather map?

Reading Skills

Directions (8–10): Read the passage below. Then, answer the questions.

Tornado Alley

Although tornadoes are not unique to the area, the violent, rotating, funnel-shaped clouds and their trails of destruction are so common in the central United States that the area is called Tornado Alley. Severe thunderstorms and the super-cell tornadoes that they spawn are formed when warm, moist air from the Gulf of Mexico becomes trapped beneath hot, dry air from the southwest desert region. Above the hot, dry air, cold, dry air sweeps in from the Rocky Mountains. The interaction between high-altitude winds and thunderstorms creates the funnel-shaped vortex of high-speed winds known as a tornado.

The largest outbreak of tornadoes in this region occurred in April of 1974. Before the storms ended, 148 separate tornadoes roared through 13 different states. More than 300 people lost their lives, and another 5,000 people were injured. More than 1,300 buildings were destroyed.

8. Why is the central part of the United States known as Tornado Alley?
- **F.** Tornadoes in this part of the country move in straight lines known as alleys.
- **G.** The destruction left by tornadoes makes this part of the country look like an unkempt alley.
- **H.** Areas between buildings are the safest places to be during of a tornado.
- **I.** Tornadoes are a common occurrence in this part of the country.

9. Which of the following statements can be inferred from the information in the passage?
- **A.** In the United States, tornadoes are more common in some areas than in other areas.
- **B.** Tornadoes can form only in the area near the Rocky Mountains.
- **C.** All tornadoes cause injuries to humans.
- **D.** Multiple tornadoes are a rare occurrence.

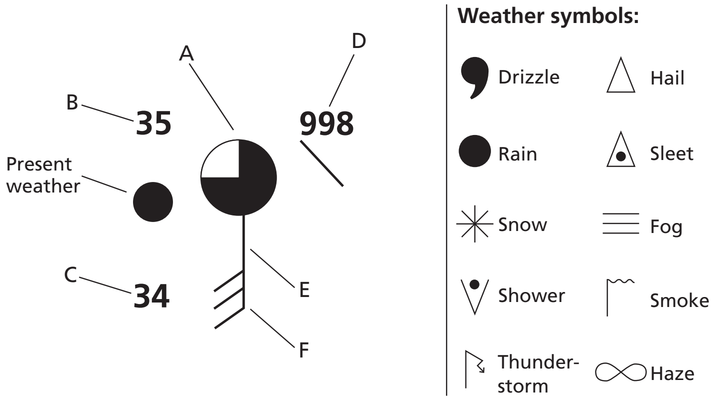
10. What makes tornadoes so much more difficult to predict than other severe weather systems?

Interpreting Graphics

Directions (11–14): For each question below, record the correct answer on a separate sheet of paper.

The diagram below shows a station model. Use this diagram to answer questions 11 and 12.

Interpreting a Station Model



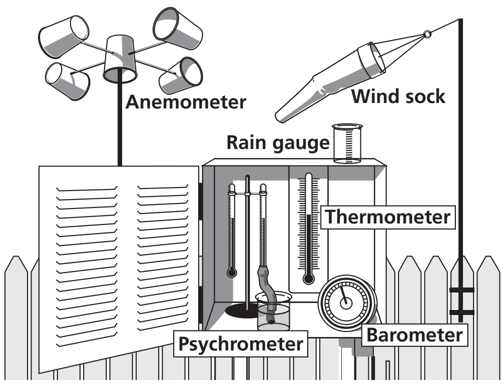
11. What letter in the station model represents the current barometric reading?

F. letter A
G. letter B
H. letter C
I. letter D

12. What weather information do the symbols indicated by the letters E and F provide? Interpret this part of the station model.

The diagram below shows a home weather station. Use this diagram to answer questions 13 and 14.

Weather Instruments



13. Which of the following weather instruments shown measures atmospheric pressure?

A. a rain gauge
B. a barometer
C. a wind sock
D. a thermometer

14. Describe how an anemometer is used to calculate wind speed.

Test Tip

Sometimes, only one part of a diagram, graph, or table is needed to answer a question. In such cases, focus on only that information to answer the question.