2 Understanding Weather

About the PHOTO

Flamingos in the bathroom? This may look like someone's idea of a practical joke, but in fact, it's a practical idea! These flamingos reside at the Miami-Metro Zoo in Florida. They were put in the bathroom for protection against the incredibly dangerous winds of Hurricane Floyd in September of 1999.

PI[redacted] ACTIVITY

FOLDNOTES

Four-Corner Fold

Before you read the chapter, create the FoldNote entitled "Four-Corner Fold" described in the **Study Skills** section of the Appendix. Label the flaps of the four-corner fold with "Water in the air," "Air masses and fronts," "Severe weather," and "Forecasting the weather." Write what you know about each topic under the appropriate flap. As you read the chapter, add other information that you learn.

START-UP ACTIVITY

Meeting of the Masses

In this activity, you will model what happens when two air masses that have different temperature characteristics meet.

Procedure

1. Pour **500 mL of water** into a **beaker.** Pour **500 mL of cooking oil** into a **second beaker.** The water represents a dense cold air mass. The cooking oil represents a less dense warm air mass.
2. Predict what would happen to the two liquids if you tried to mix them.
3. Pour the contents of both beakers into a **clear, plastic, rectangular container** at the same time from opposite ends of the container.
4. Observe the interaction of the oil and water.

Analysis

1. What happens when the liquids meet?
2. Does the prediction that you made in step 2 of the Procedure match your results?
3. Using your results, hypothesize what would happen if a cold air mass met a warm air mass.

SECTION 1

Water in the Air

What will the weather be this weekend? Depending on what you have planned, knowing the answer to this question could be important. A picnic in the rain can be a mess!

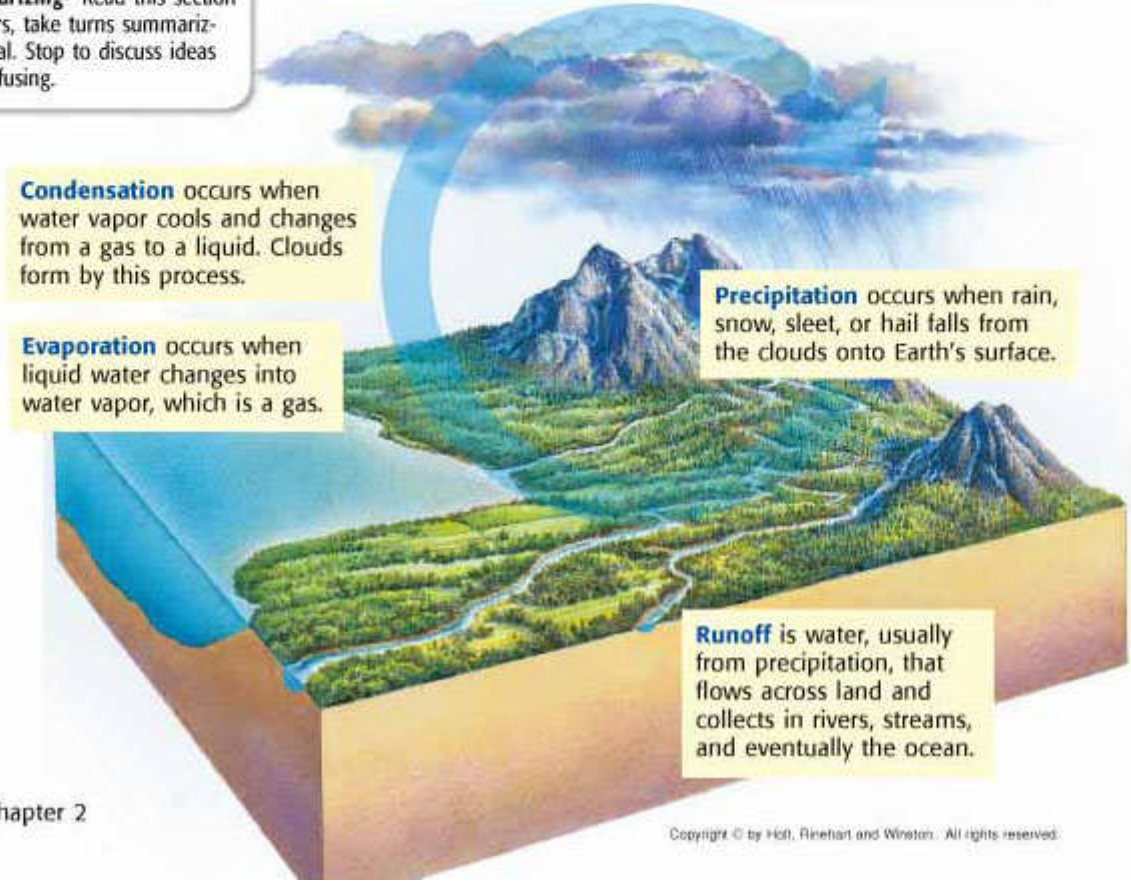
Have you ever wondered what weather is? **Weather** is the condition of the atmosphere at a certain time and place. The condition of the atmosphere is affected by the amount of water in the air. So, to understand weather, you need to understand how water cycles through Earth's atmosphere.

The Water Cycle

Water in liquid, solid, and gaseous states is constantly being recycled through the water cycle. The *water cycle* is the continuous movement of water from sources on Earth's surface—such as lakes, oceans, and plants—into the air, onto and over land, into the ground, and back to the surface. The movement of water through the water cycle is shown in **Figure 1.**

Reading Check **What is the water cycle?** (*See the Appendix for answers to Reading Checks.*)

Figure 1 **The Water Cycle**



READING WARM-UP

Objectives

- Explain how water moves through the water cycle.
- Describe how relative humidity is affected by temperature and levels of water vapor.
- Describe the relationship between dew point and condensation.
- List three types of cloud forms.
- Identify four kinds of precipitation.

Terms to Learn

weather
humidity
relative humidity
condensation
cloud
precipitation

READING STRATEGY

Paired Summarizing Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.

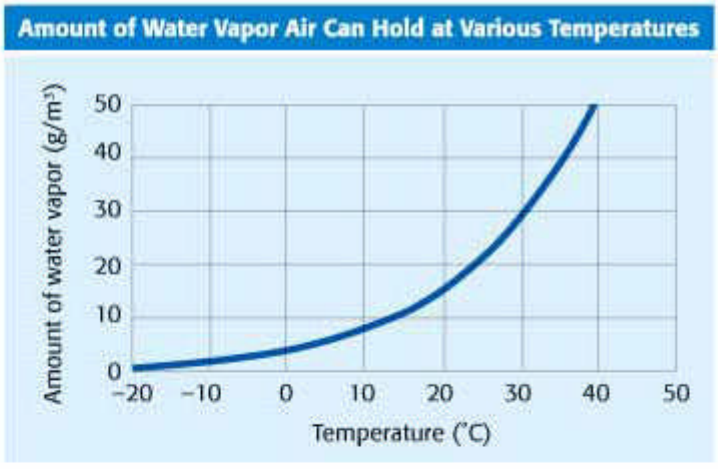


Figure 2 *This graph shows that as air gets warmer, the amount of water vapor that the air can hold increases.*

Humidity

As water evaporates from lakes, oceans, and plants, it becomes *water vapor,* or moisture in the air. Water vapor is invisible. The amount of water vapor in the air is called **humidity.** As water evaporates and becomes water vapor, the humidity of the air increases. The air's ability to hold water vapor changes as the temperature of the air changes. **Figure 2** shows that as the temperature of the air increases, the air's ability to hold water vapor also increases.

weather the short-term state of the atmosphere, including temperature, humidity, precipitation, wind, and visibility

humidity the amount of water vapor in the air

relative humidity the ratio of the amount of water vapor in the air to the maximum amount of water vapor the air can hold at a set temperature

Relative Humidity

One way to express humidity is through relative humidity. **Relative humidity** is the amount of water vapor in the air compared with the maximum amount of water vapor that the air can hold at a certain temperature. So, relative humidity is given as a percentage. When air holds all of the water that it can at a given temperature, it is said to be *saturated.* Saturated air has a relative humidity of 100%. But how do you find the relative humidity of air that is not saturated? If you know the maximum amount of water vapor that air can hold at a given temperature and the actual amount of water vapor in the air, you can calculate the relative humidity.

Suppose that 1 m^3 of air at a certain temperature can hold 24 g of water vapor. However, you know that the air actually contains 18 g of water vapor. You can calculate the relative humidity by using the following formula:

$$\frac{\textit{actual water vapor content } (g/m^3)}{\textit{saturation water vapor content } (g/m^3)} \times 100 = \textit{relative humidity } (\%)$$

$$\frac{18\ g/m^3}{24\ g/m^3} = 75\%$$

MATH PRACTICE

Relative Humidity

Assume that 1 m^3 of air at 25°C contains 11 g of water vapor. At this temperature, the air can hold 24 g/m^3 of water vapor. Calculate the relative humidity of the air.

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HZ5WEAW.**

Factors Affecting Relative Humidity

Two factors that affect relative humidity are amount of water vapor and temperature. At constant temperature and pressure, as the amount of water vapor in air changes, the relative humidity changes. The more water vapor there is in the air, the higher the relative humidity is. If the amount of water vapor in the air stays the same but the temperature changes, the relative humidity changes. The relative humidity decreases as the temperature rises and increases as the temperature drops.

Measuring Relative Humidity

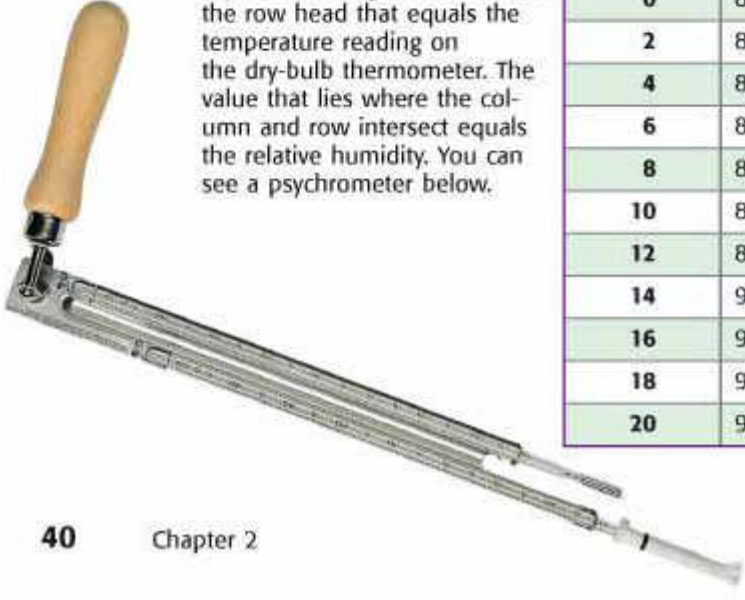
A *psychrometer* (sie KRAHM uht uhr) is an instrument that is used to measure relative humidity. A psychrometer consists of two thermometers, one of which is a wet-bulb thermometer. The bulb of a wet-bulb thermometer is covered with a damp cloth. The other thermometer is a dry-bulb thermometer.

The difference in temperature readings between the thermometers indicates the amount of water vapor in the air. The larger the difference between the two readings is, the less water vapor the air contains and thus the lower the humidity is. **Figure 3** shows how to use a table of differences between wet-bulb and dry-bulb readings to determine relative humidity.

Reading Check **What tool is used to measure relative humidity?**

Figure 3 **Determining Relative Humidity**

Find the relative humidity by locating the column head that is equal to the difference between the wet-bulb and dry-bulb readings. Then, locate the row head that equals the temperature reading on the dry-bulb thermometer. The value that lies where the column and row intersect equals the relative humidity. You can see a psychrometer below.



Relative Humidity (%)								
Dry-bulb reading (°C)	Difference between wet-bulb reading and dry-bulb reading (°C)							
	1	2	3	4	5	6	7	8
0	81	64	46	29	13			
2	84	68	52	37	22	7		
4	85	71	57	43	29	16		
6	86	73	60	48	35	24	11	
8	87	75	63	51	40	29	19	8
10	88	77	66	55	44	34	24	15
12	89	78	68	58	48	39	29	21
14	90	79	70	60	51	42	34	26
16	90	81	71	63	54	46	38	30
18	91	82	73	65	57	49	41	34
20	91	83	74	66	59	51	44	37

How a Wet-Bulb Thermometer Works

A wet-bulb thermometer works differently than a dry-bulb thermometer, which measures only air temperature. As air passes over the wet-bulb thermometer, the water in the cloth evaporates. As the water evaporates, the cloth cools. If the humidity is low, the water will evaporate more quickly and the temperature reading on the wet-bulb thermometer will drop. If the humidity is high, only a small amount of water will evaporate from the cloth of the wet-bulb thermometer and the change in temperature will be small.

Reading Check **Explain how a wet-bulb thermometer works.**

Condensation

You have probably seen water droplets form on the outside of a glass of ice water, as shown in **Figure 4.** Where did those water drops come from? The water came from the surrounding air, and droplets formed as a result of condensation. **Condensation** is the process by which a gas, such as water vapor, becomes a liquid. Before condensation can occur, the air must be saturated, which means that the air must have a relative humidity of 100%. Condensation occurs when saturated air cools.

Figure 4 *Condensation occurred when the air next to the glass cooled to its dew point.*

Dew Point

Air can become saturated when water vapor is added to the air through evaporation. Air can also become saturated when it cools to its dew point. The *dew point* is the temperature at which a gas condenses into a liquid. At its dew point, air is saturated. The ice in the glass of water causes the air surrounding the glass to cool to its dew point.

Before water vapor can condense, though, it must have a surface to condense on. In the case of the glass of ice water, water vapor condenses on the outside of the glass.

condensation the change of state from a gas to a liquid

Out of Thin Air

1. Pour **room-temperature water** into a **plastic container,** such as a drinking cup, until the water level is near the top of the cup.
2. Observe the outside of the container, and record your observations.
3. Add **one or two ice cubes** to the container of water.
4. Watch the outside of the container for any changes.
5. What happened to the outside of the container?
6. What is the liquid on the container?
7. Where did the liquid come from? Explain your answer.

Figure 5 Three Forms of Clouds

Cumulus clouds look like piles of cotton balls.

Stratus clouds are not as tall as cumulus clouds, but they cover more area.

Cirrus clouds are made of ice crystals.

cloud a collection of small water droplets or ice crystals suspended in the air, which forms when the air is cooled and condensation occurs

Clouds

Have you ever wondered what clouds are and how they form? A **cloud** is a collection of millions of tiny water droplets or ice crystals. Clouds form as warm air rises and cools. As the rising air cools, it becomes saturated. When the air is saturated, the water vapor changes to a liquid or a solid, depending on the air temperature. At temperatures above freezing, water vapor condenses on small particles in the air and forms tiny water droplets. At temperatures below freezing, water vapor changes to a solid to form ice crystals. Clouds are classified by form, as shown in **Figure 5,** and by altitude.

Cumulus Clouds

Puffy, white clouds that tend to have flat bottoms are called *cumulus clouds* (KYOO myoo luhs KLOWDZ). Cumulus clouds form when warm air rises. These clouds generally indicate fair weather. However, when these clouds get larger, they produce thunderstorms. Thunderstorms come from a kind of cumulus cloud called a *cumulonimbus cloud* (KYOO myoo loh NIM buhs KLOWD). Clouds that have names that include *-nimbus* or *nimbo-* are likely to produce precipitation.

Stratus Clouds

Clouds called *stratus clouds* (STRAYT uhs KLOWDZ) are clouds that form in layers. Stratus clouds cover large areas of the sky and often block out the sun. These clouds can be caused by a gentle lifting of a large body of air into the atmosphere. *Nimbostratus clouds* (NIM boh STRAYT uhs KLOWDZ) are dark stratus clouds that usually produce light to heavy, continuous rain. *Fog* is a stratus cloud that has formed near the ground.

CONNECTION TO Language Arts

Cloud Clues Did you know that the name of a cloud actually describes the characteristics of the cloud? For example, the word *cumulus* comes from the Latin word meaning "heap." A cumulus cloud is a puffy, white cloud, which could be described as a "heap" of clouds. Use a dictionary or the Internet to find the word origins of the names of the other cloud types you learn about in this section.

Cirrus Clouds

As you can see in **Figure 5,** *cirrus clouds* (SIR uhs KLOWDZ) are thin, feathery, white clouds found at high altitudes. Cirrus clouds form when the wind is strong. If they get thicker, cirrus clouds indicate that a change in the weather is coming.

Clouds and Altitude

Clouds are also classified by the altitude at which they form. **Figure 6** shows two altitude groups used to describe clouds and the altitudes at which they form in the middle latitudes. The prefix *cirro-* is used to describe clouds that form at high altitudes. For example, a cumulus cloud that forms high in the atmosphere is called a *cirrocumulus cloud*. The prefix *alto-* describes clouds that form at middle altitudes. Clouds that form at low altitudes do not have a specific prefix to describe them.

Reading Check **At what altitude does an altostratus cloud form?**

Figure 6 **Cloud Types Based on Form and Altitude**

High Clouds Because of the cold temperatures at high altitude, high clouds are made up of ice crystals. The prefix *cirro-* is used to describe high clouds.

Middle Clouds Middle clouds can be made up of both water drops and ice crystals. The prefix *alto-* is used to describe middle clouds.

Low Clouds Low clouds are made up of water drops. There is no specific prefix used to describe low clouds.

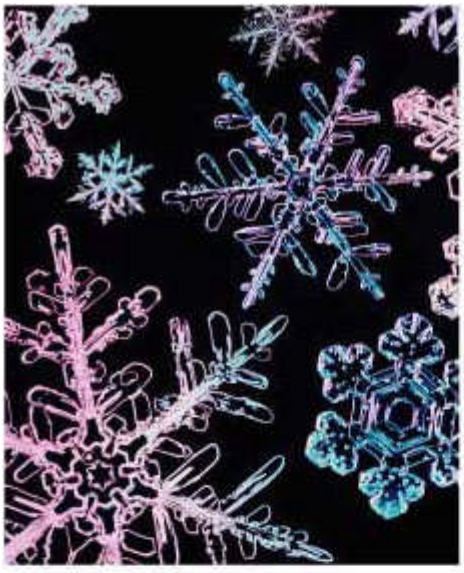


Figure 7 *Snowflakes are six-sided ice crystals that can be several millimeters to several centimeters in size.*

Precipitation

When water from the air returns to Earth's surface, it returns as precipitation. **Precipitation** is water, in solid or liquid form, that falls from the air to Earth. There are four major forms of precipitation—rain, snow, sleet, and hail.

Rain

The most common form of precipitation is *rain*. A cloud produces rain when the water drops in the cloud become large enough to fall. A water drop in a cloud begins as a droplet that is smaller than the period at the end of this sentence. Before such a water drop falls as rain, it must become about 100 times its original size.

Sleet and Snow

Sleet forms when rain falls through a layer of freezing air. The rain freezes in the air, which produces falling ice. *Snow* forms when temperatures are so cold that water vapor changes directly to a solid. Snow can fall as single ice crystals or can join to form snowflakes, as shown in **Figure 7.**

Hail

Balls or lumps of ice that fall from clouds are called *hail*. Hail forms in cumulonimbus clouds. When updrafts of air in the clouds carry raindrops high in the clouds, the raindrops freeze and hail forms. As hail falls, water drops coat it. Another updraft of air can send the hail up again. Here, the water drops collected on the hail freeze to form another layer of ice on the hail. This process can happen many times. Eventually, the hail becomes too heavy to be carried by the updrafts and so falls to Earth's surface, as shown in **Figure 8.**

precipitation any form of water that falls to the Earth's surface from the clouds

Figure 8 *The impact of large hailstones can damage property and crops. The inset photograph shows layers inside of a hailstone, which reveal how it formed.*

SECTION
Review

Summary

- Weather is the condition of the atmosphere at a certain time and place. Weather is affected by the amount of water vapor in the air.
- The water cycle describes the movement of water above, on, and below Earth's surface.
- Humidity describes the amount of water vapor in the air. Relative humidity is a way to express humidity.
- When the temperature of the air cools to its dew point, the air has reached saturation and condensation occurs.
- Clouds form as air cools to its dew point. Clouds are classified by form and by the altitude at which they form.
- Precipitation occurs when the water vapor that condenses in the atmosphere falls back to Earth in solid or liquid form.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *relative humidity*, *condensation*, *cloud*, and *precipitation*.

Understanding Key Ideas

2. Which of the following clouds is most likely to produce light to heavy, continuous rain?
   - **a.** cumulus cloud
   - **b.** cumulonimbus cloud
   - **c.** nimbostratus cloud
   - **d.** cirrus cloud
3. How is relative humidity affected by the amount of water vapor in the air?
4. What does a relative humidity of 75% mean?
5. Describe the path of water through the water cycle.
6. What are four types of precipitation?

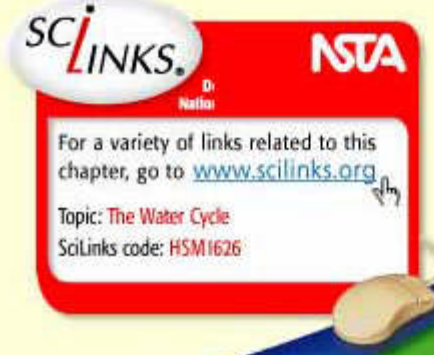
Critical Thinking

7. **Applying Concepts** Why are some clouds formed from water droplets, while others are made up of ice crystals?
8. **Applying Concepts** How can rain and hail fall from the same cumulonimbus cloud?
9. **Identifying Relationships** What happens to relative humidity as the air temperature drops below the dew point?

Interpreting Graphics

Use the image below to answer the questions that follow.

10. What type of cloud is shown in the image?
11. How is this type of cloud formed?
12. What type of weather can you expect when you see this type of cloud? Explain.



SECTION 2

Air Masses and Fronts

Have you ever wondered how the weather can change so quickly? For example, the weather may be warm and sunny in the morning and cold and rainy by afternoon.

Changes in weather are caused by the movement and interaction of air masses. An **air mass** is a large body of air where temperature and moisture content are similar throughout. In this section, you will learn about air masses and their effect on weather.

READING WARM-UP

Objectives

- Identify the four kinds of air masses that influence weather in the United States.
- Describe the four major types of fronts.
- Explain how fronts cause weather changes.
- Explain how cyclones and anticyclones affect the weather.

Terms to Learn

air mass
front
cyclone
anticyclone

READING STRATEGY

Reading Organizer As you read this section, make a table comparing cold, warm, occluded, and stationary fronts.

Air Masses

Air masses are characterized by their moisture content and temperature. The moisture content and temperature of an air mass are determined by the area over which the air mass forms. These areas are called *source regions*. An example of a source region is the Gulf of Mexico. An air mass that forms over the Gulf of Mexico is warm and wet because this area is warm and has a lot of water that evaporates. There are many types of air masses, each of which is associated with a particular source region. The characteristics of these air masses are represented on maps by a two-letter symbol, as shown in **Figure 1.** The first letter indicates the moisture content that is characteristic of the air mass. The second letter represents the temperature that is characteristic of the air mass.

Figure 1 **Air Masses That Affect Weather in North America**

maritime (m)
forms over water; wet

continental (c)
forms over land; dry

polar (P)
forms over the polar regions; cold

tropical (T)
develops over the Tropics; warm

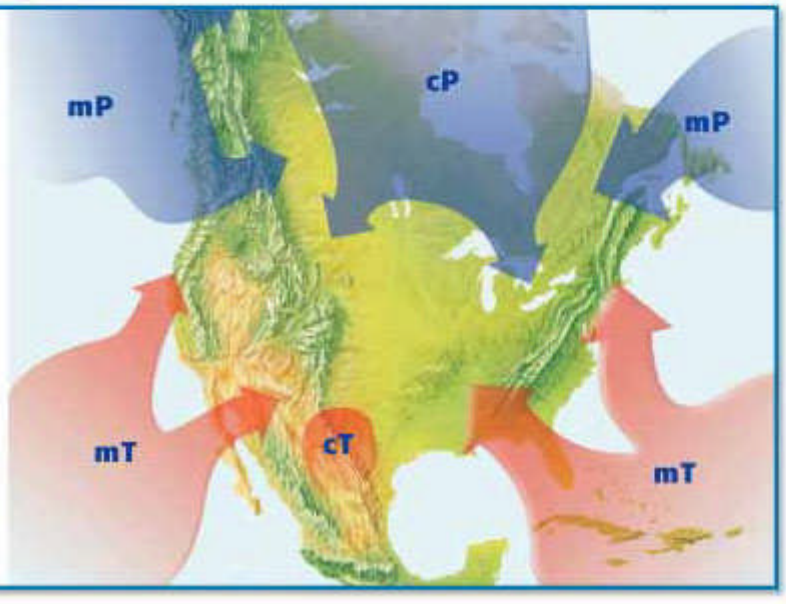


Figure 2 *Cold air masses that form over the North Atlantic Ocean can bring severe weather, such as blizzards, in the winter.*

Cold Air Masses

Most of the cold winter weather in the United States is influenced by three polar air masses. A continental polar (cP) air mass forms over northern Canada, which brings extremely cold winter weather to the United States. In the summer, a cP air mass generally brings cool, dry weather.

A maritime polar (mP) air mass that forms over the North Pacific Ocean is cool and very wet. This air mass brings rain and snow to the Pacific Coast in the winter and cool, foggy weather in the summer.

A maritime polar air mass that forms over the North Atlantic Ocean brings cool, cloudy weather and precipitation to New England in the winter, as shown in **Figure 2.** In the summer, the air mass brings cool weather and fog.

air mass a large body of air where temperature and moisture content are constant throughout

Warm Air Masses

Four warm air masses influence the weather in the United States. A maritime tropical (mT) air mass that develops over warm areas in the Pacific Ocean is milder than the maritime polar air mass that forms over the Pacific Ocean.

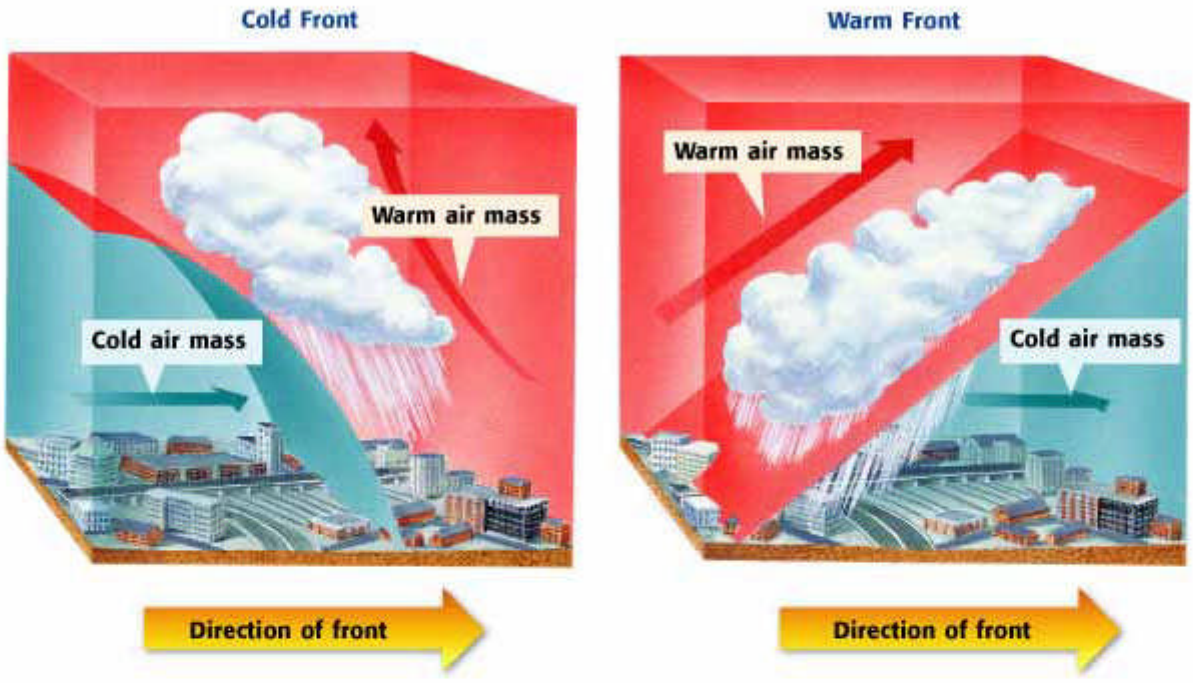
Other maritime tropical air masses develop over the warm waters of the Gulf of Mexico and the Atlantic Ocean. These air masses move north across the East Coast and into the Midwest. In the summer, they bring hot and humid weather, hurricanes, and thunderstorms, as shown in **Figure 3.** In the winter, they bring mild, often cloudy weather.

A continental tropical (cT) air mass forms over the deserts of northern Mexico and the southwestern United States. This air mass moves northward and brings clear, dry, and hot weather in the summer.

Reading Check **What type of air mass contributes to the hot and humid summer weather in the midwestern United States?** (*See the Appendix for answers to Reading Checks.*)

Figure 3 *Warm air masses that develop over the Gulf of Mexico bring thunderstorms in the summer.*

Figure 4 **Fronts That Affect Weather in North America**



front the boundary between air masses of different densities and usually different temperatures

Fronts

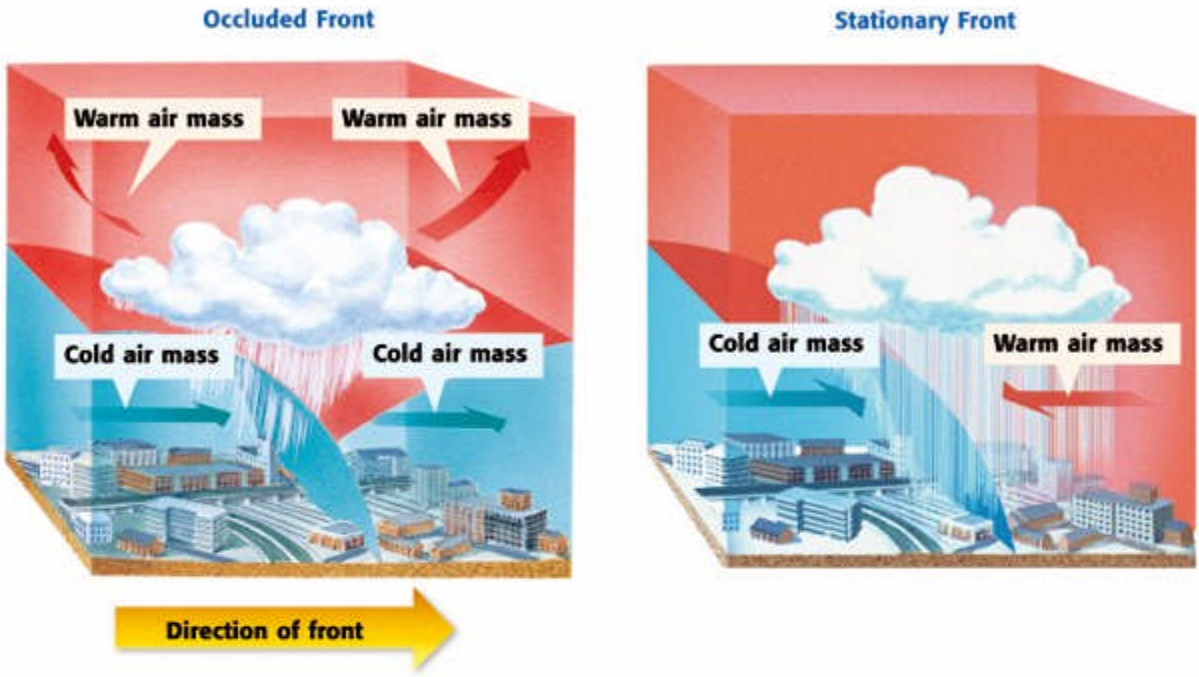
Air masses that form from different areas often do not mix. The reason is that the air masses have different densities. For example, warm air is less dense than cold air. So, when two types of air masses meet, warm air generally rises. The area in which two types of air masses meet is called a **front.** The four kinds of fronts—cold fronts, warm fronts, occluded fronts, and stationary fronts—are shown in **Figure 4.** Fronts are associated with weather in the middle latitudes.

Cold Front

A cold front forms where cold air moves under warm air, which is less dense, and pushes the warm air up. Cold fronts can move quickly and bring thunderstorms, heavy rain, or snow. Cooler weather usually follows a cold front because the air mass behind the cold front is cooler and drier than the air mass that it is replacing.

Warm Front

A warm front forms where warm air moves over cold, denser air. In a warm front, the warm air gradually replaces the cold air. Warm fronts generally bring drizzly rain and are followed by clear and warm weather.



Occluded Front

An occluded front forms when a warm air mass is caught between two colder air masses. The coldest air mass moves under and pushes up the warm air mass. The coldest air mass then moves forward until it meets a cold air mass that is warmer and less dense. The colder of these two air masses moves under and pushes up the warmer air mass. Sometimes, though, the two colder air masses mix. An occluded front has cool temperatures and large amounts of rain and snow.

Reading Check **What type of weather would you expect an occluded front to produce?**

Stationary Front

A stationary front forms when a cold air mass meets a warm air mass. In this case, however, both air masses do not have enough force to lift the warm air mass over the cold air mass. So, the two air masses remain separated. This may happen because there is not enough wind to keep the air masses pushing against each other. A stationary front often brings many days of cloudy, wet weather.

Figure 5 *This satellite image shows a cyclone system forming.*

Air Pressure and Weather

You may have heard a weather reporter on TV or radio talking about areas of low pressure and high pressure. These areas of different pressure affect the weather.

Cyclones

cyclone an area in the atmosphere that has lower pressure than the surrounding areas and has winds that spiral toward the center

Areas that have lower pressure than the surrounding areas do are called **cyclones.** Cyclones are areas where air masses come together, or converge, and rise. **Figure 5** shows a satellite image of the formation of a cyclone system.

Anticyclones

anticyclone the rotation of air around a high-pressure center in the direction opposite to Earth's rotation

Areas that have high pressure are called **anticyclones.** Anticyclones are areas where air moves apart, or diverges, and sinks. The sinking air is denser than the surrounding air, and the pressure is higher. Cooler, denser air moves out of the center of these high-pressure areas toward areas of lower pressure. **Figure 6** shows how wind can spiral out of an anticyclone and into a cyclone.

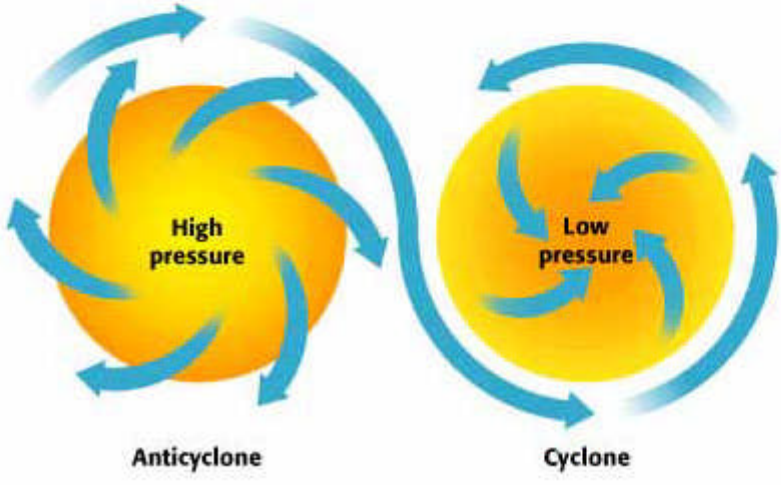


Figure 6 *As the colder, denser air spirals out of the anticyclone, it moves towards areas of low pressure, which sometimes forms a cyclone.*

Cyclones, Anticyclones, and Weather

You have learned what cyclones and anticyclones are. So, now you might be wondering how do cyclones and anticyclones affect the weather? As the air in the center of a cyclone rises, it cools and forms clouds and rain. The rising air in a cyclone causes stormy weather. In an anticyclone, the air sinks. As the air sinks, it gets warmer and absorbs moisture. The sinking air in an anticyclone brings dry, clear weather. By keeping track of cyclones and anticyclones, meteorologists can predict the weather.

Reading Check **Describe the different types of weather that a cyclone and an anticyclone can produce.**

CONNECTION TO Astronomy

Storms on Jupiter Cyclones and anticyclones occur on Jupiter, too! Generally, cyclones on Jupiter appear as dark ovals, and anticyclones appear as bright ovals. Jupiter's Great Red Spot is an anticyclone that has existed for centuries. Research the existence of cyclones and anticyclones on other bodies in our solar system.

SECTION Review

Summary

- Air masses are characterized by moisture content and temperature.
- A front occurs where two air masses meet.
- Four major types of fronts are cold, warm, occluded, and stationary fronts.
- Differences in air pressure cause cyclones, which bring stormy weather, and anticyclones, which bring dry, clear weather.

Using Key Terms

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

1. *front* and *air mass*
2. *cyclone* and *anticyclone*

Understanding Key Ideas

3. What kind of front forms when a cold air mass displaces a warm air mass?
   a. a cold front
   b. a warm front
   c. an occluded front
   d. a stationary front
4. What are the major air masses that influence the weather in the United States?
5. What is one source region of a maritime polar air mass?
6. What are the characteristics of an air mass whose two-letter symbol is cP?
7. What are the four major types of fronts?
8. How do fronts cause weather changes?
9. How do cyclones and anticyclones affect the weather?

Math Skills

10. A cold front is moving toward the town of La Porte at 35 km/h. The front is 200 km away from La Porte. How long will it take the front to get to La Porte?

Critical Thinking

11. **Applying Concepts** How do air masses that form over the land and ocean affect weather in the United States?
12. **Identifying Relationships** Why does the Pacific Coast have cool, wet winters and warm, dry summers? Explain.
13. **Applying Concepts** Which air masses influence the weather where you live? Explain.

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For a variety of links related to this chapter, go to www.scilinks.org

Topic: Air Masses and Fronts

SciLinks code: HSM0032

SECTION 3

Severe Weather

CRAAAACK! BOOM! What made that noise? You didn't expect it, and it sure made you jump.

A big boom of thunder has probably surprised you at one time or another. And the thunder was probably followed by a thunderstorm. A thunderstorm is an example of severe weather. *Severe weather* is weather that can cause property damage and sometimes death.

READING WARM-UP

Objectives

- Describe how lightning forms.
- Describe the formation of thunderstorms, tornadoes, and hurricanes.
- Describe the characteristics of thunderstorms, tornadoes, and hurricanes.
- Explain how to stay safe during severe weather.

Terms to Learn

thunderstorm
lightning
thunder
tornado
hurricane

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

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

Thunderstorms

Thunderstorms can be very loud and powerful. **Thunderstorms,** such as the one shown in **Figure 1,** are small, intense weather systems that produce strong winds, heavy rain, lightning, and thunder. Thunderstorms can occur along cold fronts. But thunderstorms can develop in other places, too. There are only two atmospheric conditions required to produce thunderstorms: warm and moist air near Earth's surface and an unstable atmosphere. The atmosphere is unstable when the surrounding air is colder than the rising air mass. The air mass will continue to rise as long as the surrounding air is colder than the air mass.

When the rising warm air reaches its dew point, the water vapor in the air condenses and forms cumulus clouds. If the atmosphere is extremely unstable, the warm air will continue to rise, which causes the cloud to grow into a dark, cumulonimbus cloud. Cumulonimbus clouds can reach heights of more than 15 km.

Figure 1 *A typical thunderstorm, such as this one over Dallas, Texas, generates an enormous amount of electrical energy.*

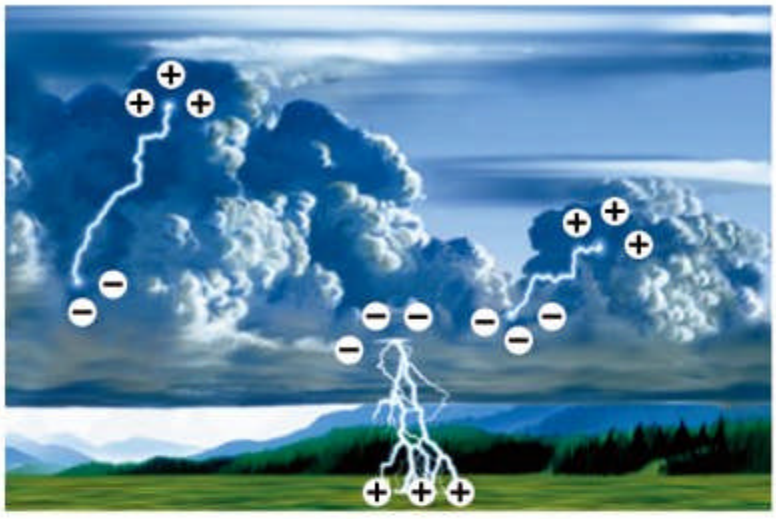


Figure 2 *The upper part of a cloud usually carries a positive electric charge, while the lower part of the cloud carries mainly negative charges.*

Lightning

Thunderstorms are very active electrically. **Lightning** is an electric discharge that occurs between a positively charged area and a negatively charged area, as shown in **Figure 2.** Lightning can happen between two clouds, between Earth and a cloud, or even between two parts of the same cloud. Have you ever touched someone after scuffing your feet on the carpet and received a mild shock? If so, you have experienced how lightning forms. While you walk around, friction between the floor and your shoes builds up an electric charge in your body. When you touch someone else, the charge is released.

When lightning strikes, energy is released. This energy is transferred to the air and causes the air to expand rapidly and send out sound waves. **Thunder** is the sound that results from the rapid expansion of air along the lightning strike.

lightning an electric discharge that takes place between two oppositely charged surfaces, such as between a cloud and the ground, between two clouds, or between two parts of the same cloud

thunder the sound caused by the rapid expansion of air along an electrical strike

Severe Thunderstorms

Severe thunderstorms can produce one or more of the following conditions: high winds, hail, flash floods, and tornadoes. Hailstorms damage crops, dent the metal on cars, and break windows. Flash flooding that results from heavy rains causes millions of dollars in property damage annually. And every year, flash flooding is a leading cause of weather-related deaths.

Lightning, as shown in **Figure 3,** happens during all thunderstorms and is very powerful. Lightning is responsible for starting thousands of forest fires each year and for killing or injuring hundreds of people a year in the United States.

Reading Check **What is a severe thunderstorm?** (*See the Appendix for answers to Reading Checks.*)

Figure 3 *Lightning often strikes the tallest object in an area, such as the Eiffel Tower in Paris, France.*

Tornadoes

tornado a destructive, rotating column of air that has very high wind speeds, is visible as a funnel-shaped cloud, and touches the ground

Tornadoes happen in only 1% of all thunderstorms. A **tornado** is a small, spinning column of air that has high wind speeds and low central pressure and that touches the ground. A tornado starts out as a funnel cloud that pokes through the bottom of a cumulonimbus cloud and hangs in the air. The funnel cloud becomes a tornado when it makes contact with Earth's surface. **Figure 4** shows how a tornado forms.

Figure 4 How a Tornado Forms

1 Wind moving in two directions causes a layer of air in the middle to begin to spin like a roll of toilet paper.

2 The spinning column of air is turned to a vertical position by strong updrafts of air in the cumulonimbus cloud. The updrafts of air also begin to spin.

3 The spinning column of air moves to the bottom of the cumulonimbus cloud and forms a funnel cloud.

4 The funnel cloud becomes a tornado when it touches the ground.

Figure 5 *The tornado that hit Kissimmee, Florida, in 1998 had wind speeds of up to 416 km/h.*

Twists of Terror

About 75% of the world's tornadoes occur in the United States. Most of these tornadoes happen in the spring and early summer when cold, dry air from Canada meets warm, moist air from the Tropics. The size of a tornado's path of destruction is usually about 8 km long and 10 to 60 m wide. Although most tornadoes last only a few minutes, they can cause a lot of damage. Their ability to cause damage is due to their strong spinning winds. The average tornado has wind speeds between 120 and 180 km/h, but rarer, more violent tornadoes can have spinning winds of up to 500 km/h. The winds of tornadoes have been known to uproot trees and destroy buildings, as shown in **Figure 5.** Tornadoes are capable of picking up heavy objects, such as mobile homes and cars, and hurling them through the air.

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

A large, rotating tropical weather system that has wind speeds of at least 120 km/h is called a **hurricane,** shown in **Figure 6.** Hurricanes are the most powerful storms on Earth. Hurricanes have different names in different parts of the world. In the western Pacific Ocean, hurricanes are called *typhoons*. Hurricanes that form over the Indian Ocean are called *cyclones*.

Most hurricanes form in the areas between 5° and 20° north latitude and between 5° and 20° south latitude over warm, tropical oceans. At higher latitudes, the water is too cold for hurricanes to form. Hurricanes vary in size from 160 to 1,500 km in diameter and can travel for thousands of kilometers.

Reading Check **What are some other names for hurricanes?**

Figure 6 *This photograph of Hurricane Fran was taken from space.*

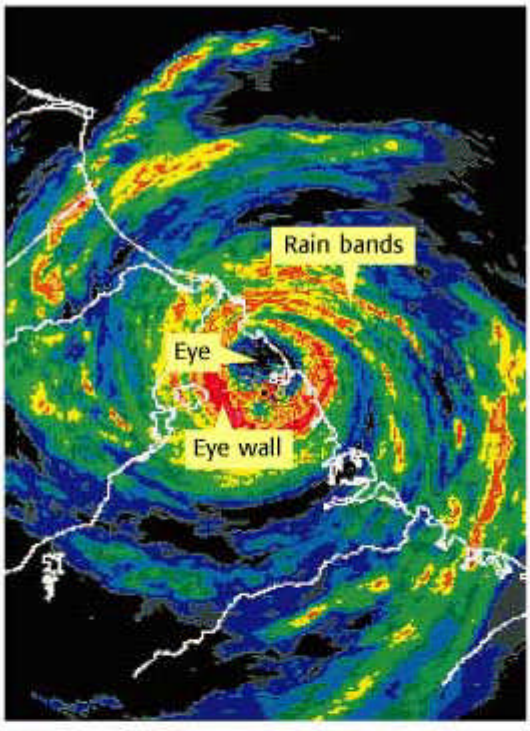


Figure 7 *The photo above gives you a bird's-eye view of a hurricane.*

How a Hurricane Forms

A hurricane begins as a group of thunderstorms moving over tropical ocean waters. Winds traveling in two different directions meet and cause the storm to spin. Because of the Coriolis effect, the storm turns counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere.

A hurricane gets its energy from the condensation of water vapor. Once formed, the hurricane is fueled through contact with the warm ocean water. Moisture is added to the warm air by evaporation from the ocean. As the warm, moist air rises, the water vapor condenses and releases large amounts of energy. The hurricane continues to grow as long as it is over its source of warm, moist air. When the hurricane moves into colder waters or over land, it begins to die because it has lost its source of energy. **Figure 7** and **Figure 8** show two views of a hurricane.

Reading Check **Where do hurricanes get their energy?**

Figure 8 **Cross Section of a Hurricane**

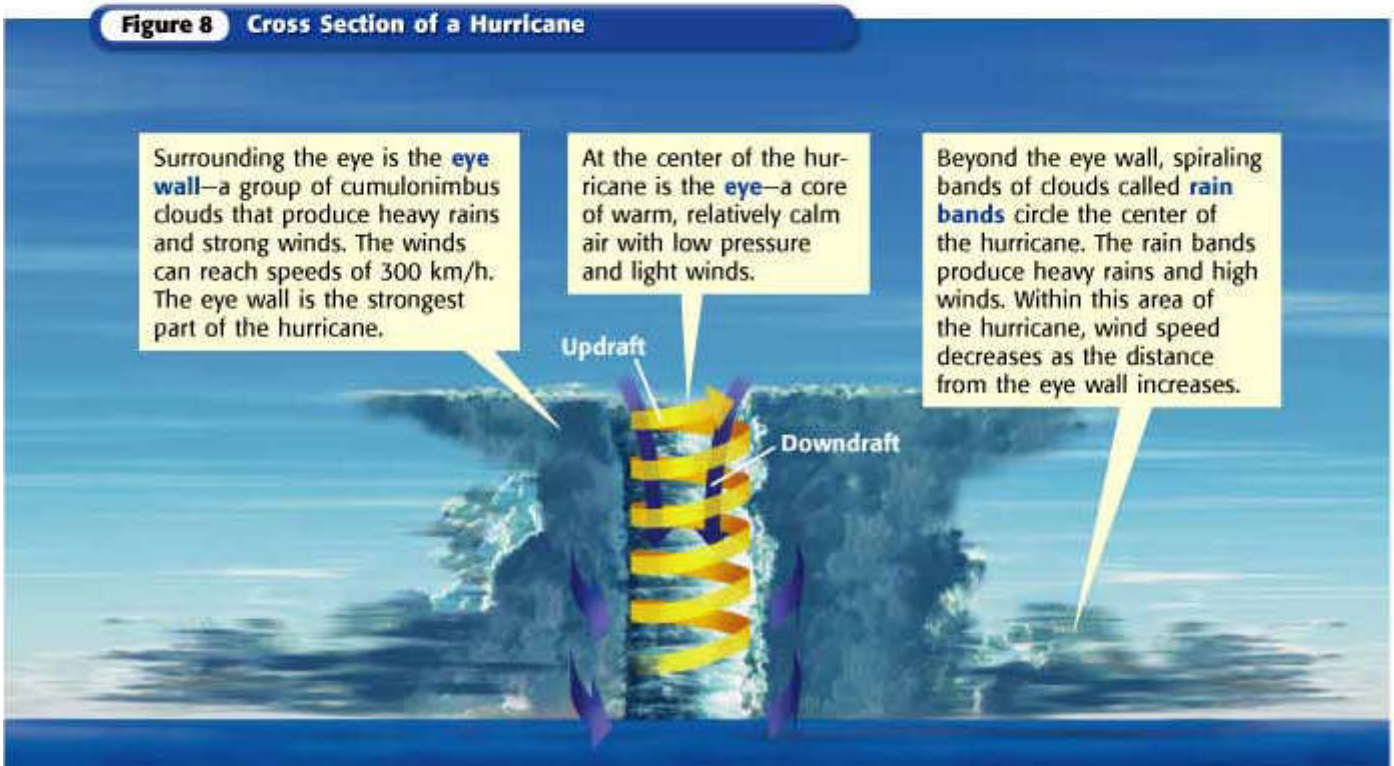


Figure 9 *A hurricane's storm surge can cause severe damage to homes near the shoreline.*

Damage Caused by Hurricanes

Hurricanes can cause a lot of damage when they move near or onto land. Wind speeds of most hurricanes range from 120 to 150 km/h. Some can reach speeds as high as 300 km/h. Hurricane winds can knock down trees and telephone poles and can damage and destroy buildings and homes.

While high winds cause a great deal of damage, most hurricane damage is caused by flooding associated with heavy rains and storm surges. A *storm surge* is a wall of water that builds up over the ocean because of the strong winds and low atmospheric pressure. The wall of water gets bigger as it nears the shore, and it reaches its greatest height when it crashes onto the shore. Depending on the hurricane's strength, a storm surge can be 1 to 8 m high and 65 to 160 km long. Flooding causes tremendous damage to property and lives when a storm surge moves onto shore, as shown in **Figure 9.**

Severe Weather Safety

Severe weather can be very dangerous, so it is important to keep yourself safe. One way to stay safe is to turn on the radio or TV during a storm. Your local radio and TV stations will let you know if a storm has gotten worse.

Thunderstorm Safety

Lightning is one of the most dangerous parts of a thunderstorm. Lightning is attracted to tall objects. If you are outside, stay away from trees, which can get struck down. If you are in the open, crouch down. Otherwise, you will be the tallest object in the area! Stay away from bodies of water. If lightning hits water while you are in it, you could be hurt or could even die.

SCHOOL to HOME

Natural Disaster Plan

WRITING SKILL Every family should have a plan to deal with weather emergencies. With a parent, discuss what your family should do in the event of severe weather. Together, write up a plan for your family to follow in case of a natural disaster. Also, make a disaster supply kit that includes enough food and water to last several days.

ACTIVITY

Figure 10 *During a tornado warning, it is best to protect yourself by crouching against a wall and covering the back of your head and neck with your hands or a book.*

Tornado Safety

Weather forecasters use watches and warnings to let people know about tornadoes. A *watch* is a weather alert that lets people know that a tornado may happen. A *warning* is a weather alert that lets people know that a tornado has been spotted.

If there is a tornado warning for your area, find shelter quickly. The best place to go is a basement or cellar. Or you can go to a windowless room in the center of the building, such as a bathroom, closet, or hallway, as **Figure 10** shows. If you are outside, lie down in a large, open field or a deep ditch.

Flood Safety

An area can get so much rain that it begins to flood. So, like tornadoes, floods have watches and warnings. However, little warning can usually be given. A flash flood is a flood that rises and falls very suddenly. The best thing to do during a flood is to find a high place to wait out the flood. You should always stay out of floodwaters. Even shallow water can be dangerous if it is moving fast.

Figure 11 *These store owners are boarding up their windows to protect the windows from strong winds during a hurricane.*

Hurricane Safety

If a hurricane is in your area, your local TV or radio station will keep you updated on its condition. People living on the shore may be asked to evacuate the area. If you live in an area where hurricanes strike, your family should have a disaster supply kit that includes enough water and food to last several days. To protect the windows in your home, you should cover them with plywood, as shown in **Figure 11.** Most important, you must stay indoors during the storm.

SECTION Review

Summary

- Thunderstorms are intense weather systems that produce strong winds, heavy rain, lightning, and thunder.
- Lightning is a large electric discharge that occurs between two oppositely charged surfaces. Lightning releases a great deal of energy and can be very dangerous.
- Tornadoes are small, rotating columns of air that touch the ground and can cause severe damage.
- A hurricane is a large, rotating tropical weather system. Hurricanes cause strong winds and can cause severe property damage.
- In the event of severe weather, it is important to stay safe. Listening to your local TV or radio station for updates and remaining indoors and away from windows are good rules to follow.

Using Key Terms

Complete each of the following sentences by choosing the correct term from the word bank.

hurricane storm surge
tornado lightning

1. Thunderstorms are very active electrically and often cause ___.
2. A ___ forms when a funnel cloud pokes through the bottom of a cumulonimbus cloud and makes contact with the ground.

Understanding Key Ideas

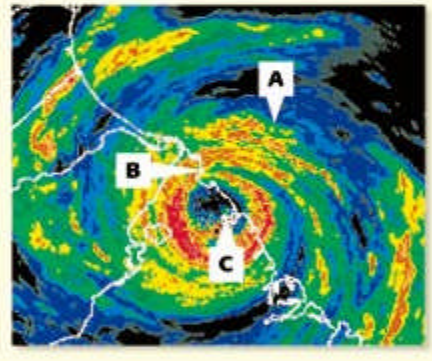
3. The safest thing to do if you are caught outdoors during a tornado is to
   a. stay near buildings and roads.
   b. head for an open area.
   c. seek shelter near a large tree.
   d. None of the above
4. Describe how tornadoes form.
5. At what latitudes do hurricanes usually form?
6. What is lightning? What happens when lightning strikes?

Critical Thinking

7. **Applying Concepts** What items do you think you would need in a disaster kit? Explain.
8. **Identifying Relationships** What happens to a hurricane as it moves over land? Explain.

Interpreting Graphics

Use the diagram below to answer the questions that follow.



9. Describe what is happening at point C.
10. What is point B?
11. What kind of weather can you expect at point A?

SECTION 4

Forecasting the Weather

You watch the weather forecast on the evening news. The news is good—there's no rain in sight. But how can the weather forecasters tell that it won't rain?

Weather affects how you dress and how you plan your day, so it is important to get accurate weather forecasts. But where do weather reporters get their information? And how do they predict the weather? A *weather forecast* is a prediction of weather conditions over the next 3 to 5 days. A *meteorologist* is a person who observes and collects data on atmospheric conditions to make weather predictions. In this section, you will learn how weather data are collected and shown.

READING WARM-UP

Objectives

- Describe the different types of instruments used to take weather measurements.
- Explain how radar and weather satellites help meteorologists forecast the weather.
- Explain how to interpret a weather map.

Terms to Learn

thermometer
barometer
anemometer

READING STRATEGY

Reading Organizer As you read this section, make a table comparing the different instruments used to collect weather data.

Weather-Forecasting Technology

To accurately forecast the weather, meteorologists need to measure various atmospheric conditions, such as air pressure, humidity, precipitation, temperature, wind speed, and wind direction. Meteorologists use special instruments to collect data on weather conditions both near and far above Earth's surface.

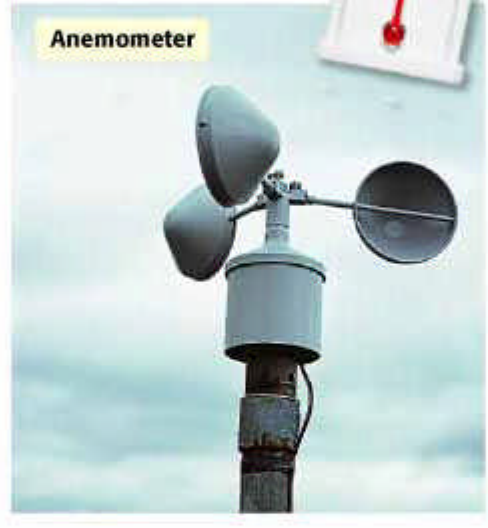
High in the Sky

Weather balloons carry electronic equipment that can measure weather conditions as high as 30 km above Earth's surface. Weather balloons, such as the one in **Figure 1,** carry equipment that measures temperature, air pressure, and relative humidity. By tracking the balloons, meteorologists can also measure wind speed and direction.

Reading Check **How do meteorologists gather data on atmospheric conditions above Earth's surface?** *(See the Appendix for answers to Reading Check.)*

Figure 1 *Weather balloons carry radio transmitters that send measurements to stations on the ground.*

Figure 2 *Meteorologists use these tools to collect atmospheric data.*



Measuring Air Temperature and Pressure

A tool used to measure air temperature is called a **thermometer.** Most thermometers use a liquid sealed in a narrow glass tube, as shown in **Figure 2.** When air temperature increases, the liquid expands and moves up the glass tube. As air temperature decreases, the liquid shrinks and moves down the tube.

A **barometer** is an instrument used to measure air pressure. A mercurial barometer consists of a glass tube that is sealed at one end and placed in a container full of mercury. As the air pressure pushes on the mercury inside the container, the mercury moves up the glass tube. The greater the air pressure is, the higher the mercury will rise.

Measuring Wind Direction

Wind direction can be measured by using a windsock or a wind vane. A windsock, shown in **Figure 2,** is a cone-shaped cloth bag open at both ends. The wind enters through the wide end and leaves through the narrow end. Therefore, the wide end points into the wind. A wind vane is shaped like an arrow with a large tail and is attached to a pole. As the wind pushes the tail of the wind vane, the wind vane spins on the pole until the arrow points into the wind.

Measuring Wind Speed

An instrument used to measure wind speed is called an **anemometer.** An anemometer, as shown in **Figure 2,** consists of three or four cups connected by spokes to a pole. The wind pushes on the hollow sides of the cups and causes the cups to rotate on the pole. The motion sends a weak electric current that is measured and displayed on a dial.

thermometer an instrument that measures and indicates temperature

barometer an instrument that measures atmospheric pressure

anemometer an instrument used to measure wind speed

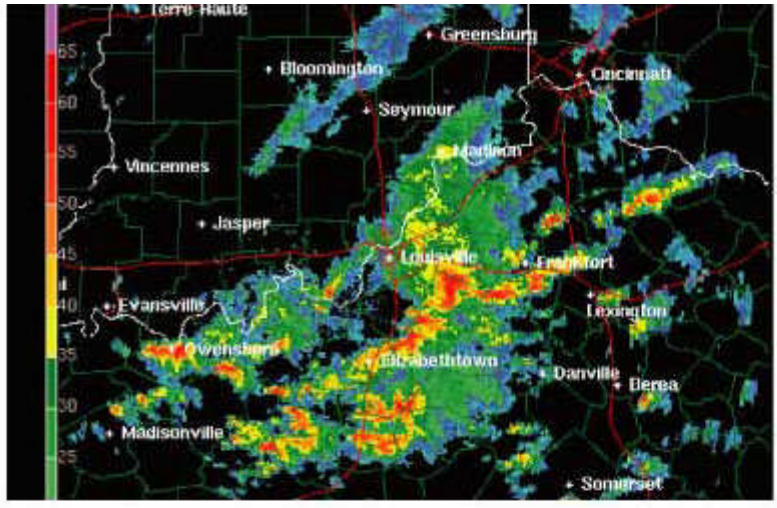


Figure 3 *Using Doppler radar, meteorologists can predict a tornado up to 20 minutes before it touches the ground.*

Radar and Satellites

Radar is used to find the location, movement, and amount of precipitation. It can also detect what form of precipitation a weather system is carrying. You might have seen a kind of radar called *Doppler radar* used in a local TV weather report. **Figure 3** shows how Doppler radar is used to track precipitation. *Weather satellites* that orbit Earth provide the images of weather systems that you see on TV weather reports. Satellites can track storms and measure wind speeds, humidity, and temperatures at different altitudes.

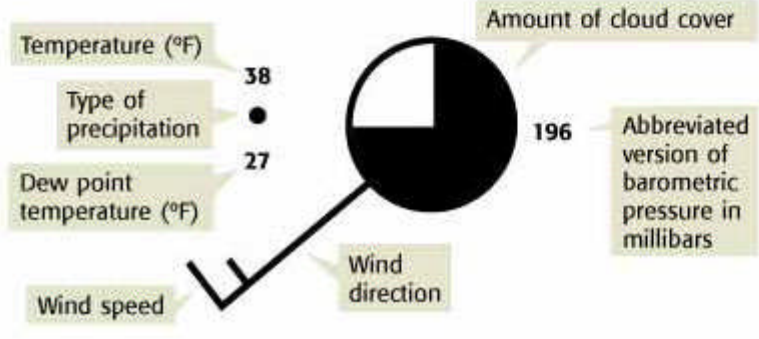
CONNECTION TO Biology

WRITING SKILL **Predicting the Weather** Throughout history, people have predicted approaching weather by interpreting natural signs. Animals and plants are usually more sensitive to changes in atmospheric conditions, such as air pressure, humidity, and temperature, than humans are. To find out more about natural signs, research this topic at the library or on the Internet. Write a short paper on your findings to share with the class.

Weather Maps

In the United States, the National Weather Service (NWS) and the National Oceanic and Atmospheric Administration (NOAA) collect and analyze weather data. The NWS produces weather maps based on information gathered from about 1,000 weather stations across the United States. On these maps, each station is represented by a station model. A *station model* is a small circle that shows the location of the weather station. As shown in **Figure 4,** surrounding the small circle is a set of symbols and numbers, which represent the weather data.

Figure 4 **A Station Model**



Reading a Weather Map

Weather maps that you see on TV include lines called *isobars*. Isobars are lines that connect points of equal air pressure. Isobars that form closed circles represent areas of high or low pressure. These areas are usually marked on a map with a capital *H* or *L*. Fronts are also labeled on weather maps, as you can see on the weather map in **Figure 5.**

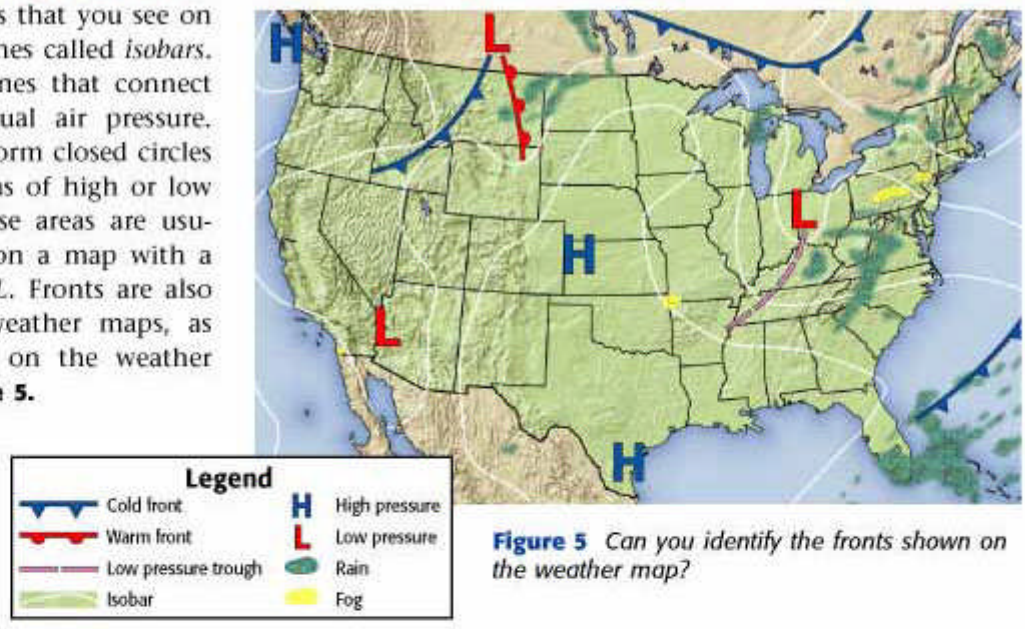


Figure 5 *Can you identify the fronts shown on the weather map?*

SECTION Review

Summary

- Meteorologists use several instruments, such as weather balloons, thermometers, barometers, anemometers, windsocks, weather vanes, radar, and weather satellites, to forecast the weather.
- Station models show the weather conditions at various points across the United States.
- Weather maps show areas of high and low pressure as well as the location of fronts.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *thermometer, barometer,* and *anemometer.*

Understanding Key Ideas

2. Which of the following instruments measures air pressure?
   a. thermometer
   b. barometer
   c. anemometer
   d. windsock
3. How does radar help meteorologists forecast the weather?
4. What does a station model represent?

Math Skills

5. If it is 75°F outside, what is the temperature in degrees Celsius? (Hint: °F = (°C × 9/5) + 32)

Critical Thinking

6. **Applying Concepts** Why would a meteorologist compare a new weather map with one that is 24 h old?
7. **Making Inferences** In the United States, why is weather data gathered from a large number of station models?
8. **Making Inferences** How might several station models from different regions plotted on a map help a meteorologist?

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Topic: Forecasting the Weather
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Chapter Review

USING KEY TERMS

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

1. *relative humidity* and *dew point*
2. *condensation* and *precipitation*
3. *air mass* and *front*
4. *lightning* and *thunder*
5. *tornado* and *hurricane*
6. *barometer* and *anemometer*

UNDERSTANDING KEY IDEAS

Multiple Choice

7. The process in which water changes from a liquid to gas is called
   - a. precipitation.
   - b. condensation.
   - c. evaporation.
   - d. water vapor.

8. What is the relative humidity of air at its dew point?
   - a. 0%
   - b. 50%
   - c. 75%
   - d. 100%

9. Which of the following is NOT a type of condensation?
   - a. fog
   - b. cloud
   - c. snow
   - d. dew

10. High clouds made of ice crystals are called ___ clouds.
    - a. stratus
    - b. cumulus
    - c. nimbostratus
    - d. cirrus

11. Large thunderhead clouds that produce precipitation are called ___ clouds.
    - a. nimbostratus
    - b. cumulonimbus
    - c. cumulus
    - d. stratus

12. Strong updrafts within a thunderhead can produce
    - a. snow.
    - b. rain.
    - c. sleet.
    - d. hail.

13. A maritime tropical air mass contains
    - a. warm, wet air.
    - b. cold, moist air.
    - c. warm, dry air.
    - d. cold, dry air.

14. A front that forms when a warm air mass is trapped between cold air masses and is forced to rise is a(n)
    - a. stationary front.
    - b. warm front.
    - c. occluded front.
    - d. cold front.

15. A severe storm that forms as a rapidly rotating funnel cloud is called a
    - a. hurricane.
    - b. tornado.
    - c. typhoon.
    - d. thunderstorm.

16. The lines connecting points of equal air pressure on a weather map are called
    - a. contour lines.
    - b. highs.
    - c. isobars.
    - d. lows.

Short Answer

17. Explain the relationship between condensation and dew point.

18 Describe the conditions along a stationary front.

19 What are the characteristics of an air mass that forms over the Gulf of Mexico?

20 Explain how a hurricane develops.

21 Describe the water cycle, and explain how it affects weather.

22 List the major similarities and differences between hurricanes and tornadoes.

23 Explain how a tornado forms.

24 Describe an interaction between weather and ocean systems.

25 What is a station model? What types of information do station models provide?

26 What type of technology is used to locate and measure the amount of precipitation in an area?

27 List two ways to keep yourself informed during severe weather.

28 Explain why staying away from floodwater is important even when the water is shallow.

CRITICAL THINKING

29 **Concept Mapping** Use the following terms to create a concept map: *evaporation, relative humidity, water vapor, dew, psychrometer, clouds,* and *fog.*

30 **Making Inferences** If both the air temperature and the amount of water vapor in the air change, is it possible for the relative humidity to stay the same? Explain.

31 **Applying Concepts** What can you assume about the amount of water vapor in the air if there is no difference between the wet- and dry-bulb readings of a psychrometer?

32 **Identifying Relationships** Explain why the concept of relative humidity is important to understanding weather.

INTERPRETING GRAPHICS

Use the weather map below to answer the questions that follow.

33 Where are thunderstorms most likely to occur? Explain your answer.

34 What are the weather conditions in Tulsa, Oklahoma? Explain your answer.