20 Weather Patterns and Severe Storms

Big idea

Weather and Climate

Q: How are air masses and severe weather related?

VIRGINIA SCIENCE STANDARDS OF LEARNING

ES.1.d, ES.12.b, ES.12.c, ES.12.d. **See lessons for details.**

On June 20, 2011, a tornado spins violently in Nebraska.

INQUIRY

TRY IT!

HOW CAN YOU MODEL A TORNADO?

Procedure

1. Pour water into a 1-L plastic bottle until it is about two-thirds full. Wipe off any water from the outside and the opening.
2. Without getting any of either substance on the outside of the bottle, add about 30 mL of liquid dishwashing soap and a spoonful of glitter to the water.
3. Center a washer on the mouth of the bottle.
4. Invert another 1-L bottle and place its mouth over the washer.
5. Without moving the washer, wrap duct tape around the mouths of the bottles to seal them.
6. Quickly invert the bottles so that the bottle holding the water is on top. Then, while holding the top bottle, carefully swirl the bottles in a counterclockwise direction.
7. Observe your mini-tornado.

Think About It

1. **Observe** How did the water move in the bottle?
2. **Use Models** What might the glitter represent?
3. **Form a Hypothesis** What forces probably acted on the water?

20.1 Air Masses

ES.12 The student will investigate and understand that energy transfer between the sun and Earth and its atmosphere drives weather and climate on Earth. Key concepts include **d.** weather phenomena and the factors that affect climate including radiation, conduction, and convection.

Key Questions

- ***What is an air mass?***
- ***What happens as an air mass moves over an area?***
- ***How are air masses classified?***
- ***Which air masses influence much of the weather in North America?***
- ***Why do continental tropical air masses have little effect on weather in North America?***

Vocabulary

- air mass

Reading Strategy

Build Vocabulary Copy the table. As you read this section, write a definition for each of the terms in the table. Refer to the table as you read the rest of the chapter.

Term	Definition
Air mass	a. ?
Source region	b. ?
Polar air mass	c. ?
Tropical air mass	d. ?
Continental air mass	e. ?
Maritime air mass	f. ?

SEVERE STORMS are among nature's most destructive forces. Every spring and summer, newspapers and television report the damage caused by short, violent windstorms called tornadoes. The force of tornado winds can be almost unbelievably strong, causing damage such as that shown in **Figure 1.** Then, during the late summer and early fall, hurricanes form over Earth's tropical oceans. As hurricanes move toward land, the strong winds and heavy rains produced by these storms often cause tremendous destruction along their paths. Thunderstorms are the type of severe storm that is probably most familiar to you. Thunderstorms produce heavy rains, thunder, and lightning.

Violent weather is scary and dramatic, but normal, day-to-day weather—the weather you hear about every day on TV—is interesting, too. The factors that determine everyday weather also affect storms. You can't understand the causes of storms until you learn about the atmospheric conditions that most often affect the daily weather.

FIGURE 1 Tornado Damage The force of the wind during a tornado was strong enough to drive a piece of metal into this utility pole.

Air Masses and Weather

For the many people who live in the middle latitudes, which include much of the United States, summer heat waves and winter cold spells are familiar experiences. During summer heat waves, several days of high temperatures and high humidity often end when a series of storms pass through the area. This stormy weather is followed by a few days of relatively cool weather. By contrast, winter cold spells are often characterized by periods of frigid temperatures under clear skies. These bitter cold periods are usually followed by cloudy, snowy, relatively warm days that seem mild when compared to those just a day earlier. In both of these situations, periods of fairly constant weather conditions are followed by a short period of changes in the weather. What do you think causes these changes?

PLANET DIARY

For links about **Tornadoes**, go to PlanetDiary.com/HSES.

Air Masses

The weather patterns just described result from air masses on the move. **An air mass is an extremely large body of air that is located in the troposphere and is characterized by similar temperatures and amounts of moisture at any given altitude.** An air mass can be 1600 kilometers or more across and several kilometers thick. Because of its size, it may take several days for an air mass to move over an area. Because the air mass takes a long time to move, the area experiences fairly constant weather. A situation in which the weather is fairly constant is called *air-mass weather.* Some day-to-day changes in the weather within the air mass may occur, but the events will be very unlike those in a nearby air mass.

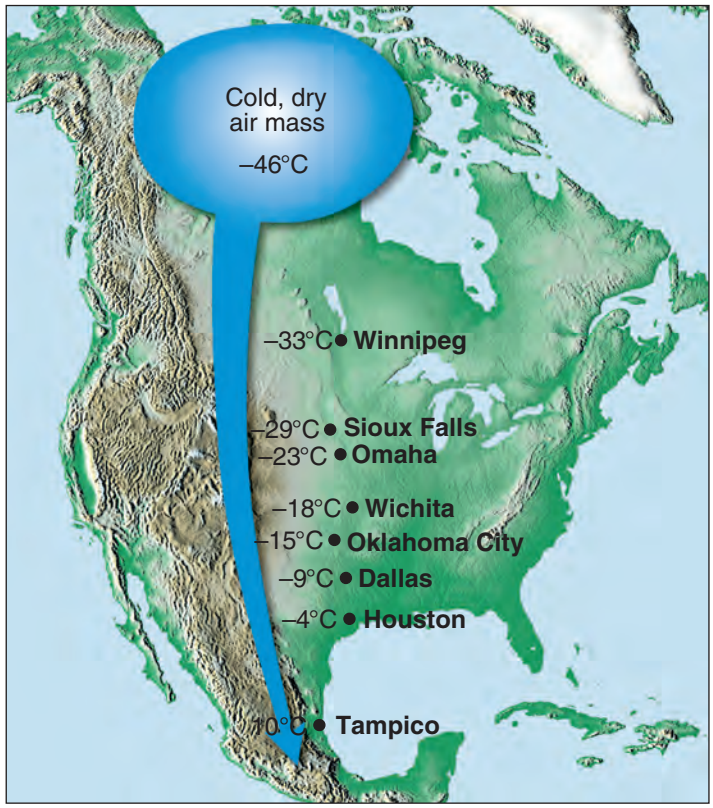


FIGURE 2 Air Mass on the Move As a frigid Canadian air mass moves southward, it brings colder weather to the area over which it moves. **Calculate** ***How much warmer was the air mass when it reached Tampico, Mexico, than when it formed?***

Movement of Air Masses

When an air mass moves out of the region over which it formed, it carries its temperature and moisture conditions with it. **Figure 2** shows the path of an air mass as it moves from northern Canada to Mexico. A cold, dry air mass from northern Canada is shown moving southward. The initial temperature of the air mass is −46°C. The air mass warms 13 degrees by the time it reaches Winnipeg. The air mass continues to warm as it moves southward through the Great Plains and into Mexico. Throughout its southward journey, as the air mass becomes warmer, it also brings some of the coldest weather of the winter to the places in its path. **As an air mass moves, its characteristics change and so does the weather in the area over which it moves.**

Reading Checkpoint *What is an air mass? What happens as it moves over an area?*

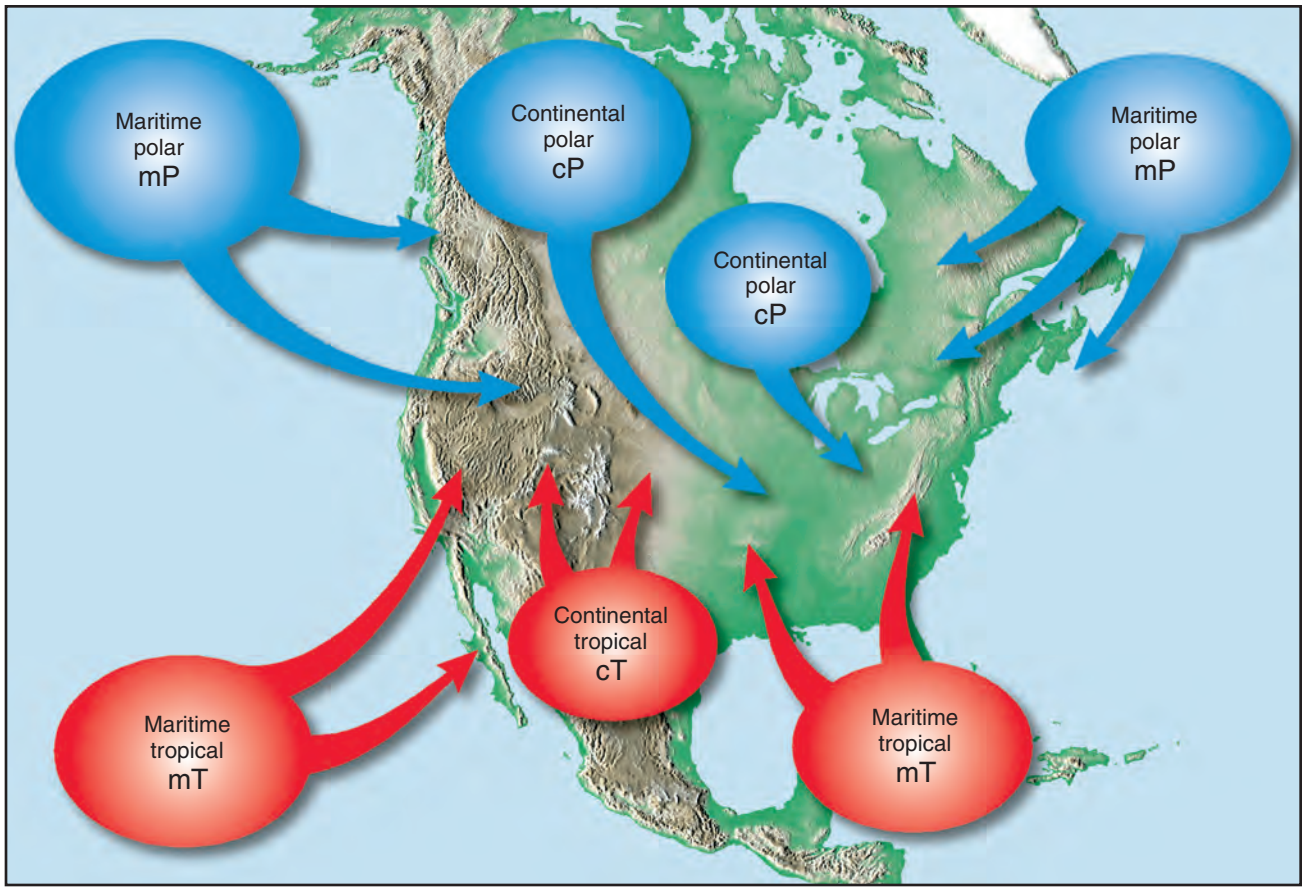


FIGURE 3 Types of Air Masses Air masses are classified by the region over which they form.
Interpret Maps ***What kinds of air masses influence the weather patterns along the west coast of the United States?***

Classifying Air Masses

The area over which an air mass gets its characteristic properties of temperature and moisture is called its *source region.* The source regions that produce air masses that influence the weather in North America are shown in **Figure 3.** Air masses are named according to their source region. Polar (P) air masses form at high latitudes toward Earth's poles. Air masses that form at low latitudes are tropical (T) air masses. The terms *polar* and *tropical* describe the temperature characteristics of an air mass. Polar air masses are cold, while tropical air masses are warm.

In addition to their overall temperature, air masses are classified according to the surface over which they form. Continental (c) air masses form over land. Maritime (m) air masses form over water. The terms *continental* and *maritime* describe the moisture characteristics of the air mass. Continental air masses are likely to be dry. Maritime air masses are humid.

Using this classification scheme, there are four basic types of air masses. A *continental polar (cP) air mass* is dry and cool. A *continental tropical (cT) air mass* is dry and warm or hot. *Maritime polar (mP)* and *maritime tropical (mT)* air masses both form over water. But a maritime polar air mass is much colder than a maritime tropical air mass.

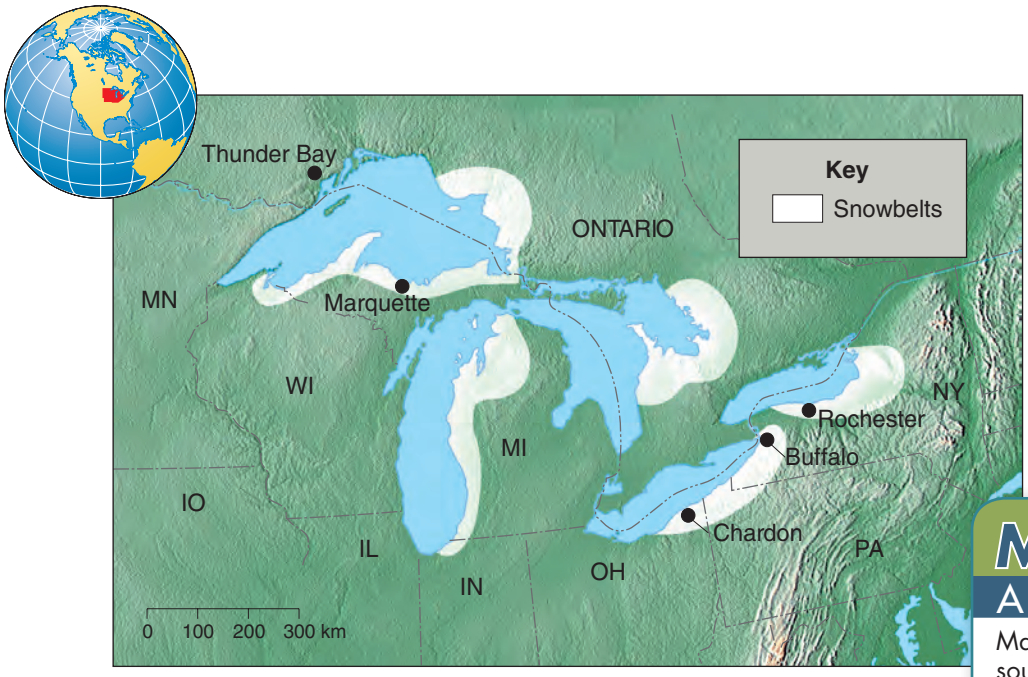


FIGURE 4 Lake-Effect Snowstorms Some areas that border the Great Lakes are prone to huge snowstorms.

MAP IT! ACTIVITY

Marquette, Michigan, is southeast of Thunder Bay, Ontario, as the map in **Figure 4** shows.

Identify What type of air mass influences the weather of these two cities in the winter?

Infer Which of these cities receives more snow in an average winter? Why?

Weather in North America

Much of the weather in North America, especially weather east of the Rocky Mountains, is influenced by continental polar (cP) and maritime tropical (mT) air masses. Figure 3 shows where these air masses originate.

Continental Polar Air Masses Continental polar air masses are uniformly cold and dry in winter and cool and dry in summer. In summer, cP air masses may bring a few days of relatively cooler weather. In winter, this continental polar air brings the clear skies and cold temperatures characteristic of a cold wave.

Continental polar air masses are not, as a rule, associated with heavy precipitation. However, those that cross the Great Lakes during late autumn and winter sometimes bring snowstorms to the land areas that the wind reaches after crossing over water. These localized snowstorms, which are known as *lake-effect snows,* make the New York cities of Buffalo and Rochester, shown in **Figure 4,** among the snowiest cities in the United States. The areas that receive heavy snow are known as *snowbelts.*

What causes lake-effect snow? During late autumn and early winter, the difference in temperature between the lakes and adjacent land areas can be large. The temperature contrast can be especially great when a very cold cP air mass pushes southward across the lakes. When this occurs, the air picks up large quantities of heat and moisture from the relatively warm lake surface. By the time it reaches the opposite shore, the air mass is humid and unstable. Heavy snow, such as that shown in **Figure 5,** is possible.

Reading Checkpoint *What causes large amounts of snow to fall on the southern and eastern shores of the Great Lakes?*

FIGURE 5 Digging Out A lake-effect snowstorm dropped 175 cm (69 in.) of snow on Chardon, Ohio.

FIGURE 6 **Rain Storm over Florida Bay in the Florida Keys**

Maritime Tropical Air Masses Maritime tropical air masses also play a dominant role in the weather of North America. These air masses are warm and loaded with moisture. In addition, they are usually unstable. Maritime tropical air is the source of much, if not most, of the precipitation received in the eastern two thirds of the United States. The heavy precipitation shown in **Figure 6** is the result of maritime tropical air masses moving through the area. In summer, when a mT air mass invades the central and eastern United States, it brings the high temperatures and oppressive humidity typically associated with its source region.

Maritime Polar Air Masses During the winter, maritime polar air masses that affect weather in North America come from the North Pacific. Such air masses often begin as cP air masses in Siberia (northern Asia). The cold, dry continental polar air changes into relatively mild, humid, unstable maritime polar air during its long journey across the North Pacific **(Figure 7)**. As this maritime polar air arrives at the western shore of North America, it is often accompanied by low clouds and showers. When this maritime polar air advances inland against the western mountains, uplift f the air produces heavy rain or snow on the windward slopes of the mountains (the sides that the wind passes over fi st).

Maritime polar air masses also originate in the North Atlantic off the coast of eastern Canada. These air masses influence the weather of the northeastern United States. In winter, when New England is on the northern or northwestern side of a passing low-pressure center, the counterclockwise winds draw in maritime polar air. The result is a storm characterized by snow and cold temperatures, known locally as a nor'easter.

Reading Checkpoint *What happens when maritime polar air crosses western mountains?*

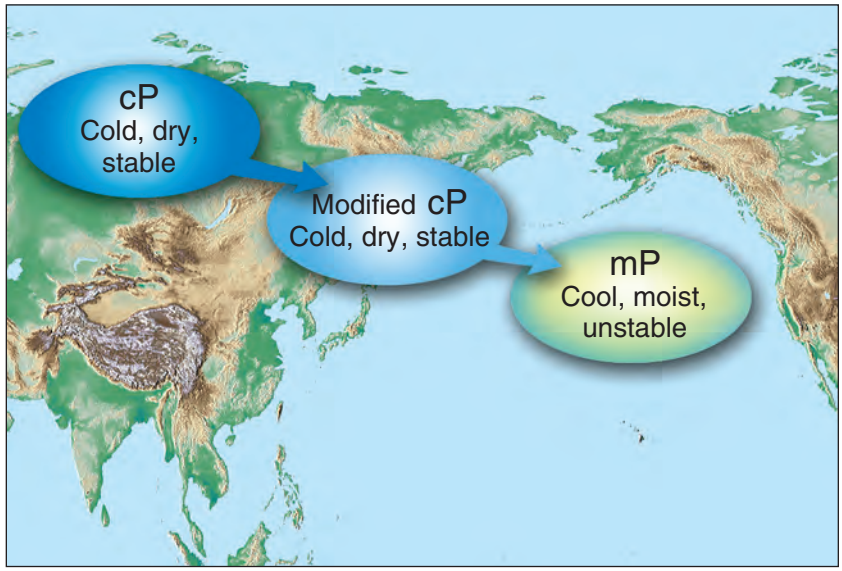


FIGURE 7 **Source of Maritime Polar Air Masses** During winter, maritime polar (mP) air masses in the northern Pacific Ocean usually begin as continental polar (cP) air masses in Siberia.
Infer ***What happens to the mP air masses as they cross the Pacific?***

FIGURE 8 Indian Summer A cT air mass produces a few days of warm weather amid the cool days of fall.

Continental Tropical Air Masses Continental tropical air masses begin in the southwestern United States and Mexico during the summer. **Only occasionally do cT air masses move outside their source regions.** However, when a cT air mass does move from its source region in the summer, it can cause extreme heat and drought in the Great Plains. Movement of such air masses in the fall results in mild weather, often called Indian summer, in the Great Lakes region.

PLANET DIARY

For links about **Tropical Storms**, go to PlanetDiary.com/HSES.

20.1 Assessment

Review Key Concepts

1. What is an air mass?
2. What happens as an air mass moves over an area?
3. How are air masses classified?
4. Which types of air masses have the greatest effect on weather in North America?
5. Why do continental tropical air masses have little effect on weather in North America?

Think Critically

6. **Compare and Contrast** Compare and contrast the four types of air masses.
7. **Explain** Explain which type of air mass could offer relief from a scorching summer to the Midwestern United States. Justify your choice.
8. **Apply Concepts** How can continental polar air be responsible for lake-effect snowstorms in the Great Lakes region?
9. **Identify** Look again at Figure 3. What kinds of air masses influence the weather patterns over Florida?
10. **Infer** What kind of weather could be expected in southern Canada if an mT air mass was to invade the region in mid-July?

WRITING IN SCIENCE

11. **Explain** Pick one of the air masses shown in Figure 3 that affects the weather in your area. Write a paragraph that explains the weather typically associated with the air mass in both the summer and the winter.

20.2 Fronts

ES.12 The student will investigate and understand that energy transfer between the sun and Earth and its atmosphere drives weather and climate on Earth. Key concepts include **b.** prediction of weather patterns; and **d.** weather phenomena and the factors that affect climate including radiation, conduction, and convection.

Key Questions

- ***What happens when two air masses meet?***
- ***How is a warm front produced?***
- ***What is a cold front?***
- ***What is a stationary front?***
- ***What are the stages in the formation of an occluded front?***
- ***What is a middle-latitude cyclone?***
- ***What fuels a middle-latitude cyclone?***

Vocabulary

- front • warm front
- cold front • stationary front
- occluded front

Reading Strategy

Outline As you read, make an outline like the one below. Include information about how each of the weather fronts discussed in this section forms and the weather associated with each.

Fronts
I. Warm front
A. ?
B. ?
II. Cold front
A. ?
B. ?

AIR MASSES have different temperatures and amounts of moisture, depending on their source. What happens when air masses come together?

Formation of Fronts

When two air masses with different properties meet, they form a front. A **front** is a boundary between two contrasting air masses. Fronts are often associated with some form of precipitation. Most weather fronts are between 15 and 200 kilometers wide. Above Earth's surface, the surface of the front slopes at a low angle, so that warmer, less dense air overlies cooler, denser air.

Occasionally, the air masses on both sides of a front move in the same direction and at the same speed. When this happens, the front acts simply as a barrier that travels with the air masses. In most cases, however, the distribution of pressure across a front causes one air mass to move faster than the other. When this happens, one air mass advances into another, and some mixing of air occurs.

FIGURE 9 Precipitation from a Storm in South Africa Storms often form along fronts.

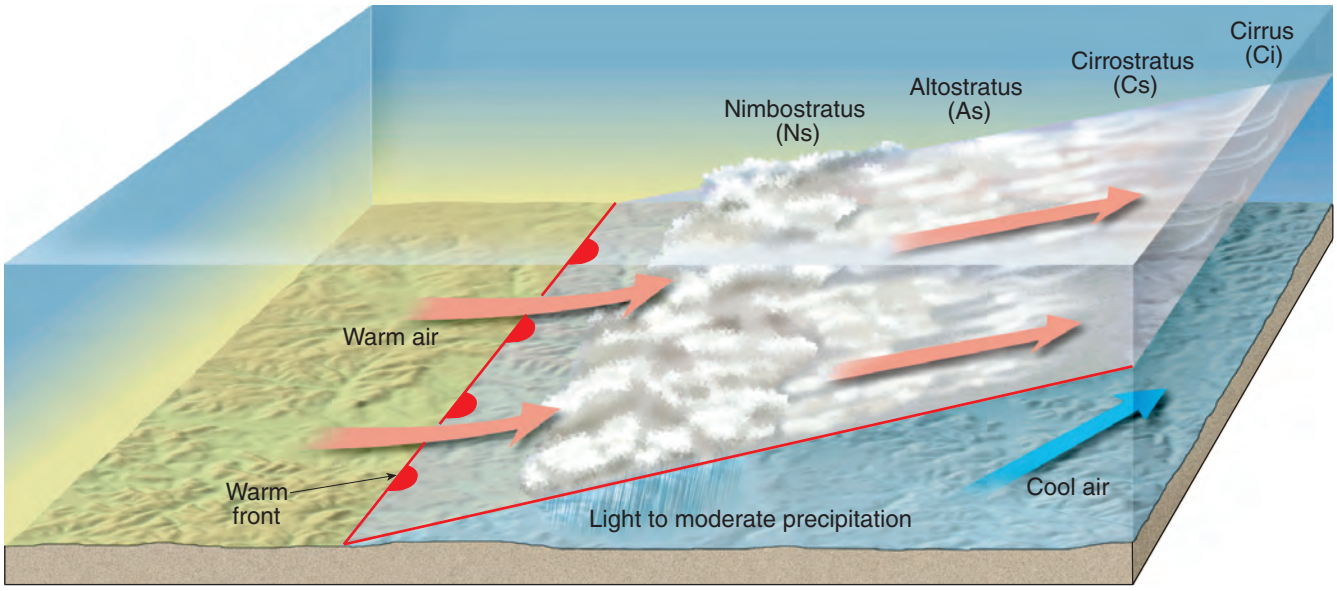


FIGURE 10 Formation of a Warm Front A warm front forms when warm air moves into an area formerly occupied by cooler air. The affected area has warmer temperatures and light to moderate precipitation.

Types of Fronts

Fronts are often classified according to the temperature of the advancing front. There are four types of fronts: warm fronts, cold fronts, stationary fronts, and occluded fronts.

Warm Fronts A **warm front** is a front along which a warm air mass rises over a retreating mass of cool air. **A warm front forms when warm air moves into an area formerly covered by cooler air.** On a weather map, the surface position of a warm front is shown by a red line with red semicircles. The semicircles point toward the cooler air mass.

The slope of the warm front is very gradual, as shown in **Figure 10.** As warm air rises, it cools to produce clouds and frequently precipitation. The sequence of clouds shown in Figure 10 typically comes before a warm front. The first sign of the approaching warm front is the appearance of cirrus clouds. As the front comes closer, cirrus clouds change into cirrostratus clouds, which blend into denser sheets of altostratus clouds. About 300 kilometers ahead of the front, thicker stratus and nimbostratus clouds appear, and rain or snow begins.

Because of their slow rate of movement and very low slope, warm fronts usually produce light to moderate precipitation over a large area for an extended period. A gradual increase in temperature occurs with the passage of a warm front. The increase is most apparent when a large temperature difference exists between adjacent air masses. In the Northern Hemisphere, a wind shift rom the east to the southwest is associated with a warm front.

Reading Checkpoint *What causes a warm front to form?*

ACTIVE ART

For: Weather Fronts activity
Visit: PearsonSchool.com
Web Code: czp-6202

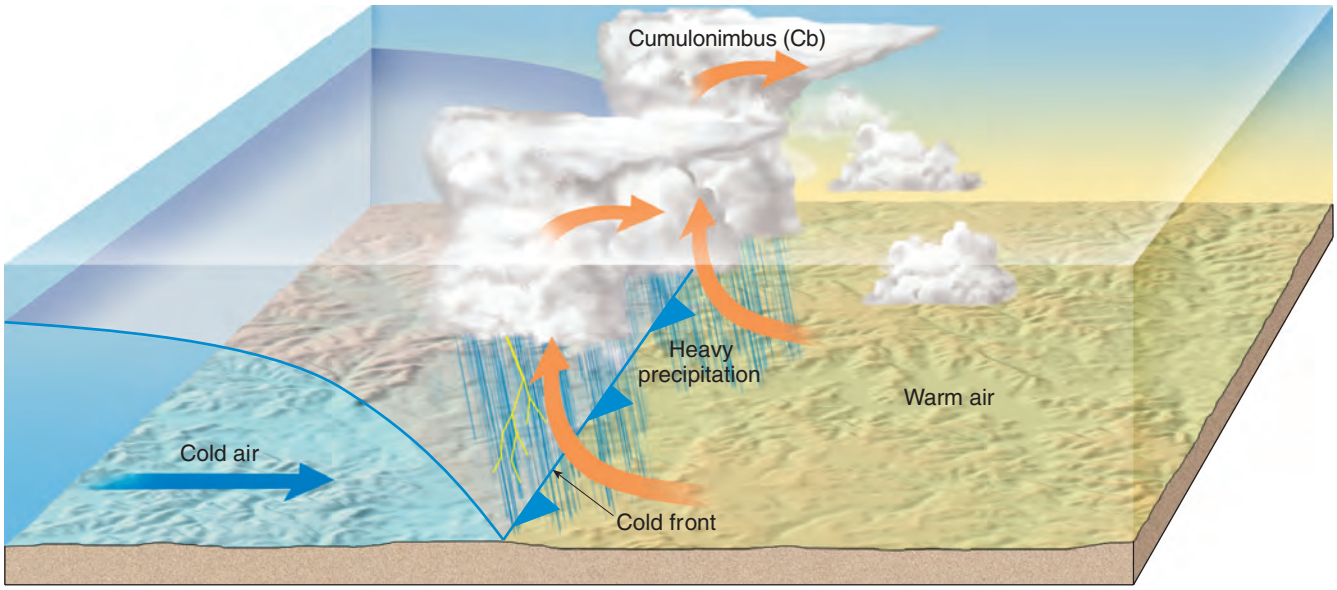


FIGURE 11 Formation of a Cold Front A cold front forms when cold air moves into an area occupied by warmer air. The affected area experiences thunderstorms if the warm air is unstable.

Cold Fronts You can see the process in which a cold front forms in **Figure 11.** **A cold front forms when cold, dense air moves into a region occupied by warmer air.** As this cold front moves, it becomes steeper. On average, cold fronts are about twice as steep as warm fronts and advance more rapidly than warm fronts do. These two differences—rate of movement and steepness of slope—account for the more violent weather associated with a cold front. On a weather map, the surface position of a cold front is shown by a blue line edged with blue triangles pointing toward the warmer air mass.

The forceful lifting of air along a cold front can lead to heavy rain and gusty winds. As a cold front approaches, cumulonimbus clouds often can be seen in the distance. Once the cold front has passed, temperatures drop and wind shifts. e weather behind a cold front is dominated by a cold air mass. So, weather clears soon after a cold front passes. When a cold front moves over a warm area, low cumulus or stratocumulus clouds may form behind the front.

Reading Checkpoint *How are cold fronts different from warm fronts?*

Stationary Fronts Occasionally, the flow of air on either side of a front is neither toward the cold air mass nor toward the warm air mass, but almost parallel to the line of the front. **When the surface position of the front does not move, a stationary front has formed.** In a **stationary front,** two air masses come together but neither displaces the other. Gentle to moderate precipitation can occur. On a weather map, stationary fronts are shown by blue triangles on one side of the front and red semicircles on the other.

Occluded Fronts An occluded front is diagrammed in **Figure 12.**

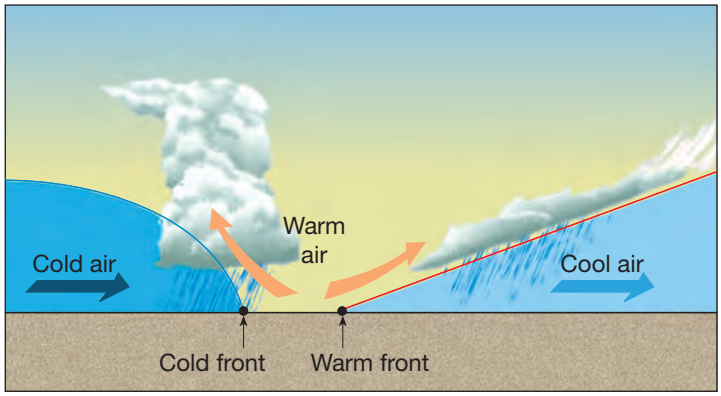
When a cold front overtakes a warm front, an occluded front forms. On a weather map, an occluded front is shown by a purple line with triangles and semicircles. An occluded front develops as the advancing cold air wedges the warm front upward. The weather associated with an occluded front is generally complex. Most precipitation is associated with warm air being forced upward. When conditions are suitable, however, the newly formed front is capable of making light precipitation of its own.

The descriptions of weather associated with fronts are general descriptions. The weather along any individual front may or may not conform to the idealized descriptions you've read about. Fronts, like all aspects of nature, do not always behave as we would expect.

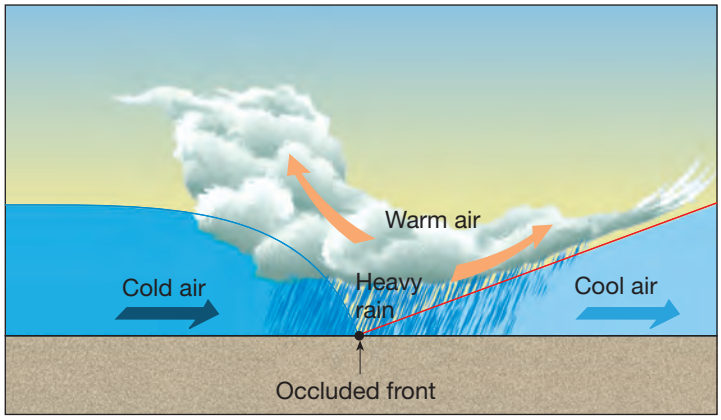
VISUAL SUMMARY

FORMATION OF AN OCCLUDED FRONT

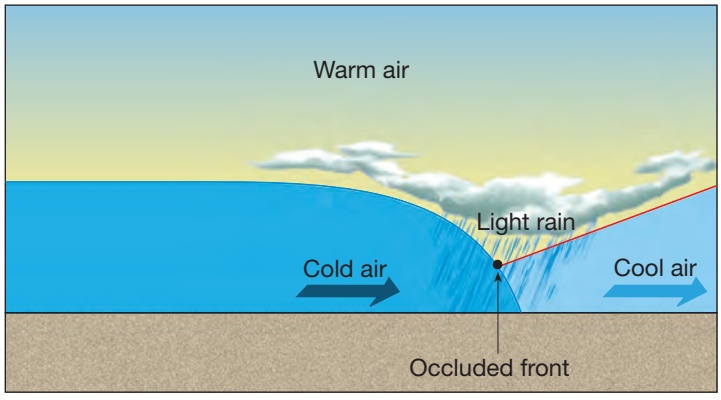
FIGURE 12 When a cold front overtakes a warm front, an occluded front forms, producing a complex weather pattern.



1 A cold front moves toward a warm front, forcing warm air aloft.



2 A cold front merges with the warm front to form an occluded front that drops heavy rains.



3 Because occluded fronts often move slowly, light precipitation can fall for several days.

Middle-Latitude Cyclones

In the Northern Hemisphere, a *cyclone* is a system with winds spinning counterclockwise with an area of low pressure at the center. The main weather producers in this country are middle-latitude cyclones. On weather maps, these low-pressure areas are shown by the letter L.

A middle-latitude cyclone is a large center of low pressure that generally travels from west to east and causes stormy weather. The air in a middle-latitude cyclone moves in a counterclockwise direction and toward the center of the low. Most middle-latitude cyclones have a cold front, and frequently a warm front, extending from the central area. Forceful lifting of air causes the formation of clouds that drop abundant precipitation.

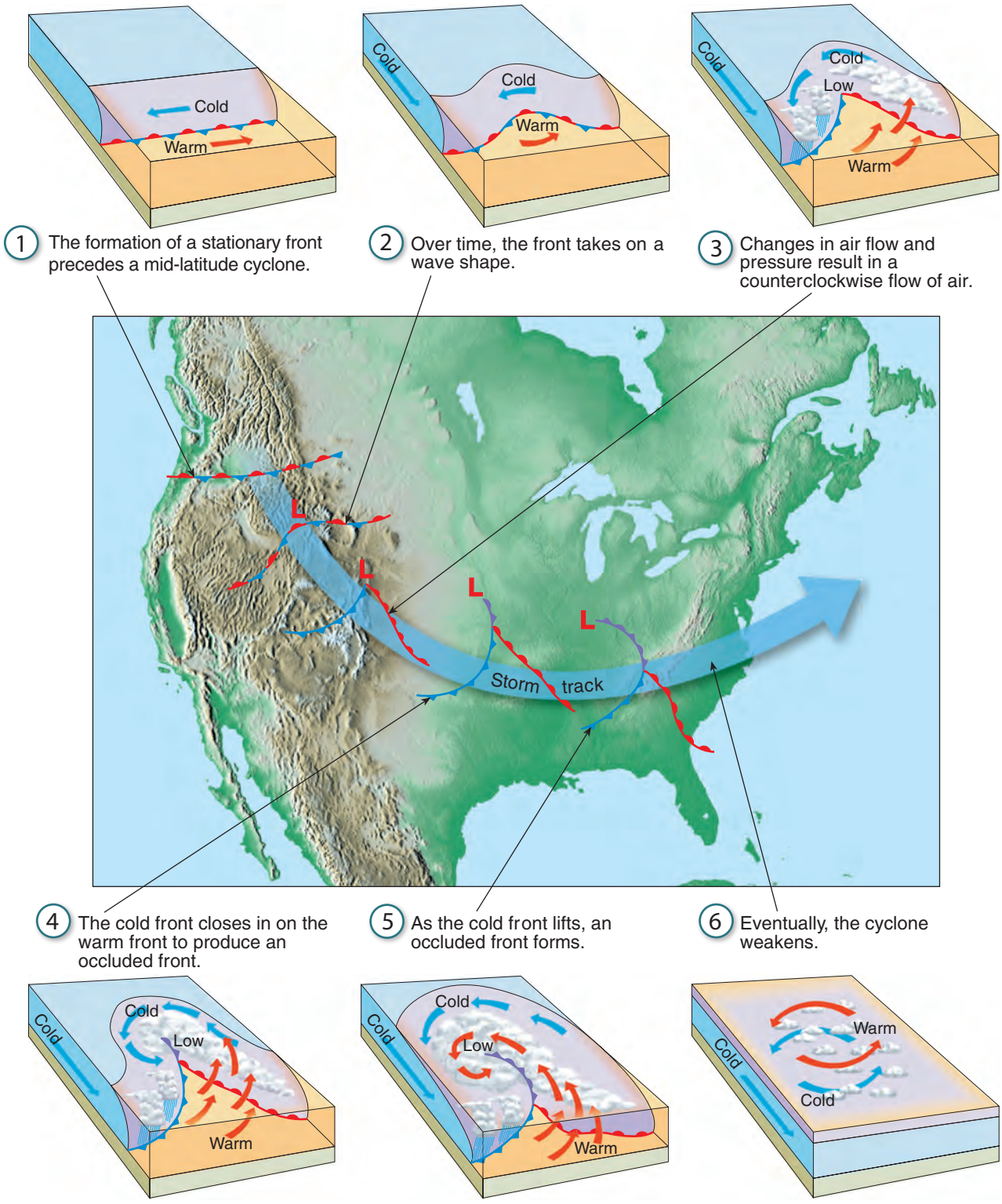
How do cyclones form? The stages of cyclone formation are diagramed in **Figure 13**. The fi st stage is the development of a stationary front. The front forms as two air masses with different temperatures move in opposite directions. Over time, the front takes on a wave shape. The wave is usually hundreds of kilometers long.

As the wave develops, warm air moves towards Earth's poles. There it invades the area formerly occupied by colder air. Meanwhile, cold air moves toward the equator. This change in airflow near the surface is accompanied by a change in pressure. The result is a counterclockwise airflow in the Northern Hemisphere.

VISUAL SUMMARY

MIDDLE-LATITUDE CYCLONE MODEL

FIGURE 13 Cyclones have a fairly predictable life cycle.



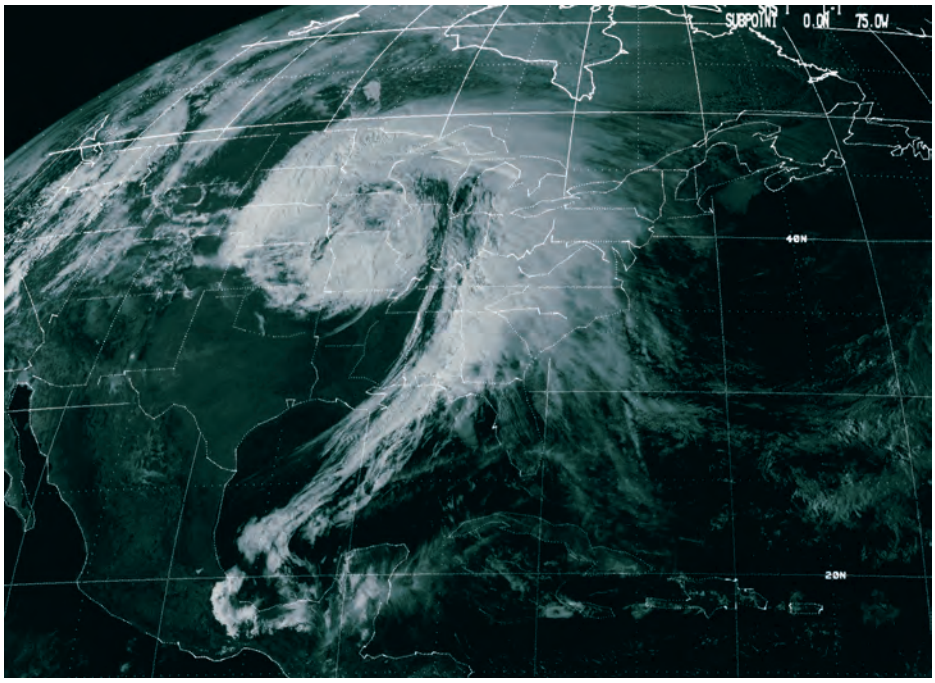


FIGURE 14 Cyclone
This is a satellite view of a mature cyclone over the eastern United States.

Occlusion Recall that a cold front advances faster than a warm front. When this occurs in the development of a middle-latitude cyclone, the cold front closes in and eventually lifts he warm front, as Figure 13 shows. This process, known as *occlusion,* forms an occluded front. As occlusion begins, the storm often gets stronger. Pressure at the storm's center falls, and wind speeds increase. In the winter, heavy snowfalls and blizzardlike conditions are possible during this phase.

As more of the warm air is forced to rise, there are smaller differences in air pressure. In a day or two, the entire warm area is displaced. Only cold air surrounds the cyclone at low levels. The horizontal temperature difference that existed between the two air masses is gone. At this point, the cyclone has exhausted its source of energy. Friction slows the airflow near the surface, and the once highly organized counterclockwise flow fades away.

The Role of Airflow Aloft

In an *anticyclone* in the Northern Hemisphere, winds move in a clockwise direction. Airflow aloft lays an important role in maintaining both cyclonic and anticyclonic circulation. In fact, cyclones and anticyclones are actually generated by upper-level flow.

Cyclones often exist for a week or longer. For this to happen, surface convergence must be offset by outflow somewhere higher in the atmosphere. As long as the spreading out of air high up is equal to or greater than the surface inflow, the low-pressure system can be sustained. **More often than not, air high up in the atmosphere fuels a middle-latitude cyclone.**

Reading Checkpoint *How do middle-latitude cyclones form and develop?*

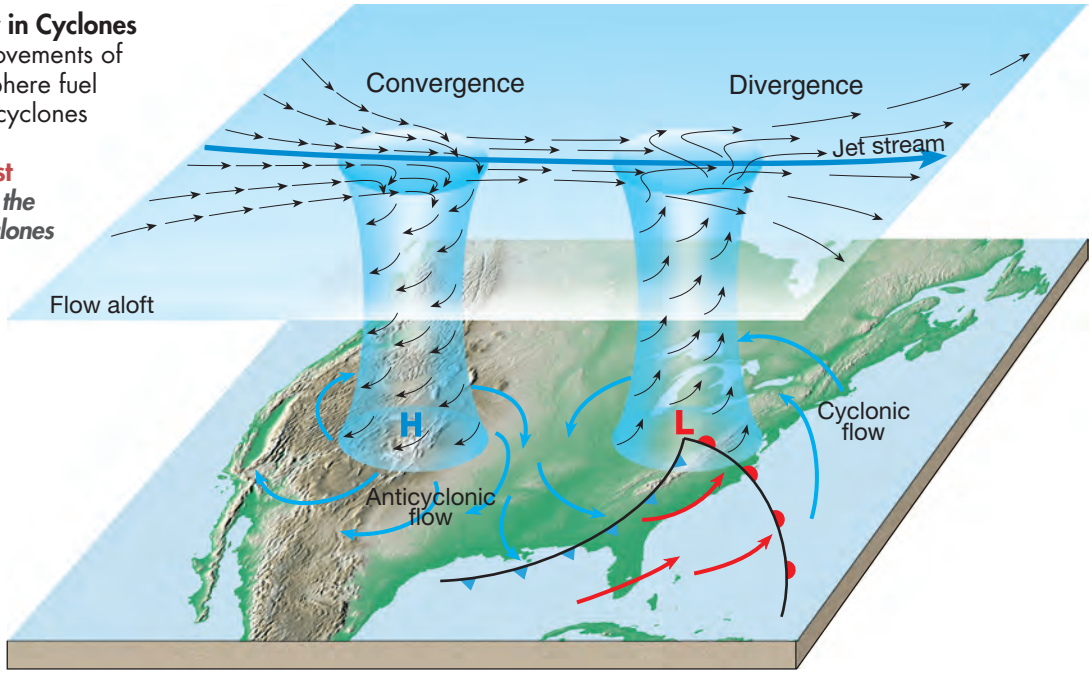


FIGURE 15 Air Flow in Cyclones and Anticyclones Movements of air high in the atmosphere fuel the cyclones and anticyclones near Earth's surface.
Compare and Contrast *Compare and contrast the movement of air in cyclones and anticyclones.*

Because cyclones bring stormy weather, they have received far more attention than anticyclones. However, a close relationship exists between these two pressure systems. As shown in **Figure 15,** the surface air that feeds a cyclone generally originates as air flowing out of an anticyclone. As a result, cyclones and anticyclones typically are found next to each other. Like a cyclone, an anticyclone depends on the flow of air high in the atmosphere to maintain its circulation. In an anticyclone, air spreading out at the surface is balanced by air coming together from high up.

20.2 Assessment

Review Key Concepts

1. What happens when two air masses with different properties meet?
2. How does a warm front form?
3. What is a cold front?
4. What is a stationary front?
5. What are the stages in the formation of an occluded front?
6. What is a middle-latitude cyclone?
7. What causes a middle-latitude cyclone to sustain itself?

Think Critically

8. **Compare and Contrast** Compare and contrast warm fronts and cold fronts.
9. **Interpret Visuals** Use Figure 15 and what you know about Earth's atmosphere to describe the air movement and pressure conditions associated with both cyclones and anticyclones.

WRITING IN SCIENCE

10. **Explain** Write a paragraph to explain this statement: The formation of an occluded front marks the beginning of the end of a middle-latitude cyclone.

20.3 Severe Storms

ES.12 The student will investigate and understand that energy transfer between the sun and Earth and its atmosphere drives weather and climate on Earth. Key concepts include **c.** severe weather occurrences, such as tornadoes, hurricanes, and major storms.

SEVERE WEATHER has a fascination that everyday weather does not provide. For example, a thunderstorm with its jagged lightning and booming thunder can be an awesome sight. However, the damage and destruction caused by severe weather can be frightening. A single severe storm can cause billions of dollars in property damage as well as many deaths. This section discusses three types of severe storms and their causes.

Thunderstorms

Have you ever seen a small whirlwind carry dust or leaves upward on a hot day? Have you observed a bird glide effortlessly skyward on an invisible updraft f hot air? If so, you have observed the effects of the vertical movements of relatively warm, unstable air. Thunderstorms develop because of a similar thermal kind of instability. **A thunderstorm is a storm that generates lightning and thunder. Thunderstorms frequently produce gusty winds, heavy rain, and hail.** A thunderstorm may be produced by a single cumulonimbus cloud and influence only a small area. Or it may be associated with clusters of cumulonimbus clouds that stretch for kilometers along a cold front.

Key Questions

- ***What is a thunderstorm?***
- ***What causes a thunderstorm to form?***
- ***What is a tornado?***
- ***How does a tornado form?***
- ***What is a hurricane?***
- ***How does a hurricane form?***

Vocabulary

- thunderstorm • tornado
- hurricane • eye wall
- eye • storm surge

Reading Strategy

Identify Cause and Effect
Copy the table and complete it as you read this section.

Severe Storms		
	Causes	**Effects**
Thunderstorms	a. ?	b. ?
Tornadoes	c. ?	d. ?
Hurricanes	e. ?	f. ?

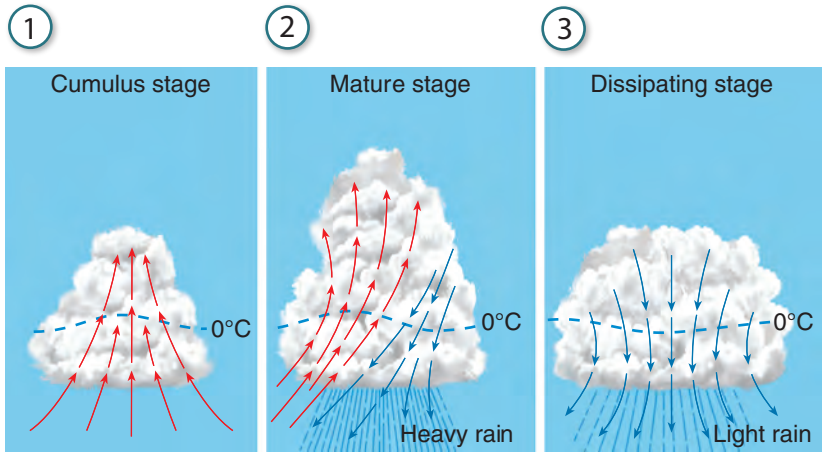
FIGURE 16 Jagged Fork in the Sky Lightning is a spectacular and potentially dangerous feature of a thunderstorm.

VISUAL SUMMARY

STAGES IN THE DEVELOPMENT OF A THUNDERSTORM

FIGURE 17

1 During the cumulus stage, air rises, supplying warm, moist air to the cloud.
2 Heavy precipitation falls during the mature stage.
3 The cloud begins to evaporate during the dissipating stage.
Observe ***How do the clouds involved in the development of a thunderstorm vary?***



PLANET DIARY

For links about **Severe Storms** go to PlanetDiary.com/HSES.

Location of Thunderstorms

At any given time, there are an estimated 2000 thunderstorms in progress on Earth. As you might expect, the greatest number occurs in the tropics where warmth, plentiful moisture, and instability are common atmospheric conditions. About 45,000 thunderstorms take place each day. More than 16 million occur annually around the world. The United States experiences about 100,000 thunderstorms each year, most frequently in Florida and the eastern Gulf Coast region. Most parts of the country have from 30 to 100 storms each year. The western coast of the United States has little thunderstorm activity because warm, moist, unstable maritime tropical air seldom penetrates this region.

Development of Thunderstorms

Thunderstorms form when warm, humid air rises in an unstable environment. The development of a thunderstorm generally involves three stages. During the *cumulus stage,* shown in **Figure 17,** strong updrafts, r upward movements of air, supply moist air. Each new surge of warm air rises higher than the last and causes the cloud to grow vertically. A tall cumulus cloud that usually produces rain is called a *cumulonimbus cloud.*

Usually within an hour of the fi st updraft, the *mature stage* begins, as shown in Figure 17. At this point in the development of the thunderstorm, the number and size of the cloud's water droplets and ice crystals are too great for the updrafts o support. So, heavy precipitation falls from the cloud. The mature stage is the most active stage of a thunderstorm. Strong winds, lightning, heavy precipitation, and sometimes hail are produced during this stage.

Eventually, downdrafts, or downward movements of air, dominate throughout the cloud, as shown in Figure 17. This fi al stage is called the *dissipating stage.* During this stage, the cooling effect of the falling precipitation and the flowing in of colder air from high above cause the storm to die down.

The life span of a single cumulonimbus unit within a thunderstorm is only about an hour or two. As the storm moves, however, fresh supplies of warm, humid air generate new cumulonimbus units to replace those that are scattering.

Reading Checkpoint *Describe the stages in the development of a thunderstorm.*

Tornadoes

A **tornado** is a violent windstorm that takes the form of a rotating column of air called a *vortex*. **A tornado's vortex extends downward from a cumulonimbus cloud all the way to the ground.** Some tornadoes consist of a single vortex. But within many stronger tornadoes, smaller vortexes rotate within the main funnel. These smaller vortexes have diameters of only about 10 meters and rotate very rapidly.

Location and Development of Tornadoes In the United States, about 770 tornadoes are reported each year. Tornadoes can occur anywhere in the United States, but they occur most frequently in Florida and the south-central part of the country. These severe storms can occur at any time during the year. However, the frequency of tornadoes is greatest from April through June. In December and January, tornadoes are far less frequent than in the spring and early summer.

Most tornadoes form in association with severe thunderstorms. An important process in the formation of many tornadoes is the development of a mesocyclone. A *mesocyclone* is a vertical cylinder of rotating air that develops in the updraft of a thunderstorm. The formation of this large vortex begins as strong winds high up in the atmosphere cause winds lower in the atmosphere to roll, as shown in **Figure 18.** In Figure 18, you can see that strong thunderstorm updrafts ause this rolling air to tilt. Once the air is completely vertical, the mesocyclone is well established. The formation of a mesocyclone does not necessarily mean that a tornado will follow.

INQUIRY
APPLY IT!

Q: ***What is the most destructive tornado on record?***

A: **The Tri-State Tornado, which occurred on March 18, 1925, started in southeastern Missouri and remained on the ground over a distance of 352 kilometers, until it reached Indiana. Casualties included 695 people dead and 2027 injured. Property losses were also great, with several small towns almost totally destroyed.**

VISUAL SUMMARY

FORMATION OF A MESOCYCLONE

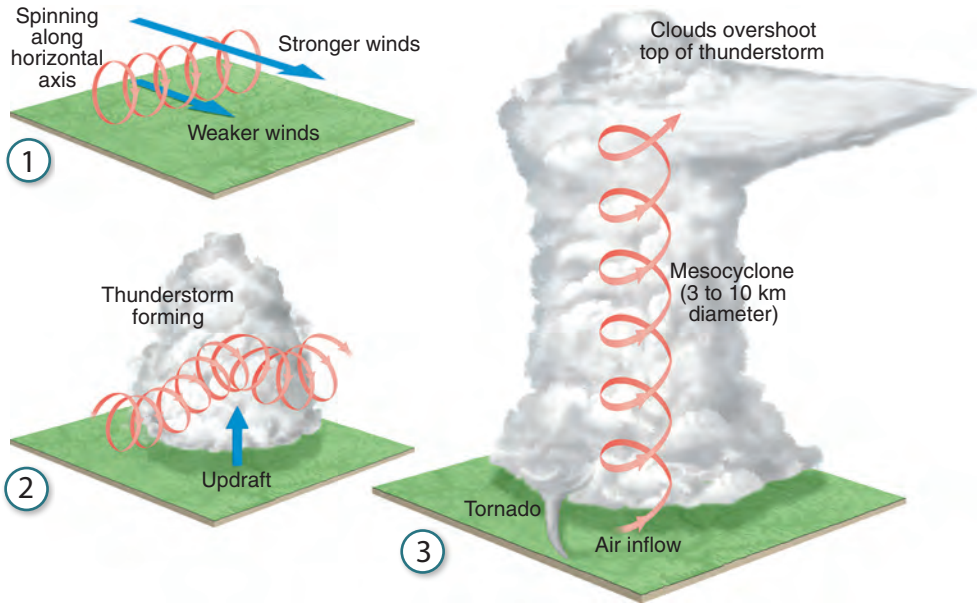


FIGURE 18 A mesocyclone can occur before the formation of a tornado. **1** First, stronger winds aloft cause lower winds to roll. **2** Updrafts tilt the rolling air so that it becomes nearly vertical. **3** When the rotating air is completely vertical, the mesocyclone is established.

FIGURE 19 Joplin, May 22, 2011
A tornado that began outside Joplin, Missouri, caused terrible destruction. This photograph shows lightning (the blue light) within the tornado's vortex.

Tornado Intensity Air pressure within some tornadoes has been estimated to be as much as 10 percent lower than air pressure immediately outside the storm. The low pressure within a tornado causes air near the ground to rush into a tornado from all directions. As the air streams inward, it spirals upward around the core. Eventually, the air merges with the airflow of the cumulonimbus cloud that formed the storm. Because of the tremendous amount of pressure change associated with a strong tornado, maximum winds can sometimes approach 480 kilometers per hour. One scale used to estimate tornado intensity is the Fujita tornado intensity scale, shown in **Table 1.** Because tornado winds are difficult to measure directly, a rating on this scale is usually determined by assessing the worst damage produced by a storm. The 2011 tornado in Joplin, Missouri, shown in **Figure 19,** was a level F5 storm.

Tornado Warning The Storm Prediction Center (SPC), which is part of the National Atmospheric and Oceanic Administration, is located in Norman, Oklahoma. The SPC monitors different kinds of severe weather. The SPC's mission is to provide timely and accurate forecasts and watches for severe thunderstorms and tornadoes. Tornado watches alert people to the possibility of tornadoes in a specified area for a particular time period. A tornado warning is issued when a tornado has actually been sighted in an area or is indicated by weather radar.

Table 1 Fujita Tornado Intensity Scale

Intensity	Wind Speed Estimates (km/h)	Typical Damage
F0	< 116	Light damage. Some damage to chimneys; branches broken off trees; shallow-rooted trees pushed over; sign boards damaged.
F1	116–180	Moderate damage. Peels surface off roofs; mobile homes pushed off foundations or overturned; moving cars blown off roads.
F2	181–253	Considerable damage. Roofs torn off frame houses; mobile homes demolished; large trees snapped or uprooted; light-object missiles generated; cars lifted off ground.
F3	254–332	Severe damage. Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; heavy cars lifted off the ground and thrown.
F4	333–419	Devastating damage. Well-constructed houses leveled; structures with weak foundations blown some distance; cars thrown; large missiles generated.
F5	> 419	Incredible damage. Strong frame houses lifted off foundations and carried away; automobile-sized missiles fly through the air in excess of 100 m; bark torn off trees.

Hurricanes

If you've ever been to the tropics, you know that the usual weather consists of warm breezes, steady temperatures, and heavy but brief showers. However, these tranquil regions sometimes produce hurricanes, the most violent storms on Earth. **Whirling tropical cyclones that produce sustained winds of at least 119 kilometers per hour are known in the United States as hurricanes.** In other parts of the world, these severe tropical storms are called *typhoons, cyclones,* and *tropical cyclones.*

Hurricanes are powerful. At sea, they can generate 15-meter waves capable of destruction hundreds of kilometers away. If a hurricane hits land, strong winds and extensive flooding can cause billions of dollars in damage and great loss of life. Hurricane Katrina, shown in a satellite image in **Figure 20,** was one such storm. In August 2005, Katrina brought flooding rains and high winds to Louisiana and Mississippi. It was the costliest natural disaster in United States history, and the deadliest U.S. hurricane since 1928.

Hurricanes are becoming a growing threat because more and more people are living and working near coasts. At the start of the twenty-fi st century, more than 50 percent of the U.S. population lived within 75 kilometers of a coast. This number is expected to increase even more in the early decades of this century.

Location of Hurricanes Most hurricanes form between about 5 and 20 degrees north and south latitude. Hurricanes form in this area because ocean water is warm here—they do not form over cooler ocean water. For example, some of these storms develop in the Gulf of Mexico, but none start in the North Atlantic. Water temperatures are much warmer in the Gulf of Mexico than in the North Atlantic ocean.

INQUIRY
APPLY IT!

Q: ***Why are hurricanes given names, and who picks the names?***

A: **Actually, the names are given once the storms reach tropical-storm status (winds between 61–119 kilometers per hour). Tropical storms are named to provide ease of communication between forecasters and the general public regarding forecasts, watches, and warnings. Tropical storms and hurricanes can last a week or longer, and two or more storms can be occurring in the same region at the same time. Thus, names can reduce the confusion about what storm is being described.**

The World Meteorological Organization creates the lists of names. The names for Atlantic storms are used again at the end of a six-year cycle unless a hurricane was particularly destructive or otherwise noteworthy. The names of those hurricanes, such as Katrina, are retired to prevent confusion when the storms are discussed in future years.

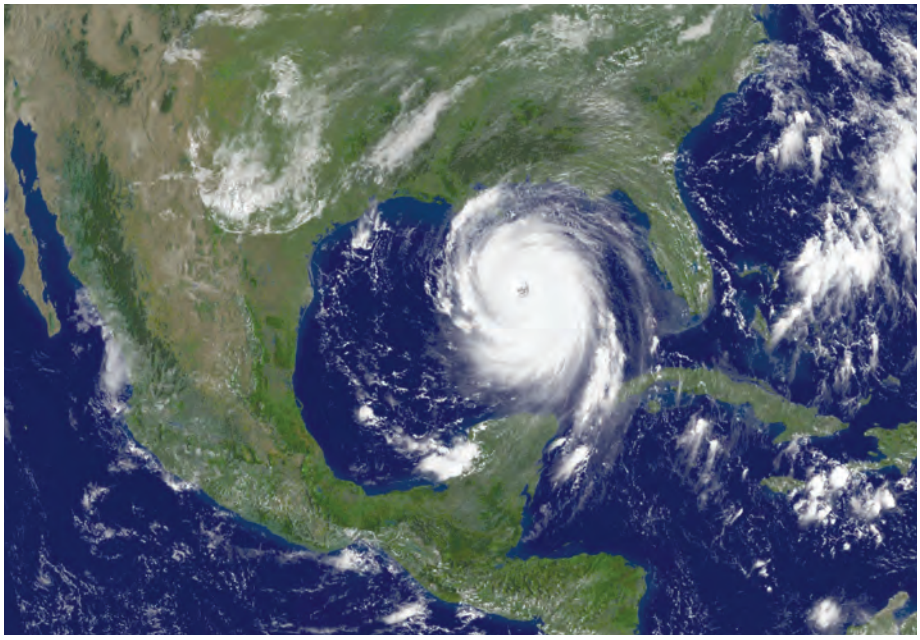


FIGURE 20 Satellite View of a Hurricane This satellite image of Hurricane Katrina shows its position in the Gulf of Mexico a day before the hurricane moved onto land. Katrina eventually made landfall near the Louisiana-Mississippi border.

PLANET DIARY

For links about **Hurricanes**, go to PlanetDiary.com/HSES.

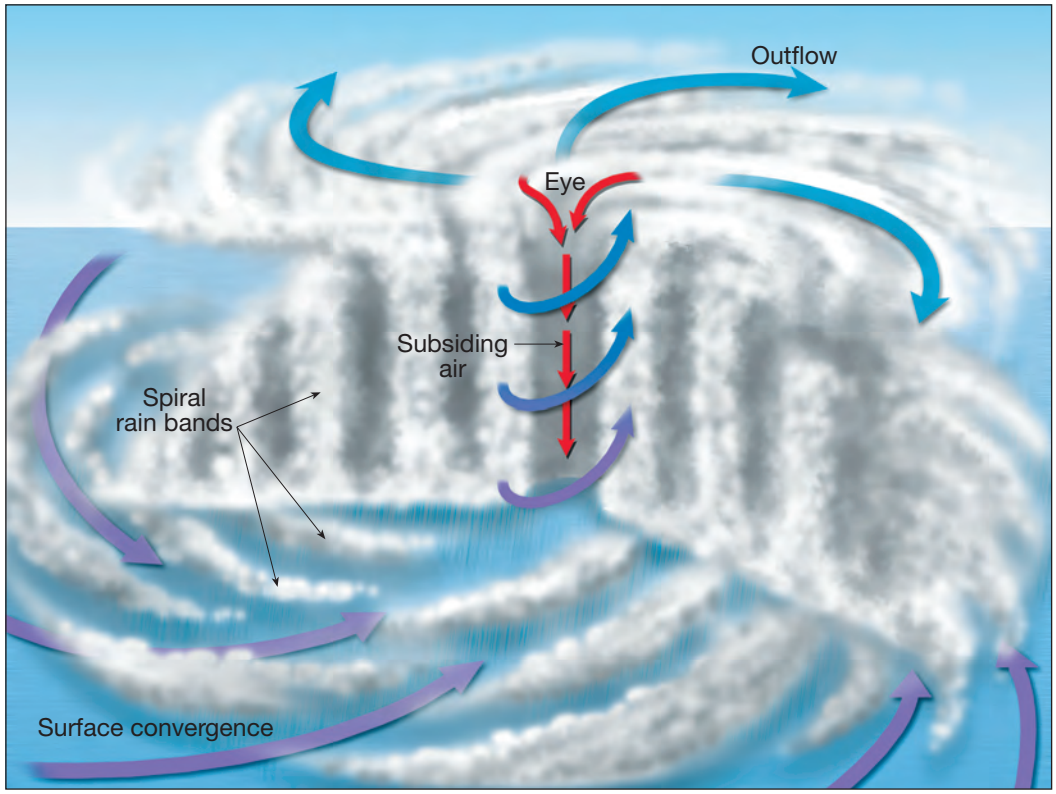
In a yearly cycle, hurricanes begin most often in the late summer when water temperatures are warm enough to provide the necessary heat and moisture to the air. After beginning, hurricanes can travel thousands of kilometers. For example, a hurricane that begins off he west coast of Africa can move west across the Atlantic and then make its way up the east coast of the United States. A hurricane can last a week or more.

Development of Hurricanes A hurricane is fueled by the energy given off hen huge quantities of water vapor condense. A hurricane begins as a tropical disturbance that consists of disorganized clouds and thunderstorms. Low atmospheric pressures and little or no rotation are characteristic of these disturbances.

Figure 21 shows a cross section of a well-developed hurricane. An inward rush of warm, moist surface air moves toward the core of the storm. The air then turns upward and rises in a ring of cumulonimbus clouds. This doughnut-shaped wall that surrounds the center of the storm is the **eye wall.** Here the greatest wind speeds and heaviest rainfall occur. Surrounding the eye wall are curved bands of clouds that trail away from the center of the storm. Notice that near the top of the hurricane, the rising air is carried away from the storm center. This outflow provides room for more inward flow at the surface.

At the very center of the storm is the eye of the hurricane. The **eye** is a zone where precipitation ceases and winds become less strong. The air within the eye gradually descends and heats, making it the warmest part of the storm.

FIGURE 21 Cross Section of a Hurricane The eye of the hurricane is a zone of relative calm.
Describe *How does the air flow in different parts of a hurricane?*



Hurricane Intensity The intensity of a hurricane is described using the Saffir-Simpson scale shown in **Table 2.** The most devastating damage from a hurricane is caused by storm surges. A **storm surge** is a dome of water about 65 to 80 kilometers wide that sweeps across the coast where a hurricane's eye moves onto land.

A hurricane weakens when it moves over cool ocean waters that cannot supply adequate heat and moisture. Intensity also drops when storms move over land, because there is not sufficient moisture in the air. In addition, contact with the rough land surface causes winds to subside. Finally, when a hurricane reaches a location where the airflow aloft s unfavorable, it will die out.

Table 2 Saffir-Simpson Hurricane Scale

Category	Sustained Wind Speeds (km/h)	Typical Damage
1	119–153	Storm surge 1.2–1.5 meters; some damage to unanchored mobile homes, shrubbery, and trees; some coastal flooding; minor pier damage.
2	154–177	Storm surge 1.6–2.4 meters; some damage to buildings' roofs, doors, and windows; considerable damage to mobile homes and piers; moderate coastal flooding.
3	178–209	Storm surge 2.5–3.6 meters; some structural damage to small buildings; some large trees blown over; mobile homes destroyed; some coastal and inland flooding.
4	210–249	Storm surge 3.7–5.4 meters; severe damage to trees and signs; complete destruction of mobile homes; extensive damage to doors and windows; severe flooding inland.
5	> 249	Storm surge >5.4 meters; complete roof failure on many buildings; some complete building failure; all trees and signs blown away; major inland flooding.

20.3 Assessment

Review Key Concepts

1. What is a thunderstorm?
2. What causes a thunderstorm?
3. What is a tornado?
4. How does a tornado form?
5. What is a hurricane?
6. How does a hurricane form?

Think Critically

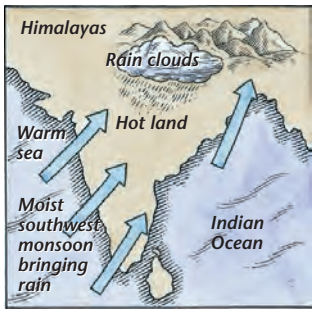
7. **Draw Conclusions** What kind of front is associated with the formation of tornadoes? Explain.
8. **Relate Cause and Effect** Explain why a hurricane quickly loses its strength as the storm moves onto land.

BIG IDEA WEATHER AND CLIMATE

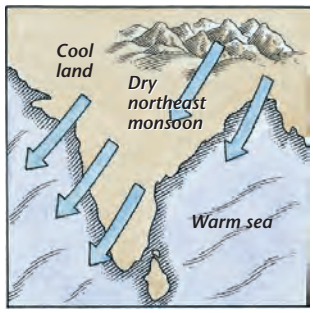
9. **Infer** Explain why even though hurricanes have lower wind speeds than tornadoes, they often cause more damage than tornadoes do.

Winds and Storms

The world's atmosphere is forever on the move. **Wind,** or air in horizontal motion, occurs because solar radiation heats up some parts of the sea and land more than others. Air above these hot spots becomes warmer and less dense than the surrounding air and therefore rises. Elsewhere, cool air sinks because it is more dense. Winds blow because air squeezed out by sinking, cold air flows toward regions of low pressure created by warm air. Wind may move slowly as in a gentle breeze, when air pressure and temperature change gradually. In extreme weather, when air pressure and temperature change rapidly, wind moves rapidly, creating terrifyingly destructive storms.



Southwest Monsoon
During the early summer, hot, dry air over Asia rises, creating low-pressure zones. Cool, moist, higher-pressure air from the Indian Ocean therefore flows inland. When the cooler, moist air collides with the hot, dry air over Asia, clouds form and rain falls.



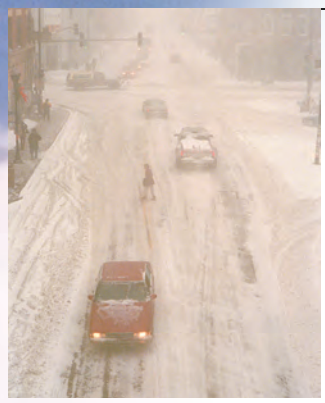
Northeast Monsoon
The cold, dry, relatively dense winter air from Central Asia flows seaward toward regions of low air pressure, bringing chilly, dusty conditions to South Asia.

▲ **MONSOONS**
Seasonal winds called monsoons affect large areas of the tropics and subtropics. They occur in South Asia, southern North America, eastern Australia, and other regions of the world. In South Asia, southwest monsoons generally bring desperately needed rain from May until October.

◀ **THUNDERSTORMS**
Thunderclouds are formed by powerful updrafts of air that occur along cold fronts or over ground heated very strongly by the sun. Ice crystals and water droplets high in the cloud are torn apart and smashed together with such ferocity that they become charged with electricity. Thunderstorms can unleash thunder, lightning, wind, rain, and hail.

◀ **LIGHTNING AND THUNDER**
Electricity is discharged from a thundercloud in the form of lightning. A bolt of lightning can heat the air around it to a temperature four times as hot as the sun's surface. The heated air expands violently and sends out a rumbling shock wave that we hear as thunder. Some lightning bolts, like the one shown at left, can arc from the top of the thundercloud all the way to the ground, striking objects up to 16 kilometers (10 miles) away.

TORNADOES ▶
Tornadoes may strike wherever thunderstorms occur. A **tornado** begins when a column of strongly rising warm air is set spinning by high winds at the top of a cloud. A funnel is formed and may touch the ground. With winds that can range from a damaging 104 kilometers per hour (65 mph) to a devastating speed greater than 400 kilometers per hour (250 mph), tornadoes can lift people, cars, and buildings high into the air and then smash them back to the ground.



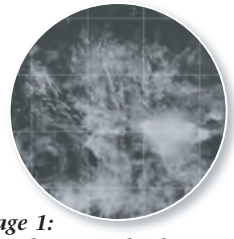
▲ BLIZZARDS
When strong, 56 kilometers per hour (35 mph) winds combine with heavy snowfall to reduce visibility to just 400 meters (0.25 miles), a blizzard is the result. Winds pile up huge drifts of snow. Travel and communication systems can grind to a halt.

IMPACT OF TROPICAL STORMS
Tropical storms are often devastating. The strongest winds, with gusts sometimes more than 249 kilometers per hour (156 mph), occur near the storm's center, within the eye wall. When a tropical storm strikes land, raging winds can uproot trees and destroy buildings. Vast areas may be swamped by torrential rain, and coastal regions may be overwhelmed by a **storm surge,** a bulge of water up to 8 meters (26 feet) high that rises in response to the extremely low air pressure of the storm's eye. When the tropical storm makes landfall, the storm surge rushes inland, swamping whatever lies in its path. ▼

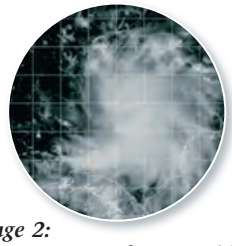
These women wade through the streets of Dhaka, Bangladesh, flooded by a tropical cyclone. In 1991, a cyclone killed more than 130,000 Bangladeshis.

A Pacific typhoon struck this ship off the coast of Taiwan in November 2000.

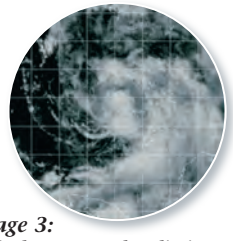
HOW TROPICAL STORMS DEVELOP
Tropical storms begin when water evaporates from warm ocean water to produce huge clouds and thunderstorms. When the storms cluster together and whirl around a low-pressure center, they form a **tropical cyclone.** Tropical cyclones with winds of at least 119 kilometers per hour (74 mph) are called hurricanes in some regions and **typhoons** in others. The sequence below shows satellite images of a hurricane. ▼



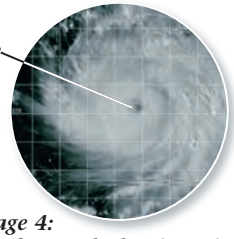
Stage 1:
Thunderstorms develop over the ocean.



Stage 2:
Storms group to form a swirl of cloud.



Stage 3:
Winds grow and a distinct center forms in the cloud swirl.



Stage 4:
Eye forms. The hurricane is now at its most dangerous.

Stage 5:
Eye passes over land. The hurricane starts to weaken.

Assessment

1. **Key Terms** Define **(a)** wind, **(b)** tornado, **(c)** blizzard, **(d)** tropical cyclone, **(e)** typhoon, **(f)** storm surge.
2. **Physical Processes** How do thunderstorms come into being?
3. **Economic Activities** **(a)** How can storms have a negative impact on economic activities? **(b)** How can monsoons benefit economic activities?
4. **Natural Hazards** How can a tropical cyclone result in the loss of thousands of lives?
5. **Critical Thinking** **Form a Hypothesis** Since 1991, the Bangladeshi government has constructed hundreds of concrete storm shelters in coastal regions of the country. **(a)** Why did the government likely decide to implement this policy? **(b)** How has this policy benefited the country?

INQUIRY

EXPLORATION LAB

Middle-Latitude Cyclones

Problem How do middle-latitude cyclones affect weather patterns?

Materials tracing paper, sharp pencil, paper clips or removable tape, metric ruler, colored pencils

Skills Observe, Compare and Contrast, Predict

Connect to the Big idea You've learned that much of the day-to-day weather in the United States is caused by middle-latitude cyclones. In this lab, you will identify some of the atmospheric conditions associated with a middle-latitude cyclone. Then you will use what you know about Earth's atmosphere and weather to predict how the movement of the low-pressure system affects weather in the area.

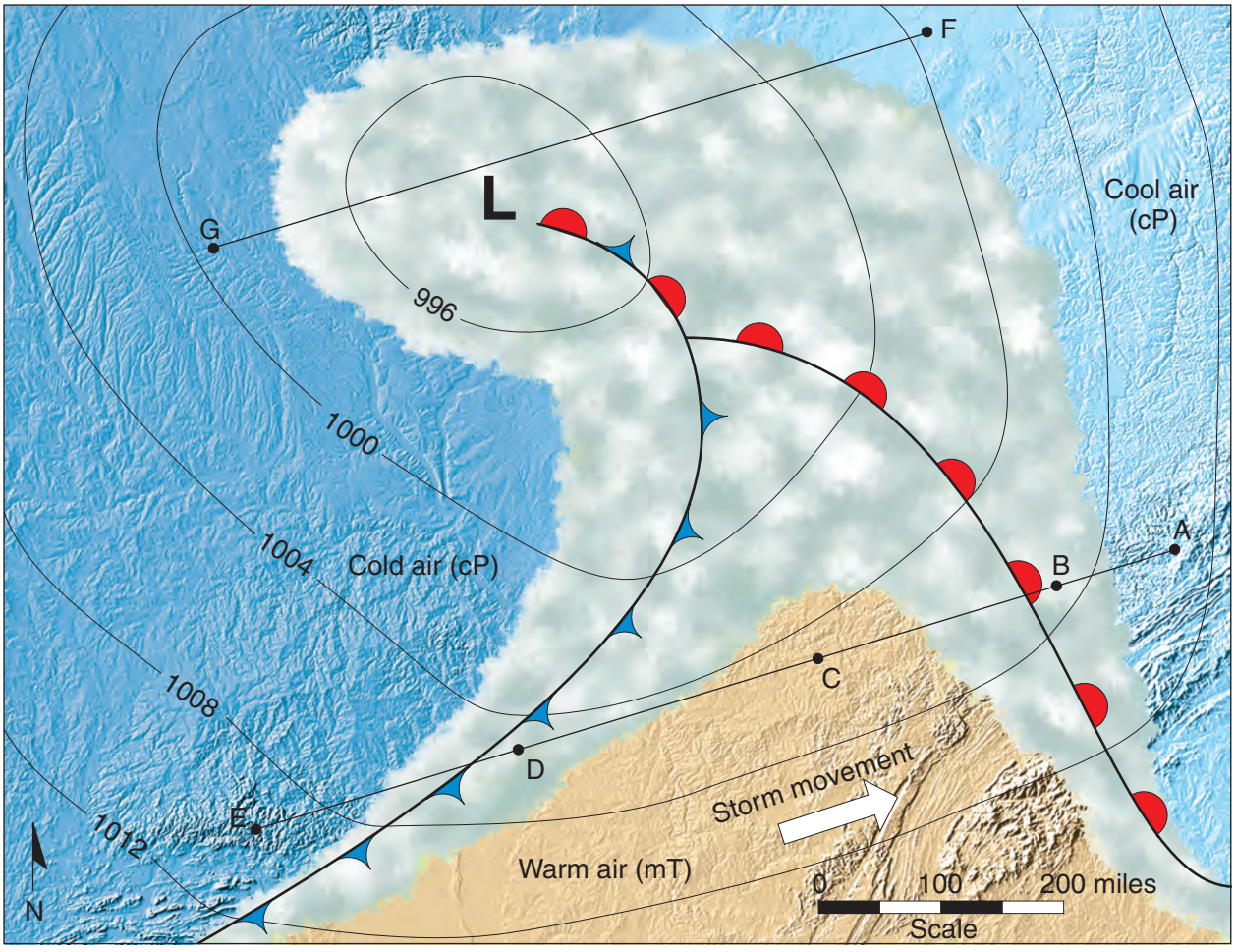
Procedure

1. Use the paper clips or removable tape to secure the tracing paper over the map on the facing page.
2. Carefully trace all of the features and boundaries on the map. Be sure to include the isobars—the lines that show atmospheric pressure. Use the ruler to trace lines EA and GF.
3. Remove the tracing paper. Place it next to the map.
4. Transfer all of the letters and numbers on the map to your tracing.
5. Use the colored pencils to color the cold air, cool air, and warm air areas on the tracing. Also color the symbols used to designate the fronts.
6. Identify and label the cold front, warm front, and occluded front on your tracing.
7. Draw arrows that show the direction of surface winds at points A, C, E, F, and G.

Analyze and Conclude

1. **Describe** In which direction are the surface winds moving?
2. **Identify** At which stage of formation is the cyclone? Explain your answer. Refer to Figure 13 if necessary.
3. **Explain** Is the air in the center of the cyclone rising or falling? What effect does this have on the potential for condensation and precipitation?
4. **Infer** Find the center of the low, which is marked with the letter L. What type of front has formed here? What happens to the maritime tropical air in this type of front?
5. **Predict** Once the warm front passes, in which direction will the wind at point B blow?
6. **Predict** Describe the changes in wind direction and moisture in the air that will likely occur at point D after the cold front passes.
7. **Explain** Describe the wind directions, humidity, and precipitation expected for a city as the cyclone moves and the city's relative position changes from point A to B, point C, point D, and fi ally from point D to E.

GO FURTHER Find out and explain how subpolar lows affect middle-latitude cyclones over the United States in winter.



ES.1 The student will plan and conduct investigations in which **d.** maps and globes are read and interpreted, including location by latitude and longitude. **ES.12** The student will investigate and understand that energy transfer between the sun and Earth and its atmosphere drives weather and climate on Earth. Key concepts include **b.** prediction of weather patterns; **c.** severe weather occurrences, such as tornadoes, hurricanes, and major storms.

20 Study Guide

Big idea Weather and Climate

20.1 Air Masses

An air mass is an extremely large body of air that is located in the troposphere and is characterized by similar temperatures and amounts of moisture at any given altitude.

As an air mass moves, its characteristics change, and so does the weather in the area over which the air mass moves.

In addition to their overall temperature, air masses are classified according to the surface over which they form.

Much of the weather in North America is influenced by continental polar (cP) and maritime tropical (mT) air masses.

Only occasionally do continental tropical (cT) air masses move outside their source regions.

air mass (559)

20.2 Fronts

When two air masses with different properties meet, they form a front, which is a boundary that separates two contrasting air masses.

A warm front forms when warm air moves into an area formerly covered by cooler air.

A cold front forms when cold, dense air moves into a region occupied by warmer air.

A stationary front forms when the surface position between two air masses does not move.

An occluded front forms when a cold front overtakes a warm front, producing a complex weather pattern.

A middle-latitude cyclone is a large center of low pressure that generally travels from west to east and causes stormy weather. More often than not, air high up in the atmosphere fuels a middle-latitude cyclone.

front (564)
warm front (565)
cold front (566)
stationary front (566)
occluded front (567)

20.3 Severe Storms

A thunderstorm generates lightning and thunder. Thunderstorms frequently produce gusty winds, heavy rain, and hail. Thunderstorms form when warm, humid air rises in an unstable environment.

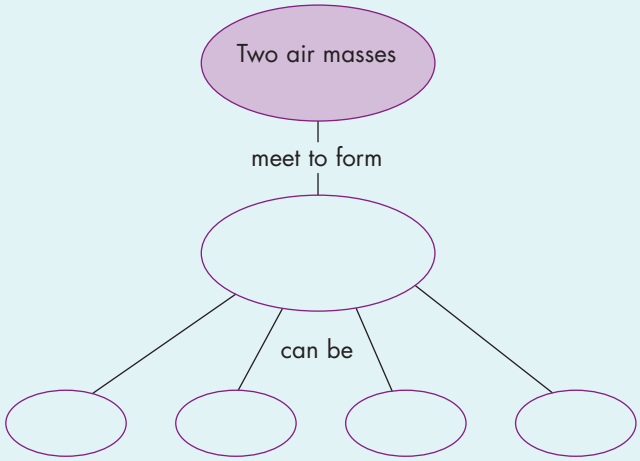
Tornadoes are violent windstorms that take the form of a rotating column of air called a vortex, which extends downward from a cumulonimbus cloud all the way to the ground. Most tornadoes form in association with severe thunderstorms.

Hurricanes are whirling tropical cyclones with sustained high winds that sometimes develop over the ocean when water temperatures are warm enough to provide the necessary heat and moisture to fuel the storms.

thunderstorm (571)
tornado (573)
hurricane (575)
eye wall (576)
eye (576)
storm surge (577)

Think Visually

Use what you know about fronts and air masses to complete this concept map.



20 Assessment

Review Content

Choose the letter that best answers the question or completes the statement.

1. If a portion of the contiguous United States is experiencing consecutive days of constant weather, this weather is called
a. air-mass weather.
b. warm-front weather.
c. cold-front weather.
d. occluded-front weather.

2. An air mass that forms over the Gulf of Mexico is a(n)
a. cP air mass.
b. mP air mass.
c. cT air mass.
d. mT air mass.

3. Air masses that have the greatest influence on weather in the midwestern United States are
a. mT and cT air masses.
b. cP and mT air masses.
c. mP and cP air masses.
d. cT and cP air masses.

4. Lake-effect snow is associated with a(n)
a. mP air mass.
b. mT air mass.
c. cP air mass.
d. cT air mass.

5. "Rain long foretold, long last; short notice, soon past." The first five words of this weather proverb refer to a(n)
a. warm front.
b. cold front.
c. anticyclone.
d. tornado.

6. Which front often produces moderate-to-light precipitation over a large area?
a. continental
b. maritime
c. cold
d. warm

7. A thunderstorm is most intense during its
a. cumulus stage.
b. wave stage.
c. mature stage.
d. dissipating stage.

8. When a hurricane reaches land, its intensity decreases as the result of
a. increase in pressure and temperature.
b. lack of cold, dry air to fuel the storm.
c. successive updrafts i to the eye wall.
d. friction and the lack of warm, moist air.

9. The eye of a hurricane
a. has the greatest wind speeds.
b. is warmer than the rest of the storm.
c. experiences high pressures.
d. is responsible for heavy precipitation.

Understand Concepts

10. Describe the effects of cP and mT air masses on much of the weather in the United States.

11. Describe weather associated with a warm front.

12. What kind of weather is associated with a cold front while it is over an area and once it passes?

13. What is a stationary front?

14. Sequence the steps that lead to the formation of an occluded front.

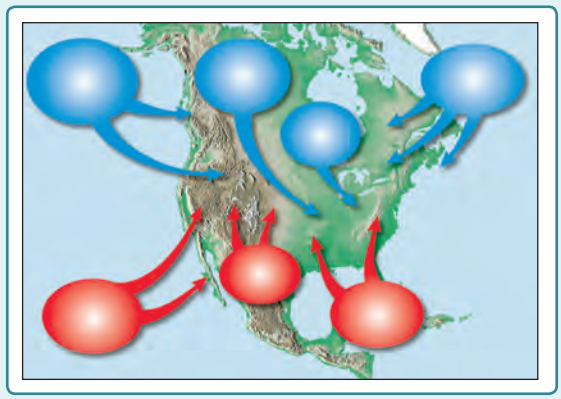
15. Describe the stages involved in the development of a middle-latitude cyclone.

16. Describe the formation of a thunderstorm.

17. What is a mesocyclone and how does it form?

18. Describe the different parts of a hurricane.

Use this map to answer Questions 19–22.



19. Name the three red air masses and identify the source region of each.

20. Identify the cold air masses, starting with the air mass farthest west and moving eastward.

21. Which air masses would supply the largest amount of precipitation to the area east of the Rocky Mountains?

22. Which of the air masses has the greatest influence on weather along the northwest coast?

Critical Thinking

23. **Compare and Contrast** Compare and contrast polar air masses with tropical air masses.

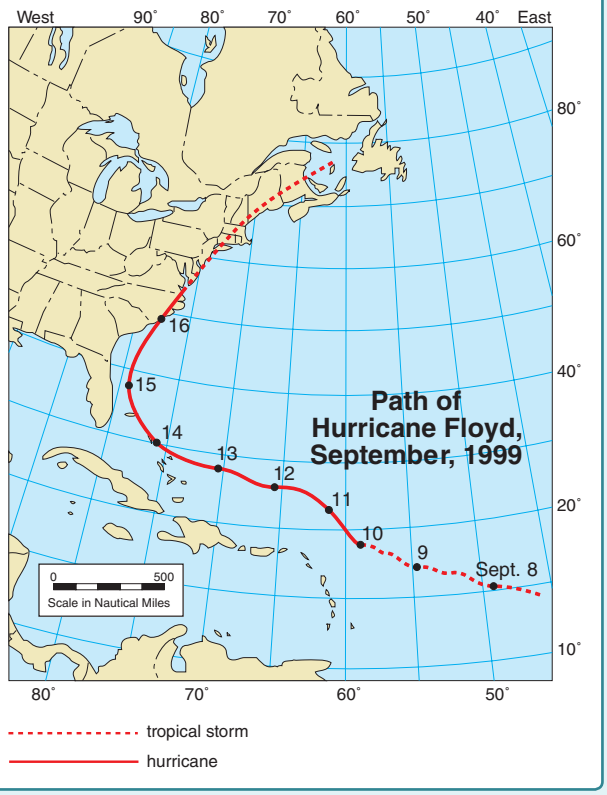
24. **Review** What type of air mass is responsible for most of the warm fronts east of the Rocky Mountains?

25. **Compare and Contrast** Compare and contrast tornadoes and hurricanes.

26. **Relate Cause and Effect** Great damage and significant loss of life can take place a day or more after a hurricane has moved ashore and weakened. Explain why this might happen.

Map Skills

Use the map to answer Questions 27–31.



27. **Interpret Maps** Over which ocean did Hurricane Floyd develop and move?

28. **Interpret Maps** On which days was Floyd a tropical storm?

29. **Interpret Maps** Describe the path of Hurricane Floyd from September 10 through September 16.

30. **Infer** When was Hurricane Floyd most intense? Explain.

31. **Interpret Maps** When and where did Hurricane Floyd move onto land?

Concepts in Action

32. **Explain** Describe weather conditions that you would observe if the center of a middle-latitude cyclone passed two kilometers north of you.

33. **Apply Concepts** What kinds of negative effects might a hurricane have on coastal ecosystems?

34. **Explain** Use what you know about weather patterns to write a paragraph to explain which parts of the Earth system interact to produce the high snowfall in the Great Lakes region of North America.

Performance-Based Assessment

Apply Concepts Find out about precautions people should take during any of the three types of severe storms discussed in this chapter. Summarize your findings in three separate posters.

Virginia SOL Test Prep

Use the maps below and what you know about thunderstorms and tornadoes to answer Questions 1–3.

Choose the letter that best answers the question or completes the statement.

1 What part of Texas experiences the greatest average number of days with thunderstorms per year?
- **A** the southernmost tip
- **B** the southwestern portion of the state
- **C** the northern tip
- **D** the easternmost portion of the state ES.12.c

2 What part of Texas experiences the lowest average number of tornadoes per year per 26,000 km^2?
- **F** central
- **G** eastern
- **H** northwestern
- **J** southwestern ES.12.c

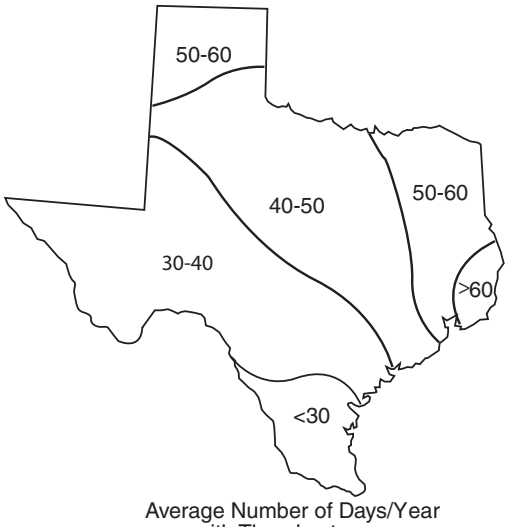
3 How many tornadoes on average are experienced per year in the area referred to in Question 2?
- **A** 1.0–2.0
- **B** 2.0–3.0
- **C** 5.0–7.0
- **D** 7.0–9.0 ES.12.c

4 What kind of air mass generally brings moisture to Virginia in summer?
- **F** maritime polar
- **G** maritime tropical
- **H** continental polar
- **J** continental tropical ES.12.b

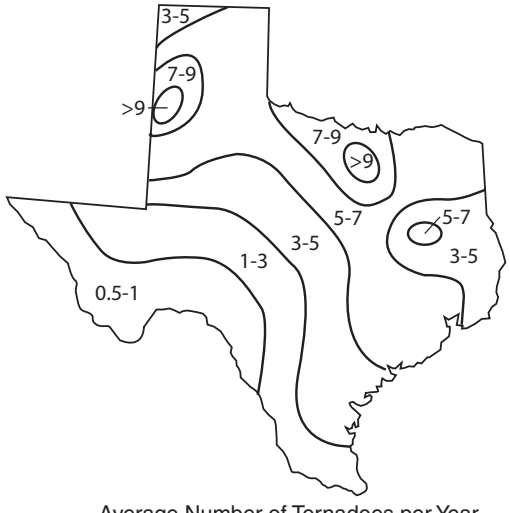
5 Which kind of front generally produces the most violent weather?
- **A** cold front
- **B** warm front
- **C** occluded front
- **D** stationary front ES.12.b

Tips for Success

Using Maps Most maps in Earth science are used to show geographic features such as mountains and bodies of water, tectonic features such as plate boundaries, and different types of rocks. Maps, like those shown below, can also be used to show statistical information. When using such maps to answer questions, be sure you understand what each map is showing before you try to answer the questions.



Average Number of Days/Year with Thunderstorms



Average Number of Tornadoes per Year per 26,000 km^2

If You Have Trouble With . . .					
Question	1	2	3	4	5
See Lesson	20.3	20.3	20.3	20.1	20.2