

Weather

chapter preview

sections

- 1 What is weather?
- 2 Weather Patterns
- 3 Weather Forecasts

Lab *Reading a Weather Map*

Lab *Measuring Wind Speed*



Virtual Lab *How do meteorologists predict the weather?*

To play or not to play?

Will this approaching storm be over before the game begins? New weather technology can provide information that allows us to make plans based on predicted weather conditions, such as whether or not to delay the start of a baseball game.

Science Journal Write three questions you would ask a meteorologist about weather.

Start-Up Activities



What causes rain?

How can it rain one day and be sunny the next? Powered by heat from the Sun, the air that surrounds you stirs and swirls. This constant mixing produces storms, calm weather, and everything in between. What causes rain and where does the water come from? Do the lab below to find out. **WARNING:** *Boiling water and steam can cause burns.*



1. Bring a pan of water to a boil on a hot plate.
2. Carefully hold another pan containing ice cubes about 20 cm above the boiling water. Be sure to keep your hands and face away from the steam.
3. Keep the pan with the ice cubes in place until you see drops of water dripping from the bottom.
4. **Think Critically** In your Science Journal, describe how the droplets formed. Infer where the water on the bottom of the pan came from.

FOLDABLES™ Study Organizer

Weather When information is grouped into clear categories, it is easier to make sense of what you are learning. Make the following Foldable to help you organize your thoughts about weather.

STEP 1 **Collect** 2 sheets of paper and layer them about 1.25 cm apart vertically. Keep the edges level.



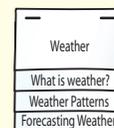
STEP 2 **Fold** up the bottom edges of the paper to form 4 equal tabs.



STEP 3 **Fold** the papers and crease well to hold the tabs in place. Staple along the fold.



STEP 4 Label the tabs *Weather*, *What is weather?*, *Weather Patterns*, and *Forecasting Weather* as shown.



Summarize As you read the chapter, summarize what you learn under the appropriate tabs.



Preview this chapter's content and activities at earth.msscience.com

What is weather?

as you read

What You'll Learn

- **Explain** how solar heating and water vapor in the atmosphere affect weather.
- **Discuss** how clouds form and how they are classified.
- **Describe** how rain, hail, sleet, and snow develop.

Why It's Important

Weather changes affect your daily activities.

Review Vocabulary

factor: something that influences a result

New Vocabulary

- weather
- humidity
- relative humidity
- dew point
- fog
- precipitation

Weather Factors

It might seem like small talk to you, but for farmers, truck drivers, pilots, and construction workers, the weather can have a huge impact on their livelihoods. Even professional athletes, especially golfers, follow weather patterns closely. You can describe what happens in different kinds of weather, but can you explain how it happens?

Weather refers to the state of the atmosphere at a specific time and place. Weather describes conditions such as air pressure, wind, temperature, and the amount of moisture in the air.

The Sun provides almost all of Earth's energy. Energy from the Sun evaporates water into the atmosphere where it forms clouds. Eventually, the water falls back to Earth as rain or snow. However, the Sun does more than evaporate water. It is also a source of heat energy. Heat from the Sun is absorbed by Earth's surface, which then heats the air above it. Differences in Earth's surface lead to uneven heating of Earth's atmosphere. Heat is eventually redistributed by air and water currents. Weather, as shown in **Figure 1**, is the result of heat and Earth's air and water.

Figure 1 The Sun provides the energy that drives Earth's weather. **Identify** storms in this image.





When air is heated, it expands and becomes less dense. This creates lower pressure.

Molecules making up air are closer together in cooler temperatures, creating high pressure. Wind blows from higher pressure toward lower pressure.

Air Temperature During the summer when the Sun is hot and the air is still, a swim can be refreshing. But would a swim seem refreshing on a cold, winter day? The temperature of air influences your daily activities.

Air is made up of molecules that are always moving randomly, even when there's no wind. Temperature is a measure of the average amount of motion of molecules. When the temperature is high, molecules in air move rapidly and it feels warm. When the temperature is low, molecules in air move less rapidly, and it feels cold.

Wind Why can you fly a kite on some days but not others? Kites fly because air is moving. Air moving in a specific direction is called wind. As the Sun warms the air, the air expands and becomes less dense. Warm, expanding air has low atmospheric pressure. Cooler air is denser and tends to sink, bringing about high atmospheric pressure. Wind results because air moves from regions of high pressure to regions of low pressure. You may have experienced this on a small scale if you've ever spent time along a beach, as in **Figure 2**.

Many instruments are used to measure wind direction and speed. Wind direction can be measured using a wind vane. A wind vane has an arrow that points in the direction from which the wind is blowing. A wind sock has one open end that catches the wind, causing the sock to point in the direction toward which the wind is blowing. Wind speed can be measured using an anemometer (a nuh MAH muh tur). Anemometers have rotating cups that spin faster when the wind is strong.

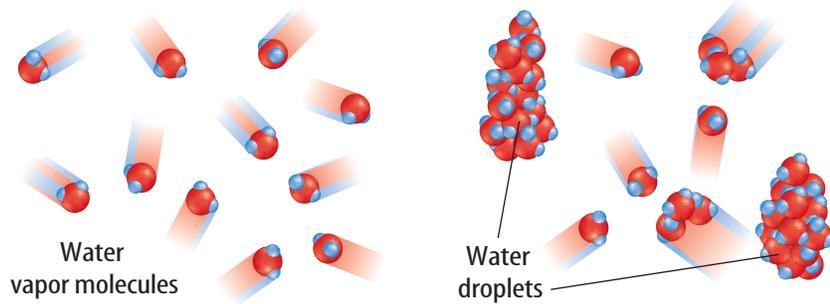
Figure 2 The temperature of air can affect air pressure. Wind is air moving from high pressure to low pressure.

Infer *In the above picture, which way would the wind move at night if the land cooled?*



Body Temperature Birds and mammals maintain a fairly constant internal temperature, even when the temperature outside their bodies changes. On the other hand, the internal temperature of fish and reptiles changes when the temperature around them changes. Infer from this which group is more likely to survive a quick change in the weather.

Figure 3 Warmer air can have more water vapor than cooler air can because water vapor doesn't easily condense in warm air.



Water vapor molecules in warm air move rapidly. The molecules can't easily come together and condense.

As air cools, water molecules in air move closer together. Some of them collide, allowing condensation to take place.

Mini LAB

Determining Dew Point

Procedure

1. Partially fill a metal can with room-temperature water. Dry the outer surface of the can.
2. Place a stirring rod in the water.
3. Slowly stir the water and add small amounts of ice.
4. Make a data table in your Science Journal. With a thermometer, note the exact water temperature at which a thin film of moisture first begins to form on the outside of the metal can.
5. Repeat steps 1 through 4 two more times.
6. The average of the three temperatures at which the moisture begins to appear is the dew point temperature of the air surrounding the metal container.

Analysis

1. What determines the dew point temperature?
2. Will the dew point change with increasing temperature if the amount of moisture in the air doesn't change? Explain.

Humidity Heat evaporates water into the atmosphere. Where does the water go? Water vapor molecules fit into spaces among the molecules that make up air. The amount of water vapor present in the air is called **humidity**.

Air doesn't always contain the same amount of water vapor. As you can see in **Figure 3**, more water vapor can be present when the air is warm than when it is cool. At warmer temperatures, the molecules of water vapor in air move quickly and don't easily come together. At cooler temperatures, molecules in air move more slowly. The slower movement allows water vapor molecules to stick together and form droplets of liquid water. The formation of liquid water from water vapor is called condensation. When enough water vapor is present in air for condensation to take place, the air is saturated.

Reading Check

Why can more water vapor be present in warm air than in cold air?

Relative Humidity On a hot, sticky afternoon, the weather forecaster reports that the humidity is 50 percent. How can the humidity be low when it feels so humid? Weather forecasters report the amount of moisture in the air as relative humidity. **Relative humidity** is a measure of the amount of water vapor present in the air compared to the amount needed for saturation at a specific temperature.

If you hear a weather forecaster say that the relative humidity is 50 percent, it means that the air contains 50 percent of the water needed for the air to be saturated.

As shown in **Figure 4**, air at 25°C is saturated when it contains 22 g of water vapor per cubic meter of air. The relative humidity is 100 percent. If air at 25°C contains 11 g of water vapor per cubic meter, the relative humidity is 50 percent.

Dew Point

When the temperature drops, less water vapor can be present in air. The water vapor in air will condense to a liquid or form ice crystals. The temperature at which air is saturated and condensation forms is the dew point. The **dew point** changes with the amount of water vapor in the air.

You've probably seen water droplets form on the outside of a glass of cold milk. The cold glass cooled the air next to it to its dew point. The water vapor in the surrounding air condensed and formed water droplets on the glass. In a similar way, when air near the ground cools to its dew point, water vapor condenses and forms dew. Frost may form when temperatures are near 0°C.

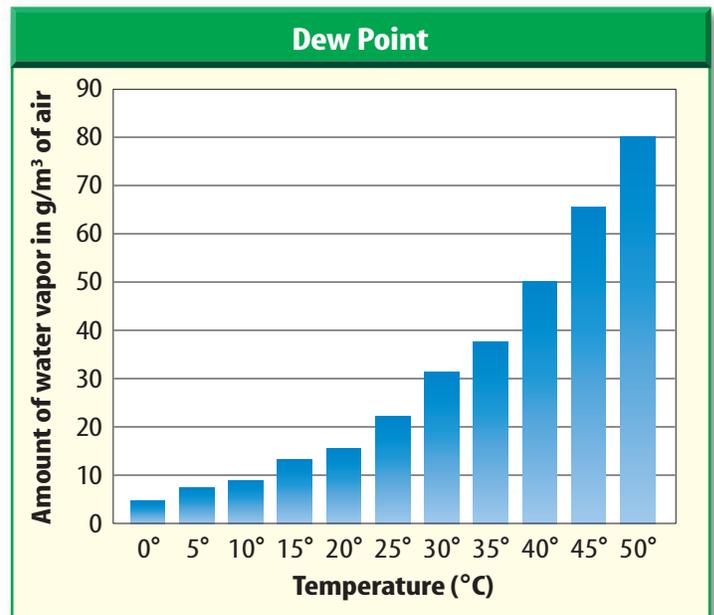


Figure 4 This graph shows that as the temperature of air increases, more water vapor can be present in the air.

Applying Math Calculate Percent

DEW POINT One summer day, the relative humidity is 80 percent and the temperature is 35°C. Use Figure 4 to find the dew point reached if the temperature falls to 25°C?

Solution

1 This is what you know:

Air Temperature (°C)	Amount of Water Vapor Needed for Saturation (g/m ³)
35	37
25	22
15	14

2 This is what you need to find out:

x = amount of water vapor in 35°C air at 80 percent relative humidity. Is $x > 22 \text{ g/m}^3$ or is $x < 22 \text{ g/m}^3$?

3 This is how you solve the problem:

$x = .80 (37 \text{ g/m}^3)$
 $x = 29.6 \text{ g/m}^3$ of water vapor
 $29.6 \text{ g/m}^3 > 22 \text{ g/m}^3$, so the dew point is reached and dew will form.

Practice Problems

- If the relative humidity is 50 percent and the air temperature is 35°C, will the dew point be reached if the temperature falls to 20°C?
- If the air temperature is 25°C and the relative humidity is 30 percent, will the dew point be reached if the temperature drops to 15°C?



For more practice, visit
earth.msscience.com/math_practice

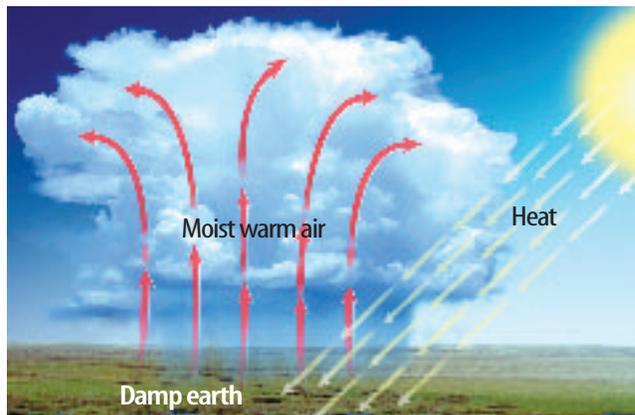
Forming Clouds

Why are there clouds in the sky? Clouds form as warm air is forced upward, expands, and cools. **Figure 5** shows several ways that warm, moist air forms clouds. As the air cools, the amount of water vapor needed for saturation decreases and the relative humidity increases. When the relative humidity reaches 100 percent, the air is saturated. Water vapor soon begins to condense in tiny droplets around small particles such as dust and salt. These droplets of water are so small that they remain suspended in the air. Billions of these droplets form a cloud.

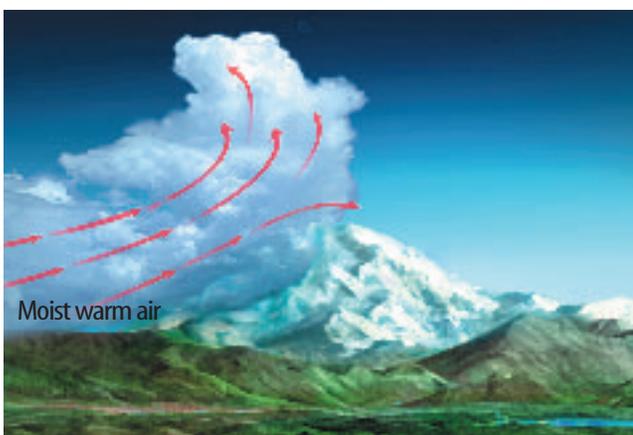
Classifying Clouds

Clouds are classified mainly by shape and height. Some clouds extend high into the sky, and others are low and flat. Some dense clouds bring rain or snow, while thin, wispy clouds appear on mostly sunny days. The shape and height of clouds vary with temperature, pressure, and the amount of water vapor in the atmosphere.

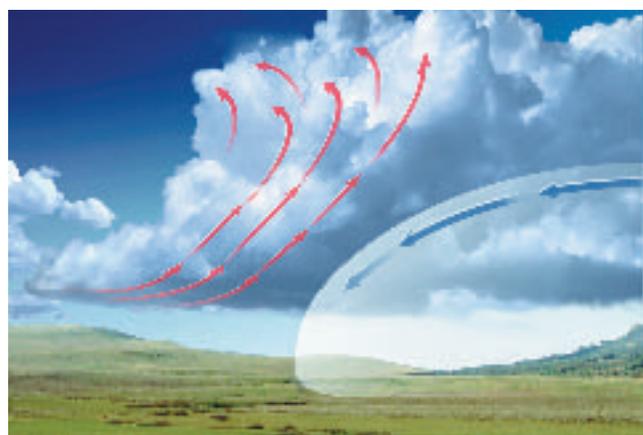
Figure 5 Clouds form when moist air is lifted and cools. This occurs where air is heated, at mountain ranges, and where cold air meets warm air.



Rays from the Sun heat the ground and the air next to it. The warm air rises and cools. If the air is moist, some water vapor condenses and forms clouds.



As moist air moves over mountains, it is lifted and cools. Clouds formed in this way can cover mountains for long periods of time.



When cool air meets warm, moist air, the warm air is lifted and cools.

Explain what happens to the water vapor when the dew point is reached.

Shape The three main cloud types are stratus, cumulus, and cirrus. Stratus clouds form layers, or smooth, even sheets in the sky. Stratus clouds usually form at low altitudes and may be associated with fair weather or rain or snow. When air is cooled to its dew point near the ground, it forms a stratus cloud called **fog**, as shown in **Figure 6**.

Cumulus (KYEW myuh lus) clouds are masses of puffy, white clouds, often with flat bases. They sometimes tower to great heights and can be associated with fair weather or thunderstorms.

Cirrus (SIHR us) clouds appear fibrous or curly. They are high, thin, white, feathery clouds made of ice crystals. Cirrus clouds are associated with fair weather, but they can indicate approaching storms.

Height Some prefixes of cloud names describe the height of the cloud base. The prefix *cirro-* describes high clouds, *alto-* describes middle-elevation clouds, and *strato-* refers to clouds at low elevations. Some clouds' names combine the altitude prefix with the term *stratus* or *cumulus*.

Cirrostratus clouds are high clouds, like those in **Figure 7**. Usually, cirrostratus clouds indicate fair weather, but they also can signal an approaching storm. Altostratus clouds form at middle levels. If the clouds are not too thick, sunlight can filter through them.



Figure 6 Fog surrounds the Golden Gate Bridge, San Francisco. Fog is a stratus cloud near the ground.

Think Critically Why do you think fog is found in San Francisco Bay?

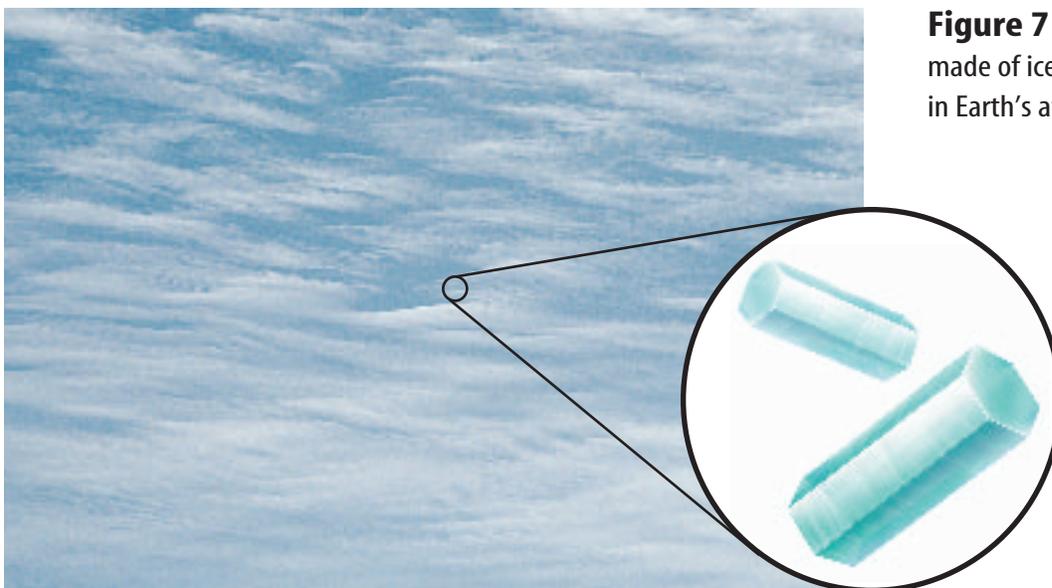
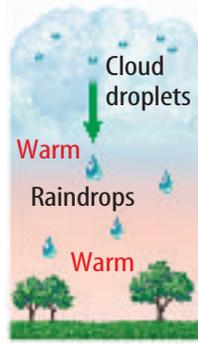


Figure 7 Cirrostratus clouds are made of ice crystals and form high in Earth's atmosphere.

Figure 8 Water vapor in air collects on particles to form water droplets or ice crystals. The type of precipitation that is received on the ground depends on the temperature of the air.



When the air is warm, water vapor forms raindrops that fall as rain.



When the air is cold, water vapor forms snowflakes.

Rain- or Snow-Producing Clouds Clouds associated with rain or snow often have the word nimbus attached to them. The term *nimbus* is Latin for “dark rain cloud” and this is a good description, because the water content of these clouds is so high that little sunlight can pass through them. When a cumulus cloud grows into a thunderstorm, it is called a cumulonimbus (kyew myuh loh NIHM bus) cloud. These clouds can tower to nearly 18 km. Nimbostratus clouds are layered clouds that can bring long, steady rain or snowfall.

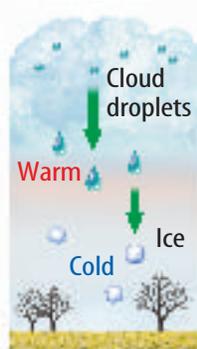
Precipitation

Water falling from clouds is called **precipitation**. Precipitation occurs when cloud droplets combine and grow large enough to fall to Earth. The cloud droplets form around small particles, such as salt and dust. These particles are so small that a puff of smoke can contain millions of them.

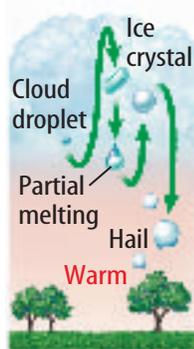
You might have noticed that raindrops are not all the same size. The size of raindrops depends on several factors. One factor is the strength of updrafts in a cloud. Strong updrafts can keep drops suspended in the air where they can combine with other drops and grow larger. The rate of evaporation as a drop falls to Earth also can affect its size. If the air is dry, the size of raindrops can be reduced or they can completely evaporate before reaching the ground.

Air temperature determines whether water forms rain, snow, sleet, or hail—the four main types of precipitation. **Figure 8** shows these different types of precipitation. Drops of water falling in temperatures above freezing fall as rain. Snow forms when the air temperature is so cold that water vapor changes directly to a solid. Sleet forms when raindrops pass through a layer of freezing air near Earth’s surface, forming ice pellets.

 **Reading Check** *What are the four main types of precipitation?*



When the air near the ground is cold, sleet, which is made up of many small ice pellets, falls.



Hailstones are pellets of ice that form inside a cloud.

Hail Hail is precipitation in the form of lumps of ice. Hail forms in cumulonimbus clouds of a thunderstorm when water freezes in layers around a small nucleus of ice. Hailstones grow larger as they're tossed up and down by rising and falling air. Most hailstones are smaller than 2.5 cm but can grow larger than a softball. Of all forms of precipitation, hail produces the most damage immediately, especially if winds blow during a hailstorm. Falling hailstones can break windows and destroy crops.

If you understand the role of water vapor in the atmosphere, you can begin to understand weather. The relative humidity of the air helps determine whether a location will have a dry day or experience some form of precipitation. The temperature of the atmosphere determines the form of precipitation. Studying clouds can add to your ability to forecast weather.

section 1 review

Summary

Weather Factors

- Weather is the state of the atmosphere at a specific time and place.
- Temperature, wind, air pressure, dew point, and humidity describe weather.

Clouds

- Warm, moist air rises, forming clouds.
- The main types of clouds are stratus, cumulus, and cirrus.

Precipitation

- Water falling from clouds is called precipitation.
- Air temperature determines whether water forms rain, snow, sleet, or hail.

Self Check

1. **Explain** When does water vapor in air condense?
2. **Compare and contrast** humidity and relative humidity.
3. **Summarize** how clouds form.
4. **Describe** How does precipitation occur and what determines the type of precipitation that falls to Earth?
5. **Think Critically** Cumulonimbus clouds form when warm, moist air is suddenly lifted. How can the same cumulonimbus cloud produce rain and hail?

Applying Math

6. **Use Graphs** If the air temperature is 30°C and the relative humidity is 60 percent, will the dew point be reached if the temperature drops to 25°C? Use the graph in **Figure 4** to explain your answer.

Weather Patterns

as you read

What You'll Learn

- **Describe** how weather is associated with fronts and high- and low-pressure areas.
- **Explain** how tornadoes develop from thunderstorms.
- **Discuss** the dangers of severe weather.

Why It's Important

Air masses, pressure systems, and fronts cause weather to change.

Review Vocabulary

barometer: instrument used to measure atmospheric pressure

New Vocabulary

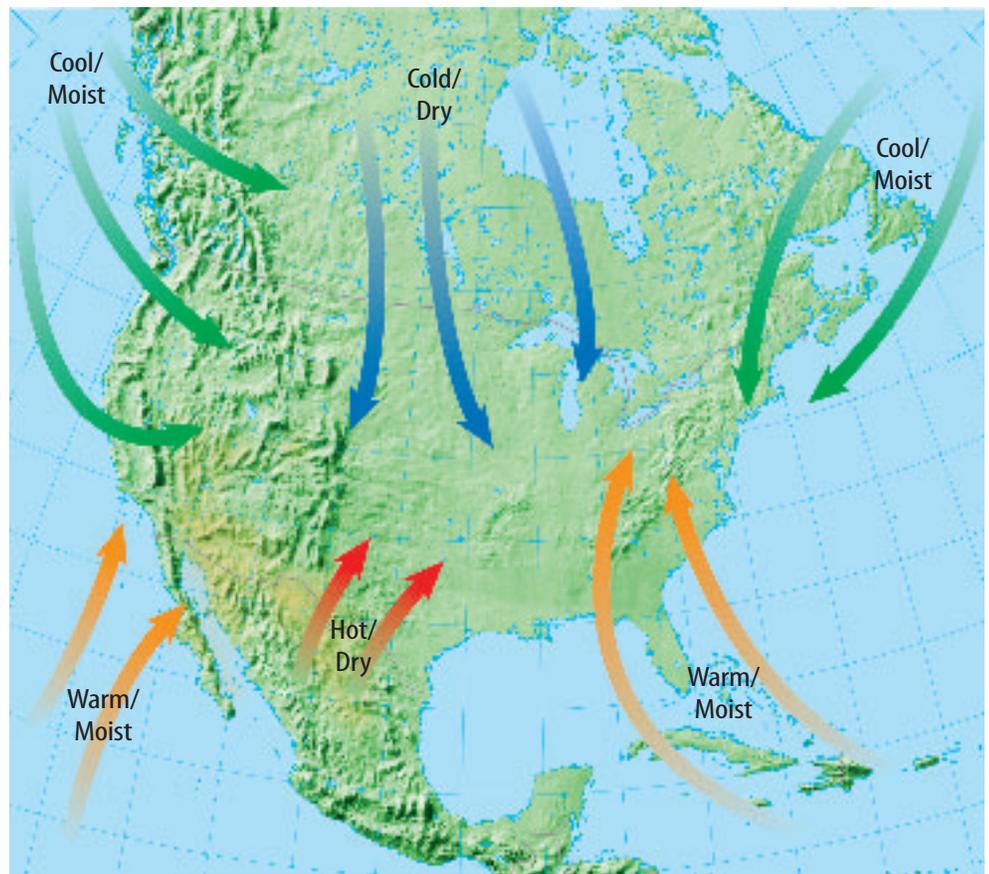
- air mass
- hurricane
- front
- blizzard
- tornado

Weather Changes

When you leave for school in the morning, the weather might be different from what it is when you head home in the afternoon. Because of the movement of air and moisture in the atmosphere, weather constantly changes.

Air Masses An **air mass** is a large body of air that has properties similar to the part of Earth's surface over which it develops. For example, an air mass that develops over land is dry compared with one that develops over water. An air mass that develops in the tropics is warmer than one that develops over northern regions. An air mass can cover thousands of square kilometers. When you observe a change in the weather from one day to the next, it is due to the movement of air masses. **Figure 9** shows air masses that affect the United States.

Figure 9 Six major air masses affect weather in the United States. Each air mass has the same characteristics of temperature and moisture content as the area over which it formed.





Highs and Lows Atmospheric pressure varies over Earth's surface. Anyone who has watched a weather report on television has heard about high- and low-pressure systems. Recall that winds blow from areas of high pressure to areas of low pressure. As winds blow into a low-pressure area in the northern hemisphere, Earth's rotation causes these winds to swirl in a counter-clockwise direction. Large, swirling areas of low pressure are called cyclones and are associated with stormy weather.

Reading Check How do winds move in a cyclone?

Winds blow away from a center of high pressure. Earth's rotation causes these winds to spiral clockwise in the northern hemisphere. High-pressure areas are associated with fair weather and are called anticyclones. Air pressure is measured using a barometer, like the one shown in **Figure 10**.

Variation in atmospheric pressure affects the weather. Low pressure systems at Earth's surface are regions of rising air. Clouds form when air is lifted and cools. Areas of low pressure usually have cloudy weather. Sinking motion in high-pressure air masses makes it difficult for air to rise and clouds to form. That's why high pressure usually means good weather.

Fronts

A boundary between two air masses of different density, moisture, or temperature is called a **front**. If you've seen a weather map in the newspaper or on the evening news, you've seen fronts represented by various types of curving lines.

Cloudiness, precipitation, and storms sometimes occur at frontal boundaries. Four types of fronts include cold, warm, occluded, and stationary.

Cold and Warm Fronts A cold front, shown on a map as a blue line with triangles ▲▲▲, occurs when colder air advances toward warm air. The cold air wedges under the warm air like a plow. As the warm air is lifted, it cools and water vapor condenses, forming clouds. When the temperature difference between the cold and warm air is large, thunderstorms and even tornadoes may form.

Warm fronts form when lighter, warmer air advances over heavier, colder air. A warm front is drawn on weather maps as a red line with red semicircles ◡◡◡.



Figure 10 A barometer measures atmospheric pressure. The red pointer points to the current pressure. Watch how atmospheric pressure changes over time when you line up the white pointer to the one indicating the current pressure each day.



Topic: Atmospheric Pressure

Visit earth.msscience.com for Web links to information about the current atmospheric pressure of your town or nearest city.

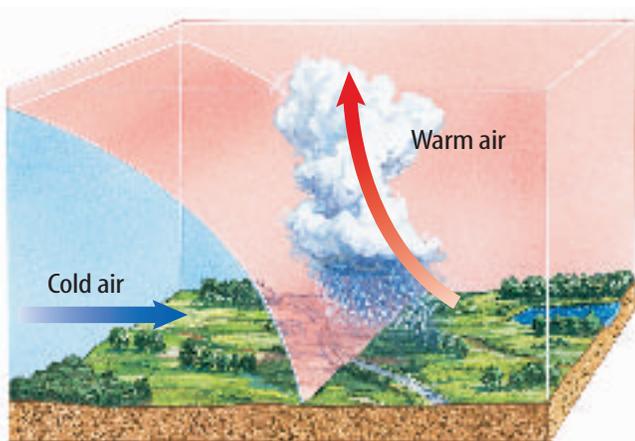
Activity Look up the pressure of a city west of your town and the pressure of a city to the east. Compare the pressures to local weather conditions. Share your information with the class.

Occluded and Stationary Fronts An occluded front involves three air masses of different temperatures—colder air, cool air, and warm air. An occluded front may form when a cold air mass moves toward cool air with warm air between the two. The colder air forces the warm air upward, closing off the warm air from the surface. Occluded fronts are shown on maps as purple lines with triangles and semicircles ▲▲▲.

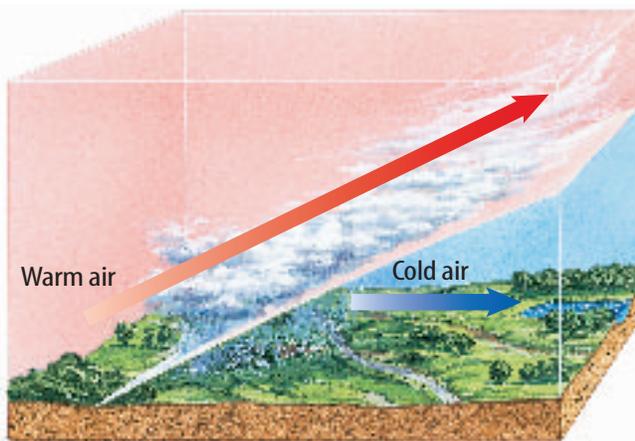
A stationary front occurs when a boundary between air masses stops advancing. Stationary fronts may remain in the same place for several days, producing light wind and precipitation. A stationary front is drawn on a weather map as an alternating red and blue line. Red semicircles point toward the cold air and blue triangles point toward the warm air ▲▼▲. **Figure 11** summarizes the four types of fronts.

Figure 11 Cold, warm, occluded, and stationary fronts occur at the boundaries of air masses.

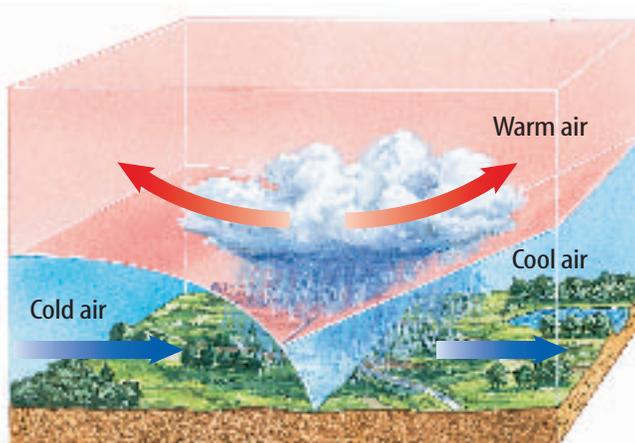
Describe what type of weather occurs at front boundaries.



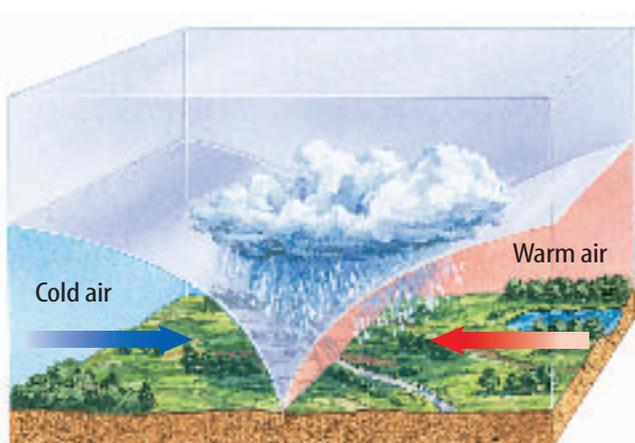
A cold front can advance rapidly. Thunderstorms often form as warm air is suddenly lifted up over the cold air.



Warm air slides over colder air along a warm front, forming a boundary with a gentle slope. This can lead to hours, if not days, of wet weather.



The term *occlusion* means “closure.” Colder air forces warm air upward, forming an occluded front that closes off the warm air from the surface.



A stationary front results when neither cold air nor warm air advances.

Severe Weather

Despite the weather, you usually can do your daily activities. If it's raining, you still go to school. You can still get there even if it snows a little. However, some weather conditions, such as those caused by thunderstorms, tornadoes, and blizzards, prevent you from going about your normal routine. Severe weather poses danger to people, structures, and animals.

Thunderstorms In a thunderstorm, heavy rain falls, lightning flashes, thunder roars, and hail might fall. What forces cause such extreme weather conditions?

Thunderstorms occur in warm, moist air masses and along fronts. Warm, moist air can be forced upward where it cools and condensation occurs, forming cumulonimbus clouds that can reach heights of 18 km, like the one in **Figure 12**. When rising air cools, water vapor condenses into water droplets or ice crystals. Smaller droplets collide to form larger ones, and the droplets fall through the cloud toward Earth's surface. The falling droplets collide with still more droplets and grow larger. Raindrops cool the air around them. This cool, dense air then sinks and spreads over Earth's surface. Sinking, rain-cooled air and strong updrafts of warmer air cause the strong winds associated with thunderstorms. Hail also may form as ice crystals alternately fall to warmer layers and are lifted into colder layers by the strong updrafts inside cumulonimbus clouds.

Thunderstorm Damage Sometimes thunderstorms can stall over a region, causing rain to fall heavily for a period of time. When streams cannot contain all the water running into them, flash flooding can occur. Flash floods can be dangerous because they occur with little warning.

Strong winds generated by thunderstorms also can cause damage. If a thunderstorm is accompanied by winds traveling faster than 89 km/h, it is classified as a severe thunderstorm. Hail from a thunderstorm can dent cars and the aluminum siding on houses. Although rain from thunderstorms helps crops grow, hail has been known to flatten and destroy entire crops in a matter of minutes.

Figure 12 Tall cumulonimbus clouds may form quickly as warm, moist air rapidly rises. **Identify** some things these clouds are known to produce.





Figure 13 This time-elased photo shows a thunderstorm over Arizona.

Lightning and Thunder

What are lightning and thunder? Inside a storm cloud, warm air is lifted rapidly as cooler air sinks. This movement of air can cause different parts of a cloud to become oppositely charged. When current flows between regions of opposite electrical charge, lightning flashes. Lightning, as shown in **Figure 13**, can occur within a cloud, between clouds, or between a cloud and the ground.

Thunder results from the rapid heating of air around a bolt of lightning. Lightning can

reach temperatures of about $30,000^{\circ}\text{C}$, which is more than five times the temperature of the surface of the Sun. This extreme heat causes air around the lightning to expand rapidly. Then it cools quickly and contracts. The rapid movement of the molecules forms sound waves heard as thunder.

Tornadoes Some of the most severe thunderstorms produce tornadoes. A **tornado** is a violently rotating column of air in contact with the ground. In severe thunderstorms, wind at different heights blows in different directions and at different speeds. This difference in wind speed and direction, called wind shear, creates a rotating column parallel to the ground. A thunderstorm's updraft can tilt the rotating column upward into the thunderstorm creating a funnel cloud. If the funnel comes into contact with Earth's surface, it is called a tornado.

Reading Check *What causes a tornado to form?*

A tornado's destructive winds can rip apart buildings and uproot trees. High winds can blow through broken windows. When winds blow inside a house, they can lift off the roof and blow out the walls, making it look as though the building exploded. The updraft in the center of a powerful tornado can lift animals, cars, and even houses into the air. Although tornadoes rarely exceed 200 m in diameter and usually last only a few minutes, they often are extremely destructive. In May 1999, multiple thunderstorms produced more than 70 tornadoes in Kansas, Oklahoma, and Texas. This severe tornado outbreak caused 40 deaths, 100 injuries, and more than \$1.2 billion in property damage.



Topic: Lightning

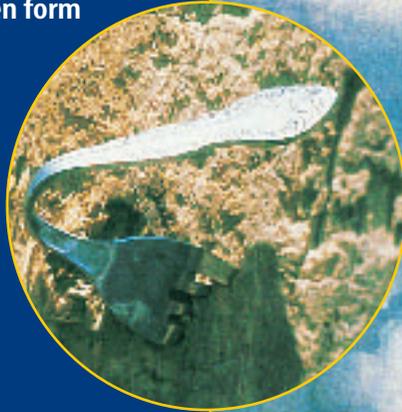
Visit earth.msscience.com for Web links to research the number of lightning strikes in your state during the last year.

Activity Compare your findings with data from previous years. Communicate to your class what you learn.

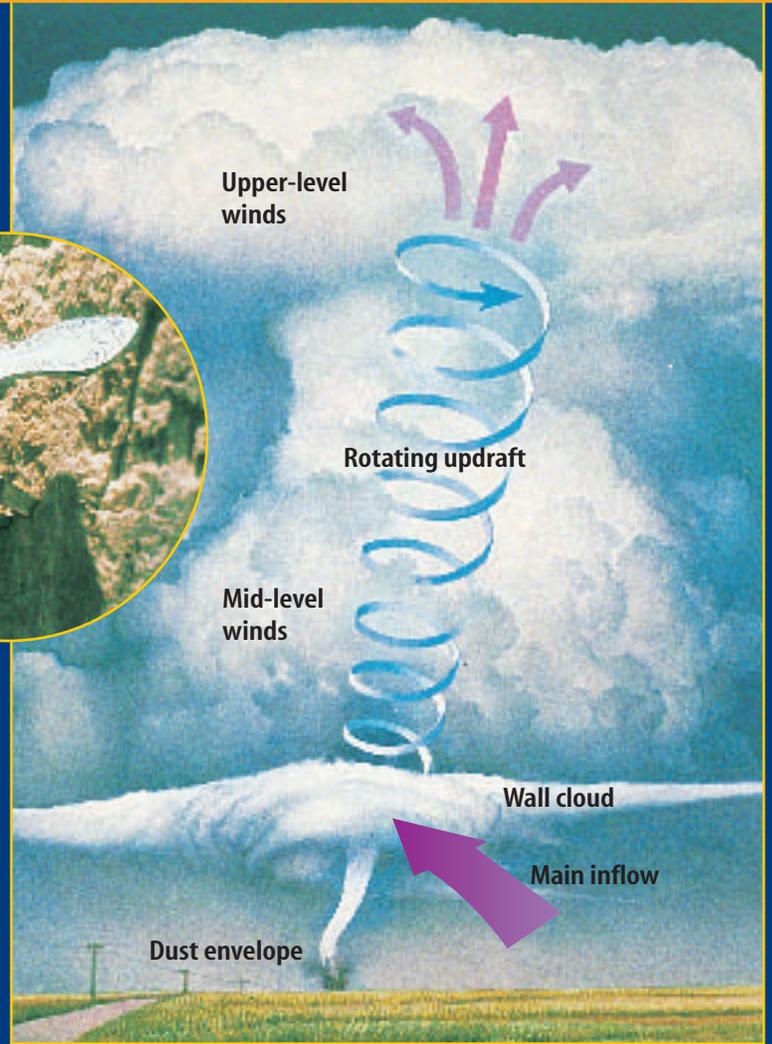


Figure 14

Tornadoes are extremely rapid, rotating winds that form at the base of cumulonimbus clouds. Smaller tornadoes may even form inside larger ones. Luckily, most tornadoes remain on the ground for just a few minutes. During that time, however, they can cause considerable—and sometimes strange—damage, such as driving a fork into a tree.



Tornadoes often form from a type of cumulonimbus cloud called a wall cloud. Strong, spiraling updrafts of warm, moist air may form in these clouds. As air spins upward, a low-pressure area forms, and the cloud descends to the ground in a funnel. The tornado sucks up debris as it moves along the ground, forming a dust envelope.



The Fujita Scale

	Wind speed (km/h)	Damage
F0	<116	Light: broken branches and chimneys
F1	116–180	Moderate: roofs damaged, mobile homes upturned
F2	181–253	Considerable: roofs torn off homes, large trees uprooted
F3	254–332	Severe: trains overturned, roofs and walls torn off
F4	333–419	Devastating: houses completely destroyed, cars picked up and carried elsewhere
F5	420–512	Incredible: total demolition

The Fujita scale, named after tornado expert Theodore Fujita, ranks tornadoes according to how much damage they cause. Fortunately, only one percent of tornadoes are classified as violent (F4 and F5).



Global Warming Some scientists hypothesize that Earth's ocean temperatures are increasing due to global warming. In your Science Journal, predict what might happen to the strength of hurricanes if Earth's oceans become warmer.

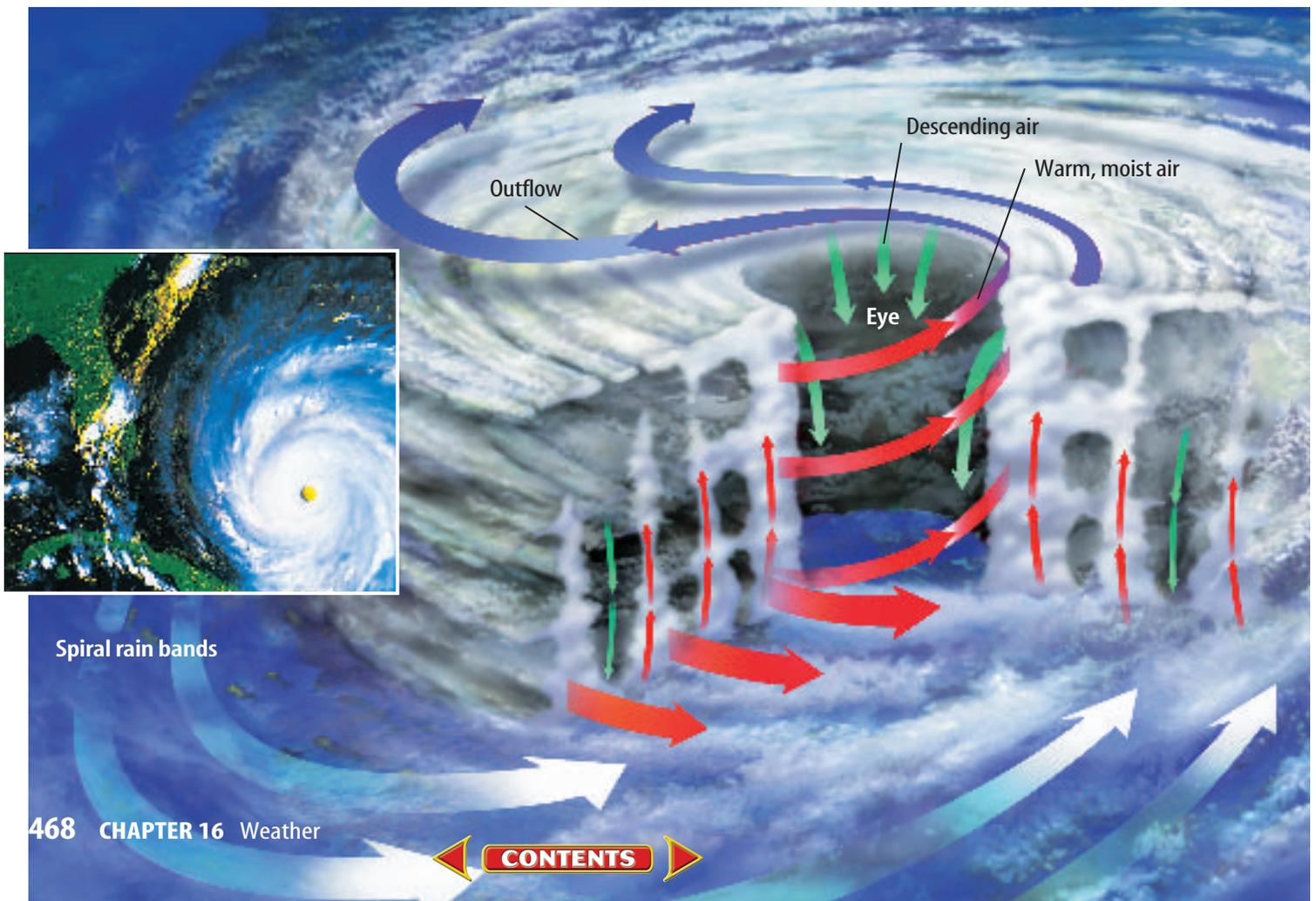
Figure 15 In this hurricane cross section, the small, red arrows indicate rising, warm, moist air. This air forms cumulus and cumulonimbus clouds in bands around the eye. The green arrows indicate cool, dry air sinking in the eye and between the cloud bands.

Hurricanes The most powerful storm is the hurricane. A **hurricane**, illustrated in **Figure 15**, is a large, swirling, low-pressure system that forms over the warm Atlantic Ocean. It is like a machine that turns heat energy from the ocean into wind. A storm must have winds of at least 119 km/h to be called a hurricane. Similar storms are called typhoons in the Pacific Ocean and cyclones in the Indian Ocean.

Hurricanes are similar to low-pressure systems on land, but they are much stronger. In the Atlantic and Pacific Oceans, low pressure sometimes develops near the equator. In the northern hemisphere, winds around this low pressure begin rotating counterclockwise. The strongest hurricanes affecting North America usually begin as a low-pressure system west of Africa. Steered by surface winds, these storms can travel west, gaining strength from the heat and moisture of warm ocean water.

When a hurricane strikes land, high winds, tornadoes, heavy rains, and high waves can cause a lot of damage. Floods from the heavy rains can cause additional damage. Hurricane weather can destroy crops, demolish buildings, and kill people and other animals. As long as a hurricane is over water, the warm, moist air rises and provides energy for the storm. When a hurricane reaches land, however, its supply of energy disappears and the storm loses power.

NASA/Science Photo Library/Photo Researchers



Blizzards Severe storms also can occur in winter. If you live in the northern United States, you may have awakened from a winter night's sleep to a cold, howling wind and blowing snow, like the storm in **Figure 16**. The National Weather Service classifies a winter storm as a **blizzard** if the winds are 56 km/h, the temperature is low, the visibility is less than 400 m in falling or blowing snow, and if these conditions persist for three hours or more.



Figure 16 Blizzards can be extremely dangerous because of their high winds, low temperatures, and poor visibility.

Severe Weather Safety When severe weather threatens, the National Weather Service issues a watch or warning. Watches are issued when conditions are favorable for severe thunderstorms, tornadoes, floods, blizzards, and hurricanes. During a watch, stay tuned to a radio or television station reporting the weather. When a warning is issued, severe weather conditions already exist. You should take immediate action. During a severe thunderstorm or tornado warning, take shelter in the basement or a room in the middle of the house away from windows. When a hurricane or flood watch is issued, be prepared to leave your home and move farther inland.

Blizzards can be blinding and have dangerously low temperatures with high winds. During a blizzard, stay indoors. Spending too much time outside can result in severe frostbite.

section 2 review

Summary

Weather Changes

- Air masses tend to have temperature and moisture properties similar to Earth's surface.
- Winds blow from areas of high pressure to areas of lower pressure.

Fronts

- A boundary between different air masses is called a front.

Severe Weather

- The National Weather Service issues watches or warnings, depending on the severity of the storm, for people's safety.

Self Check

1. **Draw Conclusions** Why is fair weather common during periods of high pressure?
2. **Describe** how a cold front affects weather.
3. **Explain** what causes lightning and thunder.
4. **Compare and contrast** a watch and a warning. How can you keep safe during a tornado warning?
5. **Think Critically** Explain why some fronts produce stronger storms than others.

Applying Skills

6. **Recognize Cause and Effect** Describe how an occluded front may form over your city and what effects it can have on the weather.

Weather Forecasts

as you read

What You'll Learn

- **Explain** how data are collected for weather maps and forecasts.
- **Identify** the symbols used in a weather station model.

Why It's Important

Weather observations help you predict future weather events.

Review Vocabulary

forecast: to predict a condition or event on the basis of observations

New Vocabulary

- meteorologist
- isotherm
- station model
- isobar

Figure 17 A meteorologist uses Doppler radar to track a tornado. Since the nineteenth century, technology has greatly improved weather forecasting.



Weather Observations

You can determine current weather conditions by checking the thermometer and looking to see whether clouds are in the sky. You know when it's raining. You have a general idea of the weather because you are familiar with the typical weather where you live. If you live in Florida, you don't expect snow in the forecast. If you live in Maine, you assume it will snow every winter. What weather concerns do you have in your region?

A **meteorologist** (mee tee uh RAH luh jist) is a person who studies the weather. Meteorologists take measurements of temperature, air pressure, winds, humidity, and precipitation. Computers, weather satellites, Doppler radar shown in **Figure 17**, and instruments attached to balloons are used to gather data. Such instruments improve meteorologists' ability to predict the weather. Meteorologists use the information provided by weather instruments to make weather maps. These maps are used to make weather forecasts.

Forecasting Weather

Meteorologists gather information about current weather and use computers to make predictions about future weather patterns. Because storms can be dangerous, you do not want to be unprepared for threatening weather. However, meteorologists cannot always predict the weather exactly because conditions can change rapidly.

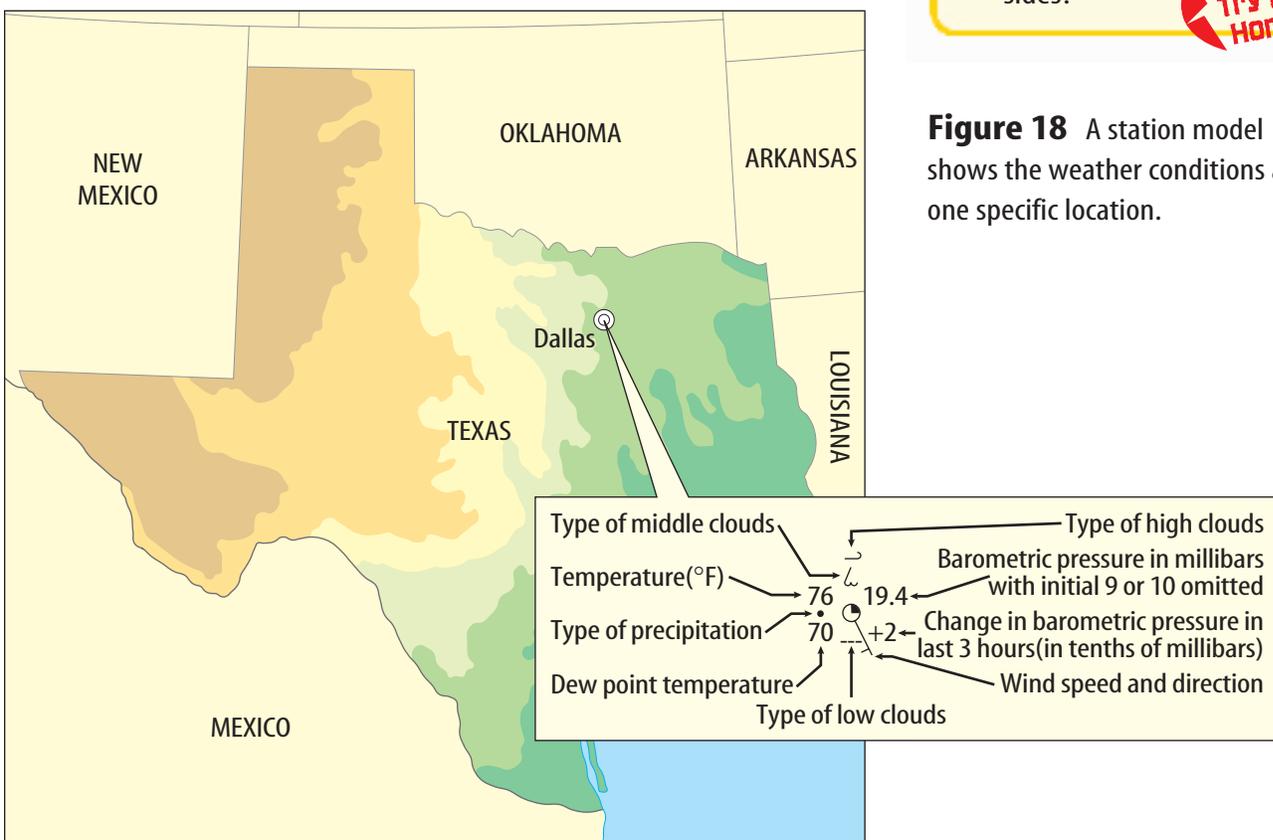
The National Weather Service depends on two sources for its information—data collected from the upper atmosphere and data collected on Earth's surface. Meteorologists of the National Weather Service collect information recorded by satellites, instruments attached to weather balloons, and from radar. This information is used to describe weather conditions in the atmosphere above Earth's surface.

Station Models When meteorologists gather data from Earth's surface, it is recorded on a map using a combination of symbols, forming a **station model**. A station model, like the one in **Figure 18**, shows the weather conditions at a specific location on Earth's surface. Information provided by station models and instruments in the upper atmosphere is entered into computers and used to forecast weather.

Temperature and Pressure In addition to station models, weather maps have lines that connect locations of equal temperature or pressure. A line that connects points of equal temperature is called an **isotherm** (I suh thurm). *Iso* means "same" and *therm* means "temperature." You probably have seen isotherms on weather maps on TV or in the newspaper.

An **isobar** is a line drawn to connect points of equal atmospheric pressure. You can tell how fast wind is blowing in an area by noting how closely isobars are spaced. Isobars that are close together indicate a large pressure difference over a small area. A large pressure difference causes strong winds. Isobars that are spread apart indicate a smaller difference in pressure. Winds in this area are gentler. Isobars also indicate the locations of high- and low-pressure areas.

 **Reading Check** How do isobars indicate wind speed?



Measuring Rain

Procedure

1. You will need a **straight-sided container**, such as a soup or coffee can, **duct tape**, and a **ruler**.
2. Tape the ruler to the inner wall of your container.
3. Place the container on a level surface outdoors, away from buildings or plants.
4. Measure the amount of water in your container after it rains. Continue to take measurements for a week.

Analysis

1. What was the average daily rainfall?
2. Why is it necessary to use containers with straight sides?



Figure 18 A station model shows the weather conditions at one specific location.

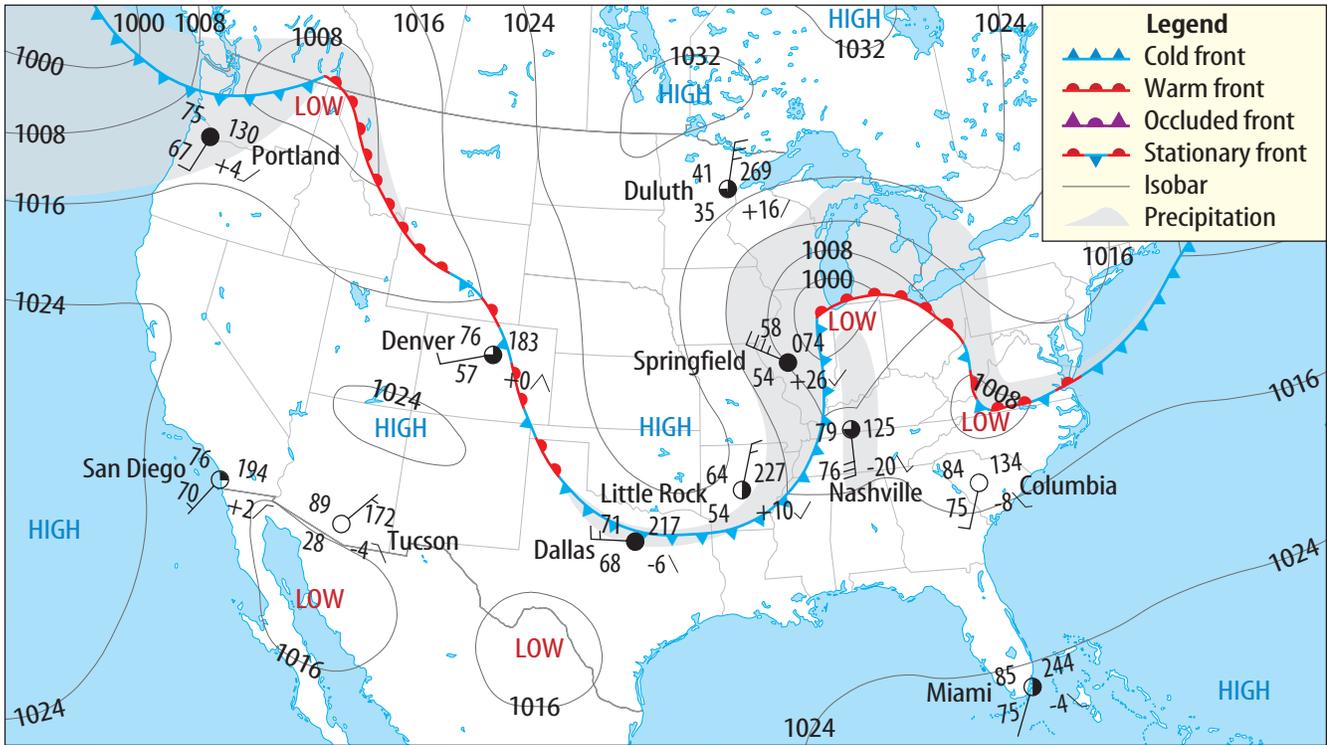


Figure 19 Highs, lows, isobars, and fronts on this weather map help meteorologists forecast the weather.

Weather Maps On a weather map like the one in **Figure 19**, pressure areas are drawn as circles with the word High or Low in the middle of the circle. Fronts are drawn as lines and symbols. When you watch weather forecasts on television, notice how weather fronts move from west to east. This is a pattern that meteorologists depend on to forecast weather.

section
3
review

Summary

Weather Observations

- Meteorologists are people who study the weather and make weather maps.

Forecasting Weather

- Meteorologists gather information about current weather and make predictions about future weather patterns.
- A station model shows weather conditions at a specific location on Earth’s surface by using symbols to record meteorological data.
- On weather maps, isotherms are lines that connect points of equal temperature.
- An isobar is a line drawn on a weather map that connects points of equal atmospheric pressure.

Self Check

1. **List** some instruments that are used to collect weather data.
2. **Describe** at least six items of data that might be recorded in a station model.
3. **Explain** how the National Weather Service makes weather maps.
4. **Explain** what closely spaced isobars on a weather map indicate.
5. **Think Critically** In the morning you hear a meteorologist forecast today’s weather as sunny and warm. After school, it is raining. Why is the weather so hard to predict?

Applying Skills

6. **Concept Map** Using a computer, make an events-chain concept map for how a weather forecast is made.

Reading a Weather Map

Meteorologists use a series of symbols to provide a picture of local and national weather conditions. With what you know, can you interpret weather information from weather map symbols?

Real-World Question

How do you read a weather map?

Materials

magnifying lens

Weather Map Symbols Appendix

Figure 19 (Weather Map)

Goals

- **Learn** how to read a weather map.
- **Use** information from a station model and a weather map to forecast weather.

Procedure

Use the information provided in the questions below and the Weather Map Symbols Appendix to learn how to read a weather map.

1. Find the station models on the map for Portland, Oregon, and Miami, Florida. Find the dew point, wind direction, barometric pressure, and temperature at each location.
2. Looking at the placement of the isobars, determine whether the wind would be stronger at Springfield, Illinois, or at San Diego, California. Record your answer. What is another way to determine the wind speed at these locations?
3. **Determine** the type of front near Dallas, Texas. Record your answer.
4. The triangles or half-circles are on the side of the line toward the direction the front is moving. In which direction is the cold front located over Washington state moving?



Conclude and Apply

1. Locate the pressure system over southeast Kansas. Predict what will happen to the weather of Nashville, Tennessee, if this pressure system moves there.
2. Prevailing westerlies are winds responsible for the movement of much of the weather across the United States. Based on this, would you expect Columbia, South Carolina, to continue to have clear skies? Explain.
3. The direction line on the station model indicates the direction from which the wind blows. The wind is named for that direction. Infer from this the name of the wind blowing at Little Rock, Arkansas.

*e*Communicating Your Data

Pretend you are a meteorologist for a local TV news station. Make a poster of your weather data and present a weather forecast to your class.

Measuring Wind Speed

Goals

- **Invent** an instrument or devise a system for measuring wind speeds using common materials.
- **Devise** a method for using your invention or system to compare different wind speeds.

Possible Materials

paper
scissors
confetti
grass clippings
meterstick
**measuring tape*
**Alternate materials*

Safety Precautions



Data Source

Refer to Section 1 for more information about anemometers and other wind speed instruments. Consult the data table for information about Beaufort's wind speed scale.

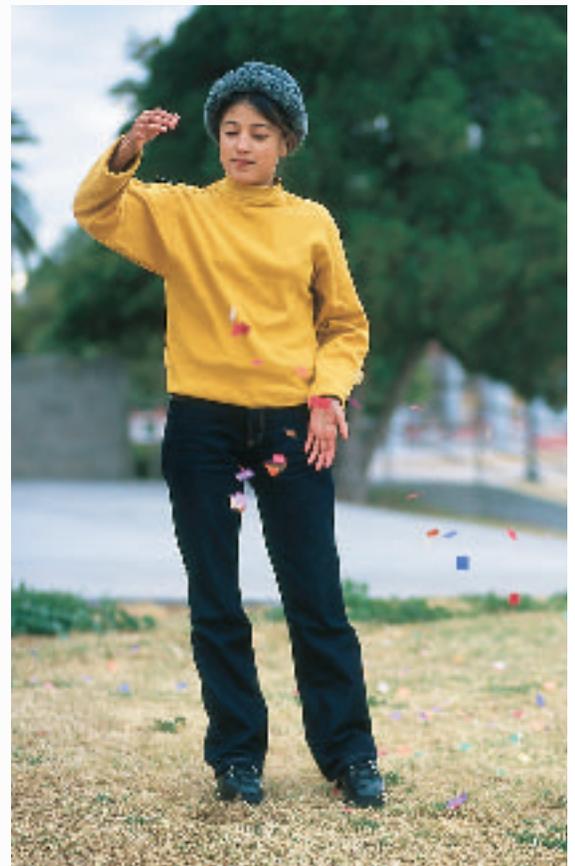
Real-World Question

When you watch a gust of wind blow leaves down the street, do you wonder how fast the wind is moving? For centuries, people could only guess at wind speeds, but in 1805, Admiral Beaufort of the British navy invented a method for estimating wind speeds based on their effect on sails. Later, Beaufort's system was modified for use on land. Meteorologists use a simple instrument called an anemometer to measure wind speeds, and they still use Beaufort's system to estimate the speed of the wind. What type of instrument or system can you invent to measure wind speed? How could you use simple materials to invent an instrument or system for measuring wind speeds? What observations do you use to estimate the speed of the wind?



Make a Model

1. Scan the list of possible materials and choose the materials you will need to devise your system.
2. **Devise** a system to measure different wind speeds. Be certain the materials you use are light enough to be moved by slight breezes.



Check the Model Plans

1. **Describe** your plan to your teacher. Provide a sketch of your instrument or system and ask your teacher how you might improve its design.
2. Present your idea for measuring wind speed to the class in the form of a diagram or poster. Ask your classmates to suggest improvements in your design that will make your system more accurate or easier to use.

Test Your Model

1. Confetti or grass clippings that are all the same size can be used to measure wind speed by dropping them from a specific height. Measuring the distances they travel in different strength winds will provide data for devising a wind speed scale.
2. Different sizes and shapes of paper also could be dropped into the wind, and the strength of the wind would be determined by measuring the distances traveled by these different types of paper.

Analyze Your Data

1. **Develop** a scale for your method.
2. **Compare** your results with Beaufort's wind speed scale.
3. **Analyze** what problems may exist in the design of your system and suggest steps you could take to improve your design.

Conclude and Apply

1. **Explain** why it is important for meteorologists to measure wind speeds.
2. **Evaluate** how well your system worked in gentle breezes and strong winds.

Beaufort's Wind Speed Scale

Description	Wind Speed (km/h)
calm—smoke drifts up	less than 1
light air—smoke drifts with wind	1–5
light breeze—leaves rustle	6–11
gentle breeze—leaves move constantly	12–19
moderate breeze—branches move	20–29
fresh breeze—small trees sway	30–39
strong breeze—large branches move	40–50
moderate gale—whole trees move	51–61
fresh gale—twigs break	62–74
strong gale—slight damage to houses	75–87
whole gale—much damage to houses	88–101
storm—extensive damage	102–120
hurricane—extreme damage	more than 120

Communicating Your Data

Demonstrate your system for the class. Compare your results and measurements with the results of other classmates.

Rainmakers

Cloud seeding is an inexact science

You listen to a meteorologist give the long-term weather forecast. Another week with no rain in sight. As a farmer, you are concerned that your crops are withering in the fields. Home owners' lawns are turning brown. Wildfires are possible. Cattle are starving. And, if farmers' crops die, there could be a shortage of food and prices will go up for consumers.

Meanwhile, several states away, another farmer is listening to the weather report calling for another week of rain. Her crops are getting so water soaked that they are beginning to rot.

Weather. Can't scientists find a way to better control it? The answer is...not exactly. Scientists have been experimenting with methods to control our weather since the 1940s. And nothing really works.

Cloud seeding is one such attempt. It uses technology to enhance the natural rainfall process. The idea has been used to create rain where it is needed or to reduce hail damage. Government officials

also use cloud seeding or weather modification to try to reduce the force of a severe storm.

Some people seed a cloud by flying a plane above it and releasing highway-type flares with chemicals, such as silver iodide. Another method is to fly beneath the cloud and spray a chemical that can be carried into the cloud by air currents.

Cloud seeding doesn't work with clouds that have little water vapor or are not near the dew point. Seeding chemicals must be released into potential rain clouds. The chemicals provide nuclei for water molecules to cluster around. Water then falls to Earth as precipitation.

Cloud seeding does have its critics. If you seed clouds and cause rain for your area, aren't you preventing rain from falling in another area? Would that be considered "rain theft" by people who live in places where the cloudburst would naturally occur? What about those cloud-seeding agents? Could the cloud-seeding chemicals, such as silver iodide and acetone, affect the environment in a harmful way? Are humans meddling with nature and creating problems in ways that haven't been determined?



Flares are lodged under a plane. The pilot will drop them into potential rain clouds.

Debate Learn more about cloud seeding and other methods of changing weather. Then debate whether or not cloud seeding can be considered "rain theft."

Science **online**

For more information, visit
earth.msscience.com/time

Reviewing Main Ideas

Section 1 What is weather?

1. Factors that determine weather include air pressure, wind, temperature, and the amount of moisture in the air.
2. More water vapor can be present in warm air than in cold air. Water vapor condenses when the dew point is reached. Clouds are formed when warm, moist air rises and cools to its dew point.
3. Rain, hail, sleet, and snow are types of precipitation.

Section 2 Weather Patterns

1. Fronts form when air masses with different characteristics meet. Types of fronts include cold, warm, occluded, and stationary fronts.

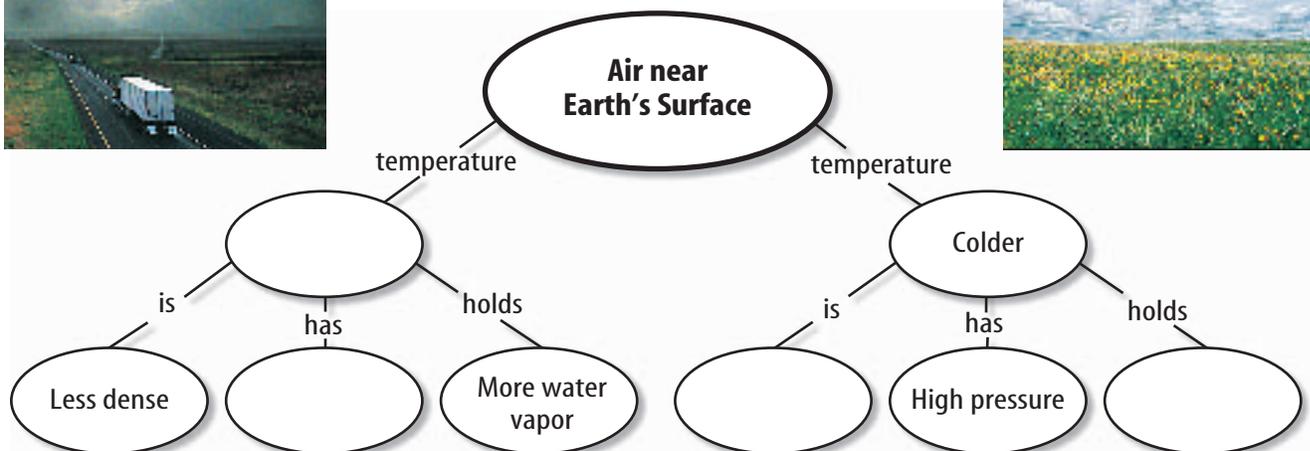
2. High atmospheric pressure at Earth's surface usually means good weather. Cloudy and stormy weather occurs under low pressure.
3. Tornadoes, thunderstorms, hurricanes, and blizzards are examples of severe weather.

Section 3 Weather Forecasts

1. Meteorologists use information from radar, satellites, computers, and other weather instruments to forecast the weather.
2. Weather maps include information about temperature and air pressure. Station models indicate weather at a particular location.

Visualizing Main Ideas

Copy and complete the following concept map about air temperature, water vapor, and pressure.



Using Vocabulary

air mass p. 462	isotherm p. 471
blizzard p. 469	meteorologist p. 470
dew point p. 457	precipitation p. 460
fog p. 459	relative humidity p. 456
front p. 463	station model p. 471
humidity p. 456	tornado p. 466
hurricane p. 468	weather p. 454
isobar p. 471	

Explain the differences between the vocabulary words in each of the following sets.

- air mass—front
- humidity—relative humidity
- relative humidity—dew point
- dew point—precipitation
- hurricane—tornado
- blizzard—fog
- meteorologist—station model
- precipitation—fog
- isobar—isotherm
- isobar—front

Checking Concepts

Choose the word or phrase that best answers the question.

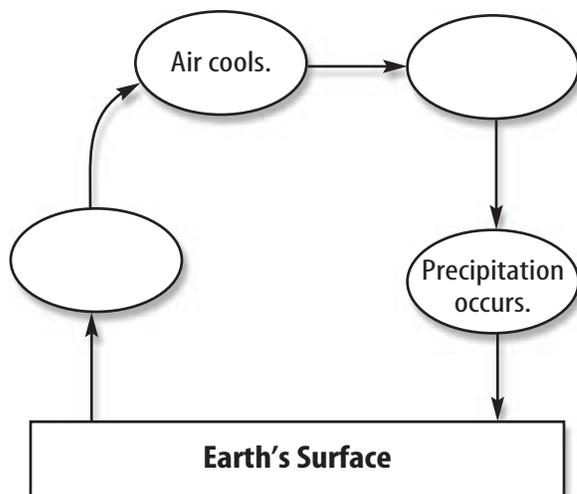
- Which term refers to the amount of water vapor in the air?
 - dew point
 - precipitation
 - humidity
 - relative humidity
- What does an anemometer measure?
 - wind speed
 - precipitation
 - air pressure
 - relative humidity
- Which type of air has a relative humidity of 100 percent?
 - humid
 - temperate
 - dry
 - saturated
- Which type of the following clouds are high feathery clouds made of ice crystals?
 - cirrus
 - nimbus
 - cumulus
 - stratus
- What is a large body of air that has the same properties as the area over which it formed called?
 - air mass
 - station model
 - front
 - isotherm
- At what temperature does water vapor in air condense?
 - dew point
 - station model
 - front
 - isobar
- Which type of precipitation forms when water vapor changes directly into a solid?
 - rain
 - hail
 - sleet
 - snow
- Which type of front may form when cool air, cold air, and warm air meet?
 - warm
 - cold
 - stationary
 - occluded
- Which is issued when severe weather conditions exist and immediate action should be taken?
 - front
 - watch
 - station model
 - warning
- What is a large, swirling storm that forms over warm, tropical water called?
 - hurricane
 - tornado
 - blizzard
 - hailstorm

Use the photo below to answer question 14.



Thinking Critically

21. **Explain** the relationship between temperature and relative humidity.
22. **Describe** how air, water, and the Sun interact to cause weather.
23. **Explain** why northwest Washington often has rainy weather and southwest Texas is dry.
24. **Determine** What does it mean if the relative humidity is 79 percent?
25. **Infer** Why don't hurricanes form in Earth's polar regions?
26. **Compare and contrast** the weather at a cold front and the weather at a warm front.
27. **Interpret Scientific Illustrations** Use the cloud descriptions in this chapter to describe the weather at your location today. Then try to predict tomorrow's weather.
28. **Compare and contrast** tornadoes and thunderstorms. Include information about wind location and direction.
29. **Concept Map** Copy and complete the sequence map below showing how precipitation forms.



30. **Observe and Infer** You take a hot shower. The mirror in the bathroom fogs up. Infer from this information what has happened.



Performance Activities

31. **Board Game** Make a board game using weather terms. You could make cards to advance or retreat a token.
32. **Design** your own weather station. Record temperature, precipitation, and wind speed for one week.

Applying Math

Use the table below to answer question 33.

Air Temperature (°C)	Amount of Water Vapor Needed for Saturation (g/m ³)
25	22
20	15

33. **Dew Point** If the air temperature is 25°C and the relative humidity is 55 percent, will the dew point be reached if the temperature drops to 20°C?
34. **Rising Temperature** If the air temperature is 30°C and the relative humidity is 60 percent, will the dew point be reached if the temperature rises to 35°C? Use the graph in **Figure 4** to explain your answer.

Part 1 Multiple Choice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

Use the table and paragraph below to answer questions 1 and 2.

Hurricanes are rated on a scale based on their wind speed and barometric pressure. The table below lists hurricane categories.

Hurricane Rating Scale		
Category	Wind Speed (km/h)	Barometric Pressure (millibars)
1	119–154	>980
2	155–178	965–980
3	179–210	945–964
4	211–250	920–944
5	>250	<920

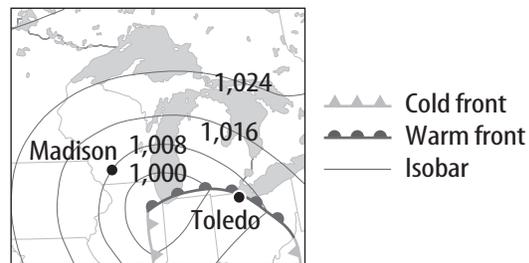
- Hurricane Mitch, with winds of 313 km/h and a pressure of 907 mb, struck the east coast of Central America in 1998. What category was Hurricane Mitch?
 - 2
 - 3
 - 4
 - 5
- Which of the following is true when categorizing a hurricane?
 - Storm category increases as wind increases and pressure decreases.
 - Storm category increases as wind decreases and pressure increases.
 - Storm category increases as wind and pressure increase.
 - Storm category decreases as wind and pressure decrease.

Test-Taking Tip

Fill In All Blanks Never leave any answer blank.

- Which of the following instruments is used to measure air pressure?
 - anemometer
 - thermometer
 - barometer
 - rain gauge
- Which of the following is a description of a tornado?
 - a large, swirling, low-pressure system that forms over the warm Atlantic Ocean
 - a winter storm with winds at least 56 km/h and low visibility
 - a violently rotating column of air in contact with the ground
 - a boundary between two air masses of different density, moisture, or temperature

Use the figure below to answer questions 5 and 6.



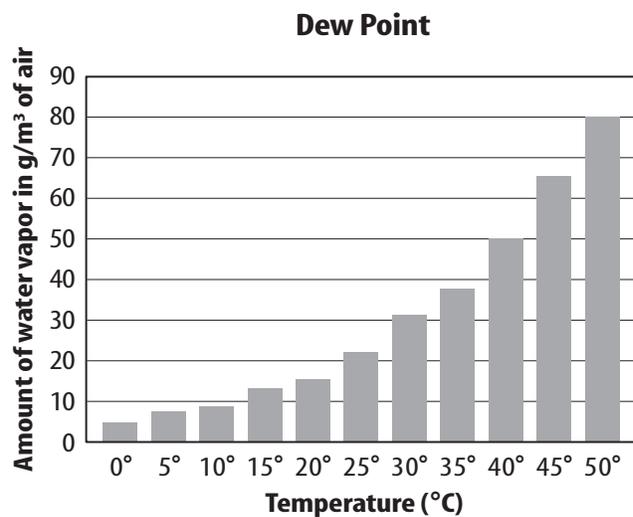
- What is the atmospheric pressure in the city of Madison, Wisconsin?
 - 1024 mb
 - 1016 mb
 - 1008 mb
 - 1000 mb
- What type of front is near Toledo, Ohio?
 - cold front
 - warm front
 - stationary front
 - occluded front
- Which of the following terms is used to describe a person studies the weather?
 - meteorologist
 - geologist
 - biologist
 - paleontologist

Part 2 Short Response/Grid In

Record your answer on the answer sheet provided by your teacher or on a sheet of paper.

- Compare and contrast the formation of stratus clouds, cumulus clouds and cirrus clouds.

Use the graph below to answer questions 9 and 10.



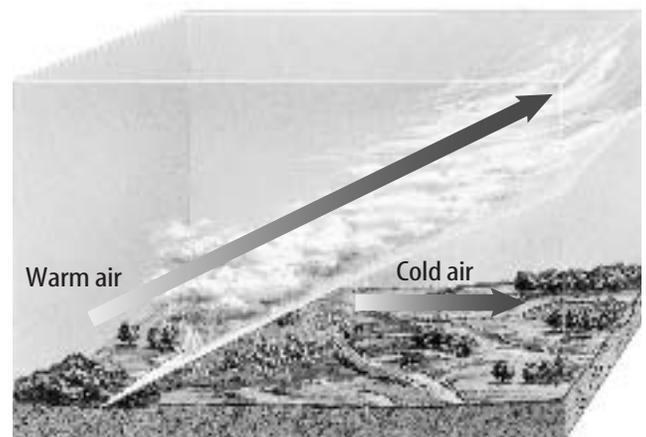
- What amount of water vapor is in air at a temperature of 45°C?
- On a fall day, the relative humidity is 72 percent and the temperature is 30°C. Will the dew point be reached if the temperature drops to 20°C? Why or why not?
- Describe weather conditions during which hailstones form and the process by which they form.
- What effects do high-pressure systems have on air circulation and weather? What effects do low-pressure systems have on weather?
- Explain the relationship between differences in atmospheric pressure and wind speed.

Part 3 Open Ended

Record your answers on a sheet of paper.

- Explain the relationship between lightning and thunder.
- Describe how a hurricane in the Northern Hemisphere forms.
- Explain why hurricanes lose power once they reach land.

Use the figure below to answer question 17.



- What type of front is shown? How does this type of front form?
- Explain what type of weather occurs at front boundaries.
- List the safety precautions you should take during a severe weather alert, including tornado warnings, flood watches, and blizzards, respectively.
- Explain how the Sun's heat energy creates Earth's weather.
- What are the four main types of precipitation? Describe the differences between each type.