chapter 12

The Atmosphere in Motion

Español

chapter preview

sections

Why's it so windy?

Hurricanes are powerful storms that develop over the ocean. If these storms reach land, damage can be severe. Hurricane Gilbert, shown in the photo, caused extensive damage on the island of Jamaica in 1988. It then struck the eastern coast of Mexico.

Science Journal Write a short newspaper article to warn people about the dangers of an approaching hurricane.

Start-Up Activities

Launch LAB

How does temperature affect gas molecules?

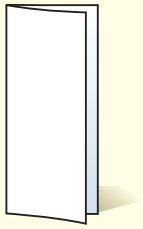
The temperature of air affects the movement of gas molecules. In the lab below, you will increase and then decrease the temperature of air and observe the changes that occur as a result of the movement of air molecules.

1. With your finger, rub a mixture of water and dish-washing liquid across the top of a narrow-necked plastic bottle until a thin film forms over the opening.
2. Hold the bottle in a beaker that is half-filled with hot water and observe what happens to the soap film.
3. Without breaking the film, remove the bottle from the hot water and place it in a beaker that is half-filled with ice water. Observe what happens to the film.
4. **Think Critically** In your Science Journal, describe what you observed. Infer what happened to change the shape of the film on top of the bottle.

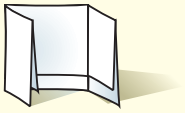
FOLDABLES™ Study Organizer

Earth's Atmosphere Make the following Foldable to identify what you already know, what you want to know, and what you learned about the atmosphere.

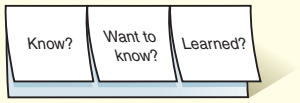
STEP 1 **Fold** a vertical sheet of paper from side to side. Make the front edge about 1.25 cm shorter than the back edge.



STEP 2 **Turn** lengthwise and **fold** into thirds.



STEP 3 **Unfold and cut** only the top layer along both folds to make three tabs. **Label** each tab as shown.



Read and Write Before you read the chapter, write what you already know and what you want to know about the atmosphere under the tabs. As you read the chapter, write what you learned.

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

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section 1

The Atmosphere

as you read

What You'll Learn

- **Explain** why air has pressure.
- **Describe** the composition of the atmosphere.
- **Describe** how energy causes water on Earth to cycle.

Why It's Important

Movements within the atmosphere create weather changes.

Review Vocabulary

air: the mixture of gases that forms Earth's atmosphere

New Vocabulary

- atmosphere
- aerosol
- troposphere
- water cycle

Investigating Air

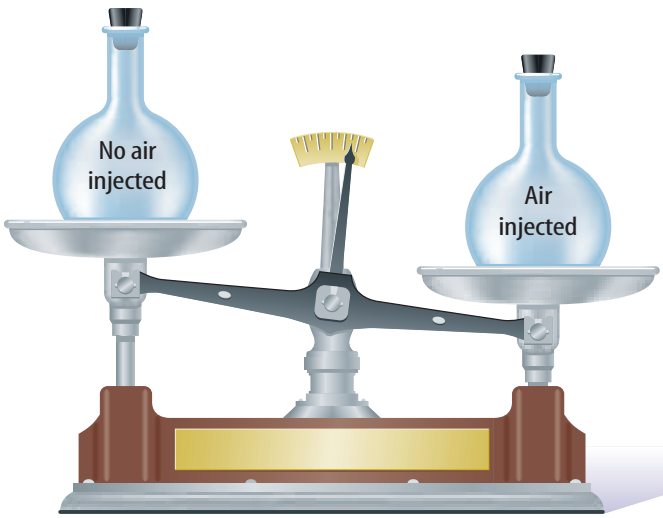
Air, air . . . everywhere. It's always there. You take it for granted, but without it, Earth would be unfit for life. The **atmosphere**—the layer of gases surrounding Earth—provides Earth with all the gases necessary to support life. It protects living things against harmful doses of ultraviolet and X-ray radiation. At the same time it absorbs and distributes warmth.

Galileo Galilei (1564–1642), an Italian astronomer and physicist, suspected that air was more than just empty space. He weighed a flask, then injected air into it and weighed it again. As shown in **Figure 1,** Galileo observed that the flask weighed more after injecting the air. He concluded that air must have weight and therefore must contain matter. Today scientists know that the atmosphere has other properties, as well. Air stores and releases heat and holds moisture. Because it has weight, air can exert pressure. All of these properties, when combined with energy from the Sun, create Earth's daily weather.

Composition of the Atmosphere

What else do scientists know about the atmosphere? Because it is composed of matter and has mass, it is subject to the pull of gravity. This is what keeps the atmosphere around Earth and prevents it from moving into space. Because it exerts pressure in all directions, you barely notice the atmosphere. Yet its weight is equal to a layer of water more than 10 m deep covering Earth. Scientists also know that the atmosphere is composed of a mixture of gases, liquid water, and microscopic particles of solids and other liquids.

Figure 1 The flask with air injected weighs more than the flask with no air injected.



Reading Check *What is Earth's atmosphere composed of?*

Gases Although the atmosphere contains many gases, two of them make up approximately 99 percent of the total. **Figure 2** shows a graph of the gases found in the atmosphere. Nitrogen (N_2) is the most abundant gas—it makes up about 78 percent of the atmosphere. Oxygen (O_2), the gas necessary for human life, makes up about 21 percent. A variety of trace gases makes up the rest.

Of the trace gases, two have important roles within the atmosphere. Water vapor (H_2O) makes up from 0.0 to 4.0 percent of the atmosphere and is critical to weather. Water in the atmosphere is responsible for clouds and precipitation. Much of the life on Earth depends on water from precipitation. The other important trace gas, carbon dioxide (CO_2), is present in small amounts. Carbon dioxide is needed for plants to make food. Also, carbon dioxide in the atmosphere absorbs heat and emits it back toward Earth's surface, helping keep Earth warm.

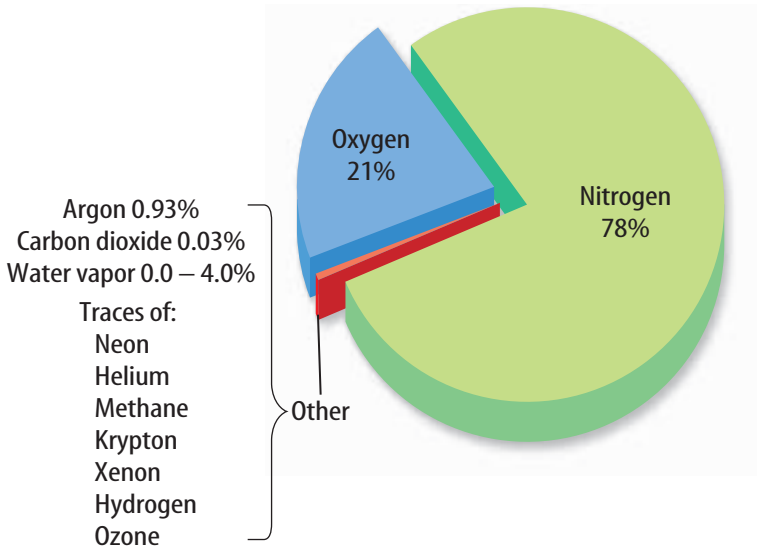


Figure 2 The percentages of gases in the atmosphere vary slightly. For example, water vapor makes up from 0.0 to 4.0 percent of the atmosphere.
Determine *what happens to the percentages of other gases when the percentage of water vapor is higher.*

Aerosols Solids such as dust, salt, and pollen and tiny liquid droplets such as acids in the atmosphere are called **aerosols** (AR uh sahlz). Dust enters the atmosphere when wind picks tiny soil particles off the ground or when ash is emitted from volcanoes. Salt enters the atmosphere when wind blows across the oceans. Pollen enters the atmosphere when it is released by plants. Such human activities as burning coal in power plants also release aerosols into the air. Some aerosols, such as those given off by the volcano in **Figure 3,** reflect incoming solar energy, which can affect weather and climate.

Figure 3 Volcanoes add many aerosols to the atmosphere. Some volcanic aerosols can remain suspended in the atmosphere for months or even years.
Infer *what happens if many aerosols are in the atmosphere.*

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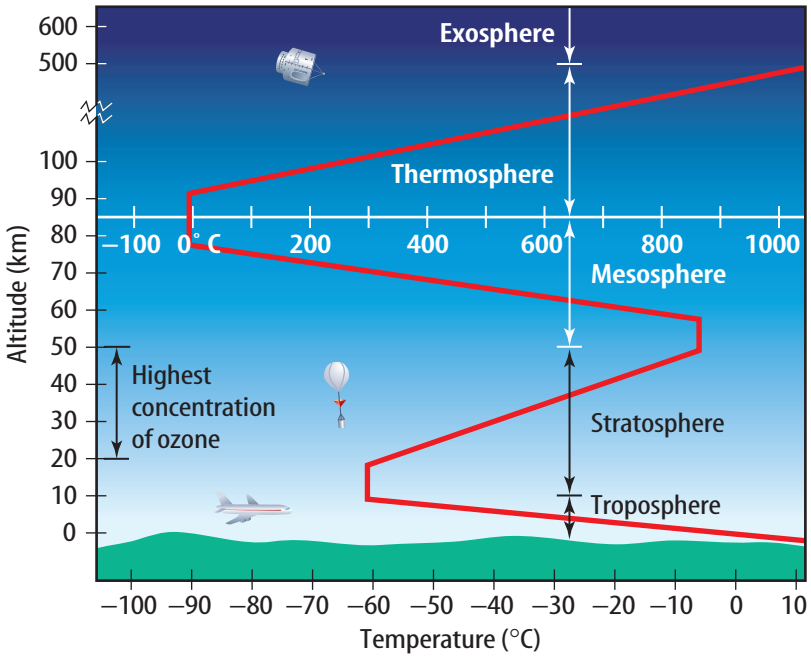

Figure 4 Temperature variations separate Earth's atmosphere into distinct layers. The white temperature scale shows temperatures in the thermosphere and exosphere.

The Ozone Layer Ozone in the stratosphere shields Earth's surface from the Sun's ultraviolet (UV) radiation. However, scientists have discovered that the ozone layer has been damaged, allowing more UV radiation to reach Earth. This radiation can cause skin cancers and cataracts, which damage vision. What should you do to protect your skin and eyes when you are outdoors?

Layers of the Atmosphere

The atmosphere is divided into the layers that you see in **Figure 4.** These layers are based on temperature changes that occur with altitude. Each atmospheric layer has unique properties. Find each layer as you read about it. The lower layers are the troposphere and stratosphere. The upper layers are the mesosphere, the thermosphere, and the exosphere.

Troposphere The **troposphere** (TROH puh sfihr) is the atmospheric layer closest to Earth's surface. Notice that it extends upward to about 10 km. The troposphere contains about three fourths of the matter in Earth's entire atmosphere and nearly all of its clouds and weather. The atmosphere absorbs some of the Sun's energy and reflects part of it back to space. However, about 50 percent of the Sun's energy passes through the troposphere and reaches Earth's surface. This energy heats Earth. The atmosphere near Earth's surface is heated by the process of conduction. This means that the source of most of the troposphere's heat is Earth's surface. Therefore, temperatures in the troposphere are usually warmest near the surface and tend to cool as altitude increases. Temperatures cool at a rate of about 6.5 Celsius degrees per kilometer of altitude. If you ever climb a mountain, you will notice that it gets colder as you go higher.

Reading Check *What is the troposphere?*

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Stratosphere Above the troposphere is the stratosphere (STRAH tuh sfihr). The stratosphere extends from about 10 km to about 50 km above Earth's surface. As shown in **Figure 4,** most atmospheric ozone is contained in the stratosphere. This ozone absorbs much of the Sun's ultraviolet radiation. As a result, the stratosphere warms as you go upward through it, which is just the opposite of the troposphere. Without the ozone in this layer, too much radiation would reach Earth's surface, causing health problems for plants and animals.

Upper Layers Above the stratosphere is the mesosphere (ME zuh sfihr). This layer extends from approximately 50 km to 85 km above Earth's surface. This layer contains little ozone, so much less heat is absorbed. Notice in **Figure 4** how the temperature in this layer drops to the lowest temperatures in the atmosphere.

The thermosphere (THUR muh sfihr) is above the mesosphere. The thermosphere extends from about 85 km to approximately 500 km above Earth's surface. Temperatures increase rapidly in this layer to more than 1,700°C. The thermosphere layer filters out harmful X rays and gamma rays from the Sun.

Because of intense interaction with the Sun's radiation, atoms can become electrically charged particles called ions. For this reason a part of the thermosphere and mesosphere is called the ionosphere (i AH nuh sfihr). This layer of ions is useful because it can reflect AM radio waves, as shown in **Figure 5,** making long-distance communication possible. If the interaction between the Sun's radiation and this layer is too active, however, the quality of radio reception is reduced. Radio signals break up and a lot of static can be heard.

The outermost layer of the atmosphere is the exosphere. It extends outward to where space begins and contains few atoms. No clear boundary separates the exosphere from space.

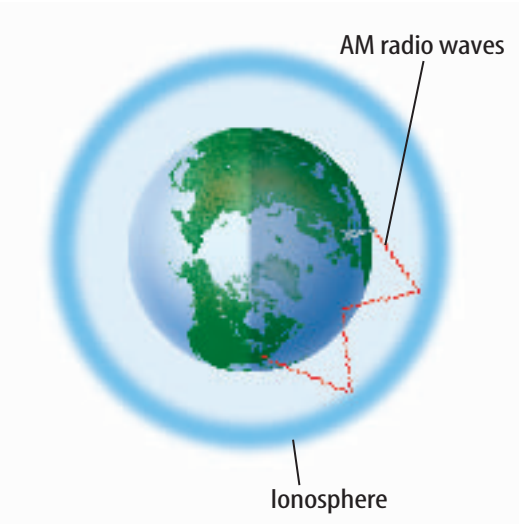

Figure 5 Radio waves are reflected by the ionosphere.

Earth's Water

Earth often is referred to as the water planet. This is because Earth's surface is about 70 percent water. Because water can exist in three separate states it can be stored throughout the entire land-ocean-atmosphere system. As **Table 1** shows, water exists as solid snow or ice in glaciers. In oceans, lakes, and rivers water exists as a liquid and in the atmosphere it exists as gaseous water vapor.

Table 1 Distribution of Earth's Water

Location	Amount of Water (%)
Oceans	97.2
Ice caps and glaciers	2.05
Groundwater	0.62
Rivers and lakes	0.009
Atmosphere	0.001
Total (rounded)	**100.00**

NATIONAL GEOGRAPHIC

VISUALIZING THE WATER CYCLE

Figure 6

As the diagram below shows, energy for the water cycle is provided by the Sun. Water continuously cycles between oceans, land, and the atmosphere through the processes of evaporation, transpiration, condensation, and precipitation.

▲ Droplets inside clouds join to form bigger drops. When they become heavy enough, they fall as rain, snow, or some other form of precipitation.

▲ As it rises into the air, water vapor cools and condenses into water again. Millions of tiny water droplets form a cloud.

▶ Rain runs off the land into streams and rivers. Water flows into lakes and oceans. Some water is taken up by plants.

▲ Water evaporates from oceans, lakes, and rivers. Plants release water vapor through transpiration.

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The Water Cycle

Earth's water is in constant motion in a never-ending process called the **water cycle,** shown in **Figure 6.** The Sun's radiant energy powers the cycle. Water on Earth's surface—in oceans, lakes, rivers, and streams—absorbs energy and stores it as heat. When water has enough heat energy, it changes from liquid water into water vapor in a process called evaporation. Water vapor then enters the atmosphere.

Evaporation occurs from all bodies of water, no matter how large or small. Have you ever noticed that a puddle of water left on the sidewalk from a rainstorm disappears after a while? The water evaporates into the atmosphere. Water also is transferred into the atmosphere from plant leaves in a process called transpiration. As water vapor moves up through the atmosphere, it becomes cooler. The molecules begin to slow down. Eventually, the water molecules change back into droplets of liquid water. This process is called condensation.

Reading Check *How do evaporation and condensation differ?*

Water droplets grow in size when two or more droplets run into each other and combine to form a larger droplet. Eventually, these droplets become large enough to be visible, forming a cloud. If the water droplets continue to grow, they become too large to remain suspended in the atmosphere and fall to Earth as precipitation. You will learn about the different forms of precipitation in the next section. After it is on the ground, some water evaporates. Most water enters streams or soaks into the soil to become groundwater. Much of this water eventually makes its way back to lakes or to the oceans, where more evaporation occurs and the water cycle continues.

Mini LAB

Observing Condensation and Evaporation

Procedure

1. Fill a **glass** with **ice water.** Make sure that the outside of the glass is dry.
2. Let the glass stand for 10 min and observe what happens on the outside of the glass.
3. Pour 500 mL of **water** into a **shallow pan.**
4. Leave the pan out for several days.
5. Use a **ruler** to measure the amount of water in the pan each day. Record your data.

Analysis

1. Infer why water droplets formed on the the glass.
2. Infer where some of the water in the pan went.

Try at Home

section 1 review

Summary

Investigating Air

- Air exerts pressure in all directions.

Composition of the Atmosphere

- The atmosphere consists of nitrogen, oxygen, and trace gases, such as water vapor and carbon dioxide.

Layers of the Atmosphere

- The atmosphere is divided into layers based on temperature changes.

Earth's Water

- A model that shows how water cycles is called the water cycle.

Self Check

1. **Explain** why air has pressure.
2. **Identify** three solid particles that occur in the atmosphere.
3. **List** the five layers of Earth's atmosphere starting at Earth's surface.
4. **Describe** four important processes that are part of the water cycle.
5. **Think Critically** Why is it possible for a high mountain at the equator to be covered by snow?

Applying Skills

6. **Recognize Cause and Effect** A closed, metal can collapses when the air is pumped out of it. Explain why.

section 2

Earth's Weather

as you read

What You'll Learn

- **Compare** ways that heat is transferred on Earth.
- **Describe** the formation of different kinds of clouds and precipitation.
- **Explain** what causes wind.

Why It's Important

Weather affects your life every day.

Review Vocabulary

cloud: an area in the atmosphere that contains enough water droplets or ice crystals to be visible

New Vocabulary

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

Weather

Your favorite television show is interrupted by a special weather bulletin. Heavy snow is expected in your area during the night. Will the schools be closed? Will people be able to get to work? How might this weather affect your family? **Weather** describes the current condition of the atmosphere. Factors of weather include temperature, cloud cover, wind speed, wind direction, humidity, and air pressure. It is the task of meteorologists (mee tee uh RAH luh jists) to monitor all weather data continuously in an attempt to forecast weather.

Temperature You learned earlier that the Sun's radiant energy powers the water cycle. In fact, the Sun is the source of almost all of the energy on Earth. When the Sun's rays reach Earth, energy is absorbed. Gas molecules are constantly in motion, but when they absorb more energy, they move faster and farther apart, as shown in **Figure 7.** Temperature is a measure of how fast air molecules are moving. When air molecules are moving rapidly, temperature is high. Temperature is measured with a thermometer that has a particular scale. The Celsius and Fahrenheit scales commonly are used to measure air temperature.

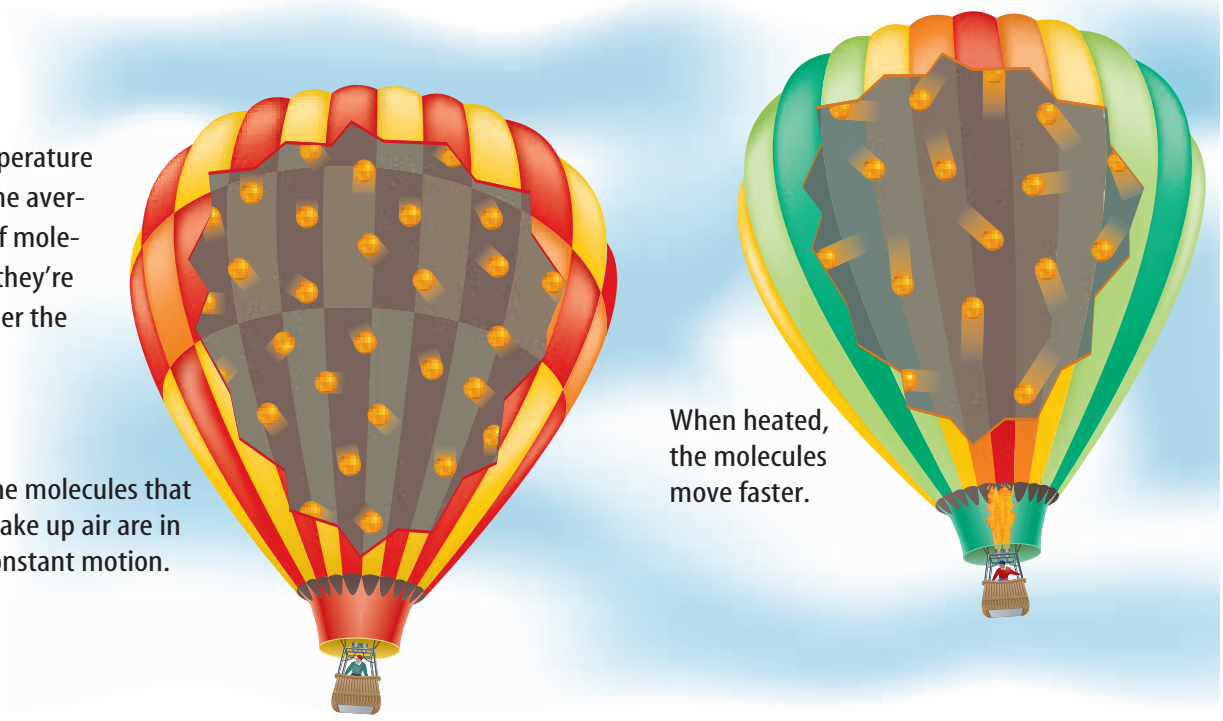

Figure 7 Temperature is a measure of the average movement of molecules. The faster they're moving, the higher the temperature is.

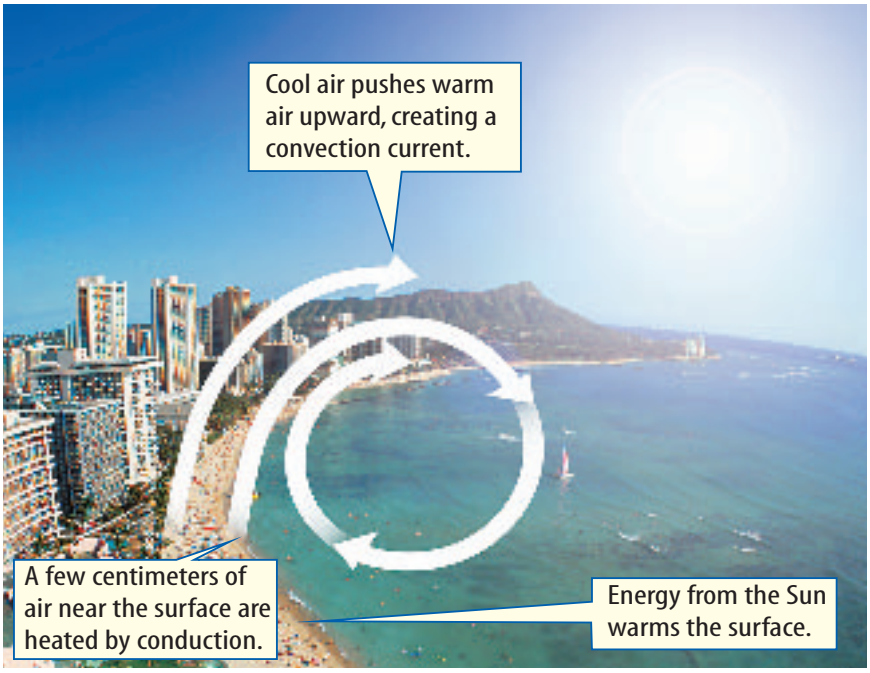

Figure 8 Energy from the Sun warms Earth's surface. Conduction and convection transfer heat on Earth.

Energy Transfer Fast-moving molecules transfer energy to slower-moving molecules when they bump into each other. The transfer of energy that results when molecules collide is called conduction. It is conduction that transfers heat from Earth's surface to those molecules in the air that are in contact with it. After it is in the atmosphere, heated air will move upward as long as it is warmer than the surrounding air. The rising air cools as it gets higher. If it becomes cooler than the surrounding air, it will sink. The process of warm air rising and cool air sinking is called convection. It is the main way heat is transferred throughout the atmosphere. Both processes are shown in **Figure 8.**

INTEGRATE Physics

Atmospheric Pressure As you have learned, because of the attraction of gravity, air has weight. Therefore, the weight of air exerts pressure. Air pressure decreases with altitude in the atmosphere. This is because as you go higher, the weight of the atmosphere above you is less.

Temperature and pressure are related. When air is heated, its molecules move faster, and the air expands. This makes the air less dense, which is why heated air gets moved upward. Less dense air also exerts less pressure on anything below it, creating lower pressure. Cooled air becomes more dense and sinks as the molecules slow down and move closer together, creating more pressure. Therefore, rising air generally means lower pressure and sinking air means higher pressure. Air pressure varies over Earth's surface.

INTEGRATE Life Science

Natural Thermometers Crickets chirp more often and rattlesnakes rattle faster when they're warm. How could these animals be used as natural thermometers?

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Science Online

Topic: Relative Humidity

Visit red.msscience.com for Web links to information about relative humidity and dew point.

Activity Do research to find the definition of the word *dew*. What is dew and how is it related to the dew point? Explain what you learn to the class.

Humidity As air warms up, it can cause water that is in contact with it to evaporate to form water vapor. The amount of water vapor in the atmosphere is called **humidity.** The graph in **Figure 9** shows how temperature affects how much moisture can be present in the air. When air is warmer, evaporation occurs more quickly, and more water vapor can be added to the air. More water vapor can be present in warm air than in cool air. When air is holding as much water vapor as it can, it is said to be saturated and condensation can occur. The temperature at which this takes place is called the **dew point.**

Relative Humidity Suppose a mass of air is chilled. The actual amount of water vapor in the air doesn't change unless condensation occurs, but the amount of moisture that can be evaporated into it decreases. **Relative humidity** is a measure of the amount of water vapor that is present compared to the amount that could be held at a specific temperature. As air cools, relative humidity increases if the amount of water vapor present doesn't change. When air is holding all of the water vapor it can at a particular temperature, it has 100 percent relative humidity.

Reading Check ***What is relative humidity?***

Sometimes local TV weather reports give the dew point on summer days. If the dew point is close to the air temperature, the relative humidity is high. If the dew point is much lower than the air temperature, relative humidity is low.

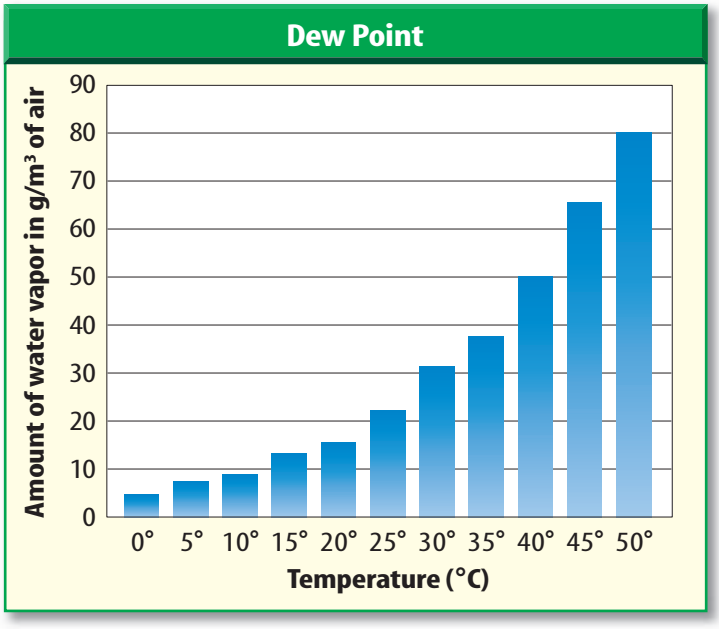


Figure 9 This graph shows how temperature affects the amount of water vapor that air can hold. **Determine** *how much water vapor the air can hold if its temperature is 30°C. How much can it hold if the temperature drops to 10°C?*

Clouds

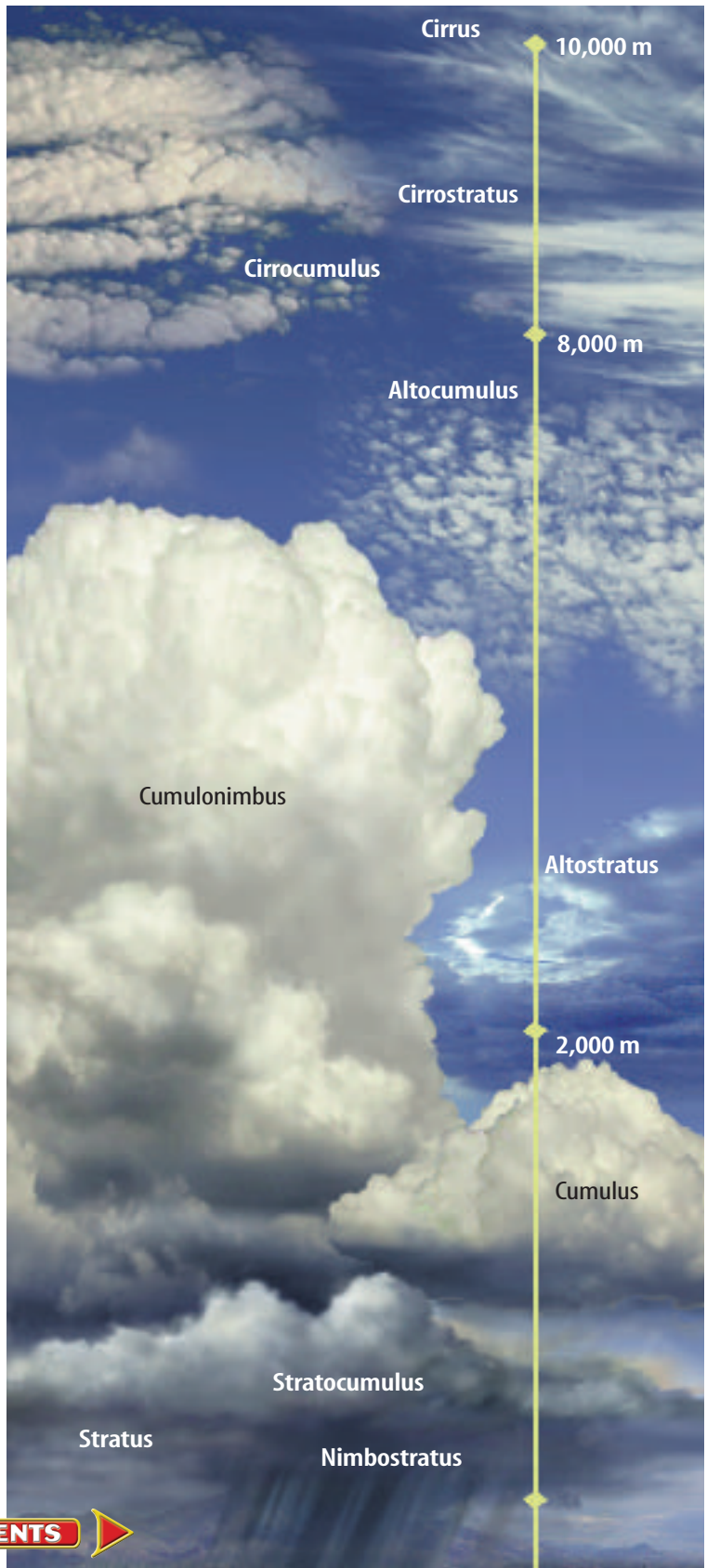
One of the best indications that Earth has an atmosphere in motion is the presence of clouds. Clouds form when air rises, cools to its dew point, and becomes saturated. Water vapor in the air then condenses onto small particles in the atmosphere. If the temperature is not too cold, the clouds will be made of small drops of water. If the temperature is cold enough, clouds can consist of small ice crystals.

Clouds commonly are classified according to the altitude at which they begin to form. The most common classification method is one that separates clouds into low, middle, or high groups. Some cloud types are shown in **Figure 10.**

Low Clouds The low-cloud group consists of clouds that form at about 2,000 m or less in altitude. These clouds include the cumulus (KYEW myuh lus) type, which are puffy clouds that form when air currents rise, carrying moisture with them. Sometimes cumulus clouds are fair weather clouds. However, when they have high vertical development, they can produce thunder, lightning, and heavy rain. Another type of low cloud includes layered stratus (STRA tus) clouds. Stratus clouds form dull, gray sheets that can cover the entire sky. Nimbostratus (nihm boh STRA tus) clouds form low, dark, thick layers that blot out the Sun. If you see either of these types of clouds, you can expect some kind of precipitation. Fog is a type of stratus cloud that is in contact with the ground.

Middle Clouds Clouds that form between about 2,000 m and 8,000 m are known as the middle-cloud group. Most of these clouds are of the layered variety. Their names often have the prefix *alto-* in front of them, such as altocumulus and altostratus. Sometimes they contain enough moisture to produce light precipitation. Middle clouds can be made up of a mixture of liquid water and ice crystals.

Figure 10 Clouds are grouped according to how high they are above the ground. The types of clouds can be used to predict weather.



High and Vertical Clouds Some clouds occur in air that is so cold they are made up entirely of ice crystals. Because this usually happens high in the atmosphere, these are known as the high-cloud group. They include cirrus (SIHR us) clouds, which are wispy, high-level clouds. Another type is cirrostratus clouds, which are high, layered clouds that sometimes cover the entire sky.

Some clouds can extend vertically throughout all the levels of the atmosphere. These are clouds of vertical development, and the most common type is cumulonimbus (kyew myuh loh NIHM bus). When you see the term *nimbus* attached to a cloud name, it usually means the cloud is creating precipitation. Cumulonimbus clouds create the heaviest precipitation of all. Known as thunderstorm clouds, they start to form at heights of less than 1,000 m but can build to more than 16,000 m high.

Precipitation

When drops of water or crystals of ice become too large to be suspended in a cloud, they fall as **precipitation.** Precipitation can be in the form of rain, freezing rain, sleet, snow, or hail. The type of precipitation that falls depends on the temperature of the atmosphere. For example, rain falls when the temperature of the atmosphere is above freezing. However, if air aloft is above freezing while air near Earth's surface is below freezing, freezing rain might occur. Hail consists of balls of ice that form within cumulonimbus clouds. Within the storm cloud, strong winds toss ice crystals up and down, as shown in **Figure 11.** As the ice crystals move, droplets of water freeze around them. Hailstones keep growing until they are too heavy for the winds to keep up. Then they fall to the ground.

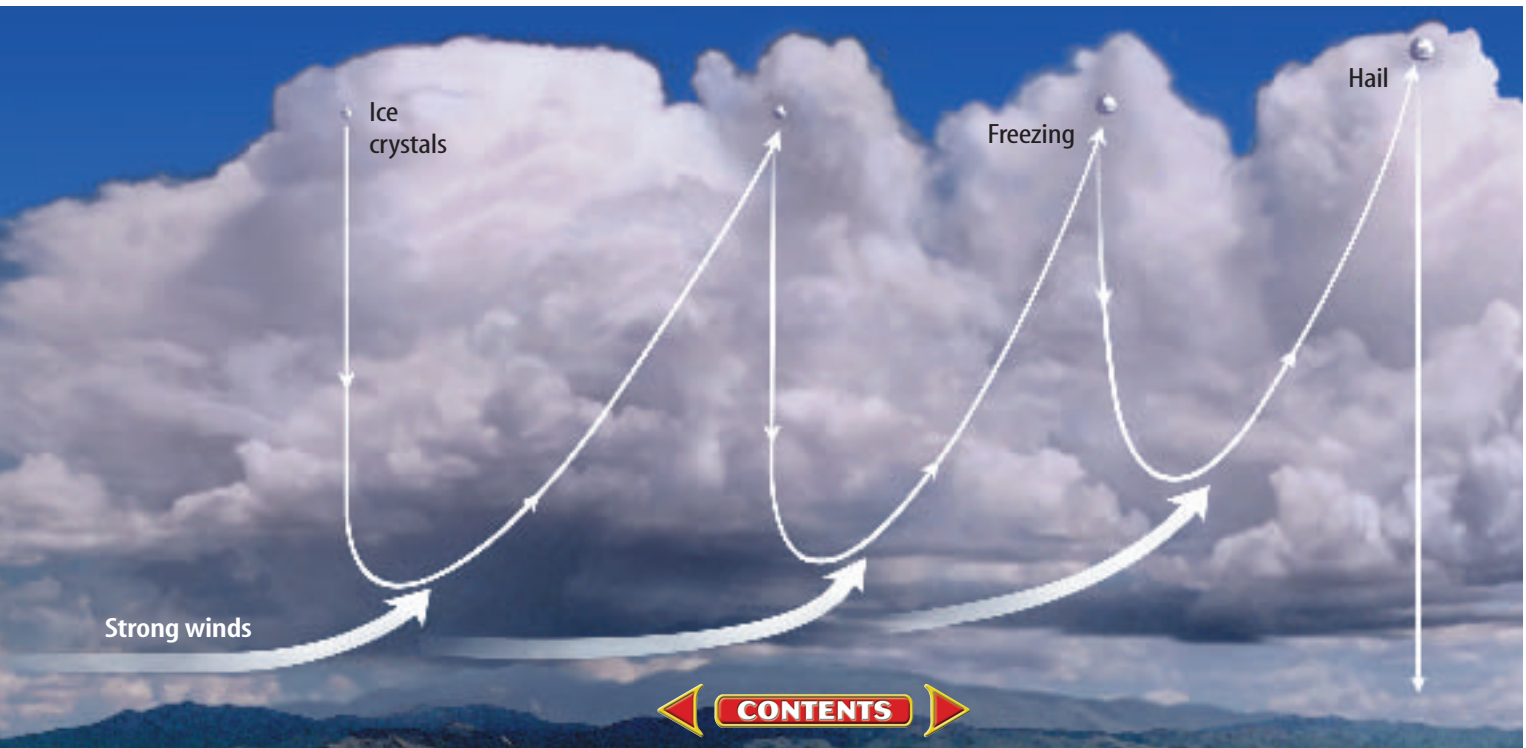


Figure 11 Hailstones develop in cumulonimbus clouds. Most hailstones are the size of peas, but some can reach the size of softballs. **Explain** *what this tells you about the strength of the winds in the cloud.*

Wind

As you learned earlier, air pressure is related to temperature. When molecules in the atmosphere are heated, they move more rapidly and spread apart. The air becomes less dense and is moved upward. This causes regions of low air pressure. When cooled, those molecules move more slowly and move closer together. The air becomes more dense and sinks, forming regions of high pressure. Typically, air moves from high-pressure areas toward low-pressure areas. Because pressure and temperature are directly related, wind can be thought of simply as air moving from one temperature or pressure area to another. The greater the difference in temperature or pressure between two areas, the stronger the winds that blow between them will be. Wind speed is measured by an instrument called an anemometer (an uh MAH muh tur), which indicates wind speed by how fast an array of cups that catch the wind rotate. The fastest wind speed ever measured was 371 km/h measured on Mount Washington, New Hampshire, in 1934.

Indian Monsoon A monsoon is a shift in wind direction that occurs during particular seasons. India is a country that is strongly affected by monsoons. During June and July, low pressure forms over the Indian continent. This causes moist winds to blow from the ocean. These winds produce the heavy rains needed for Indian agriculture. During winter, high pressure forms over India, and dry winds blow from the land to the sea.

Applying Math — Solve a One-Step Equation

WIND SPEED Air moves from an area of high air pressure to an area of low air pressure. The wind that is created travels a distance of 14 km in 2 h. What is the wind speed?

Solution

1 *This is what you know:*
- distance: $d = 14$ km
- time: $t = 2$ h

2 *This is what you need to find:*
speed (rate): r

3 *This is the procedure you need to use:*
- substitute into the equation, $r = d/t$
- $r = 14$ km/2 h $= 7$ km/h

4 *Check your answer:*
Multiply your answer by the time. Do you calculate the same distance that was given?

Practice Problems

1. Air moves from a cool area to a warmer area. The wind that is created moves 20 km in 2 h. What is the wind speed?
2. Air moves from an area of high air pressure to an area of low air pressure. The wind that is created travels a distance of 69 km in 3 h. What is the wind speed?

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

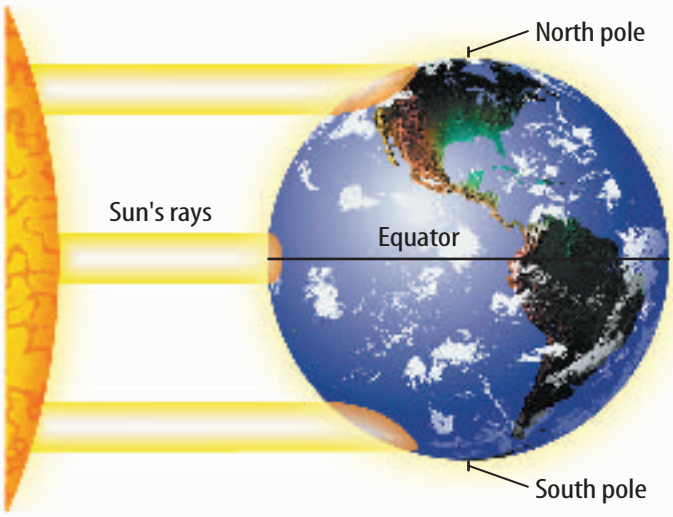


Figure 12 The angle of the Sun's rays is higher near the equator than near the poles.

Global Air Circulation

Look at **Figure 12.** In any given year, the Sun's rays strike Earth at a higher angle near the equator than near the poles. As a result, Earth's tropical areas heat up more than the polar regions do. Because of this imbalance of heat, warm air flows toward the poles from the tropics and cold air flows toward the equator from the poles. Because Earth rotates, this moving air is deflected to the right in the northern hemisphere and to the left south of the equator. This is known as the Coriolis (kor ee OH lus) effect.

Reading Check *What is the Coriolis effect?*

Surface Winds

Figure 13 shows Earth's major surface winds. Air at the equator is heated by the rays of the Sun. This air expands, becomes less dense, and gets pushed upward. Farther from the equator, at about 30° latitude, the air is somewhat cooler. This air sinks and flows toward the equator. As this air flows, it is turned by the Coriolis effect, creating steady winds called the trade winds. Trade winds also are called tropical easterlies because they blow in a general east-to-west direction. Find the trade winds in **Figure 13.**

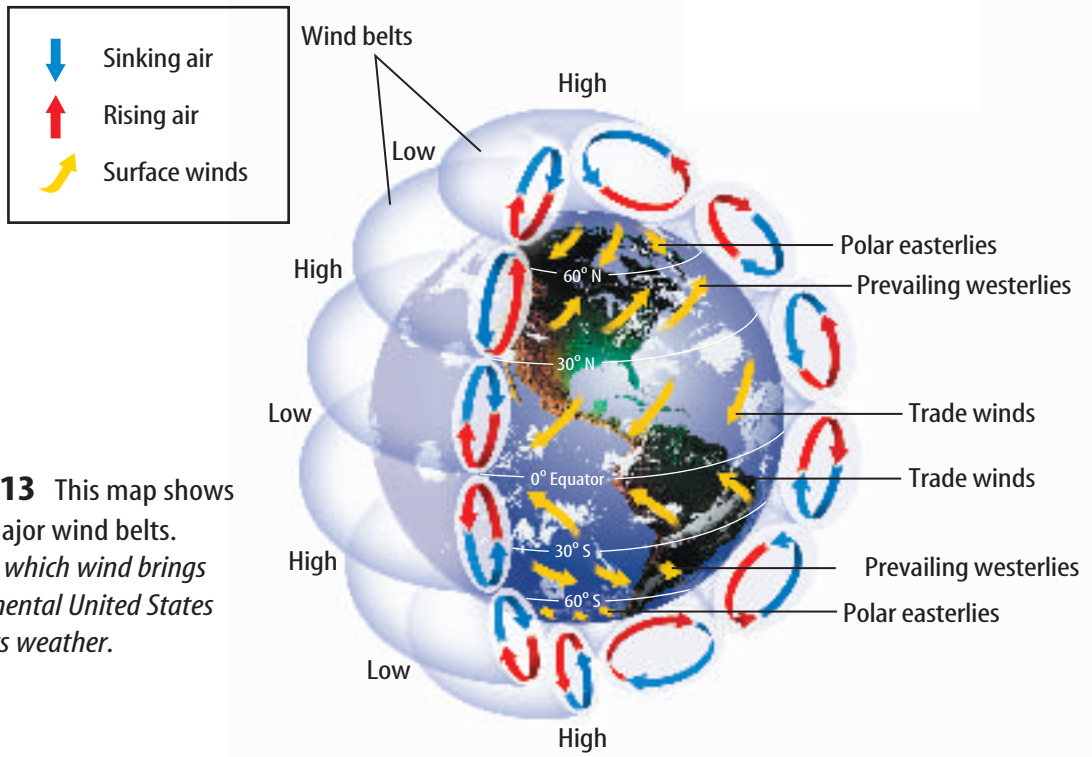


Figure 13 This map shows Earth's major wind belts. **Identify** *which wind brings the continental United States most of its weather.*

Westerlies and Easterlies Major wind cells also are located between 30° and 60° latitude north and south of the equator. They blow from the west and are called the prevailing westerlies. These winds form the boundary between cold air from the poles and milder air closer to the equator. Many of Earth's major weather systems form along these boundaries, so these regions are known for frequent storms.

Near the poles, cold, dense air sinks and flows away from the poles. It is replaced by warmer air flowing in from above. As the cold air flows away from the poles, it is turned by the Coriolis effect. These winds, the polar easterlies, blow from the east.

Figure 14 Weather forecasters often show the position of a jet stream to help explain the movements of weather systems.

Jet Streams Within the zone of prevailing westerlies are bands of strong winds that develop at higher altitudes. Called jet streams, they are like giant rivers of air, as shown in **Figure 14.** They blow near the top of the troposphere from west to east at the northern and southern boundaries of the prevailing westerlies. Their positions in latitude and altitude change from day to day and from season to season. Jet streams are important because weather systems move along their paths.

Other Winds Besides the major winds, other winds constantly are forming. Slight differences in pressure create gentle breezes. Great differences create strong winds. The strongest winds occur when air rushes into the center of low pressure. This can cause severe weather like tornadoes and hurricanes.

section 2 review

Summary

Weather

- Weather describes the current condition of the atmosphere.

Clouds

- Clouds are classified according to the altitude at which they form.

Precipitation

- Types of precipitation include rain, freezing rain, sleet, snow, and hail.

Wind

- Air moves as wind because of pressure differences on Earth.

Self Check

1. **Explain** how Earth's surface is heated. How does this affect the troposphere?
2. **Describe** what happens when water vapor rises and cools to the dew point.
3. **Explain** how air pressure is related to temperature.
4. **Define** a jet stream.
5. **Think Critically** Why doesn't precipitation fall from every cloud?

Applying Skills

6. **Compare and contrast** conduction and convection.

section 3

Air Masses and Fronts

as you read

What You'll Learn

- **Explain** the ways that air masses and fronts form.
- **Discuss** the causes of severe weather.
- **Explain** how technology is used to monitor and predict weather.

Why It's Important

By understanding how weather changes, you can better plan your outdoor activities.

Review Vocabulary

thunderstorm: a storm produced by a cumulonimbus cloud that has lightning and thunder

New Vocabulary

- air mass
- front
- tornado
- hurricane

Air Masses

Weather can change quickly. It can be sunny with calm winds in the morning and turn stormy by noon. Weather changes quickly when a different air mass enters an area. An **air mass** is a large body of air that develops over a particular region of Earth's surface.

Types of Air Masses A mass of air that remains over a region for a few days acquires the characteristics of the area over which it occurs. For example, an air mass over tropical oceans becomes warm and moist. **Figure 15** shows the location of the major air masses that affect weather in North America.

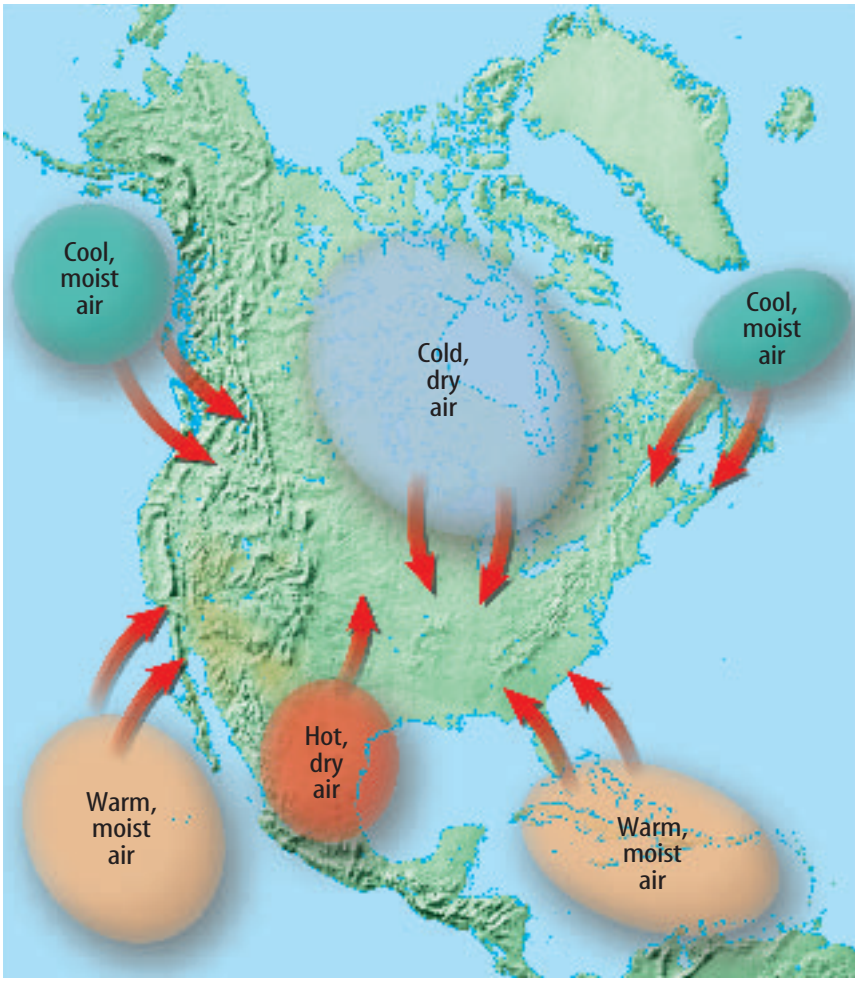


Figure 15 Six major air masses affect North America.
Infer *the characteristics of an air mass that originates over the North Pacific Ocean.*

Fronts

Where air masses of different temperatures meet, a boundary between them, called a **front,** is created. Along a front, the air doesn't mix. Because cold air is more dense, it sinks beneath warm air. The warm air is forced upward and winds develop. Fronts usually bring a change in temperature as they pass, and they always bring a change in wind direction. The four kinds of fronts are shown in **Figures 16, 17,** and **18.**

Reading Check *What is a front?*

Cold Fronts When a cold air mass advances and pushes under a warm air mass, the warm air is forced to rise. The boundary is known as a cold front, shown in **Figure 16.** As water condenses, clouds and precipitation develop. If the air is pushed upward quickly enough, a narrow band of violent storms can result. Cumulus and cumulonimbus clouds can develop. As the name implies, a drop in temperature occurs with a cold front.

Warm Fronts If warm air is advancing into a region of colder air, a warm front is formed. Notice in **Figure 16** that warm, less dense air slides up and over the colder, denser air mass. As the warm air mass moves upward, it cools. Water vapor condenses and precipitation occurs over a wide area. As a warm front approaches, high cirrus clouds are seen where condensation begins. The clouds become progressively lower as you get nearer the front.

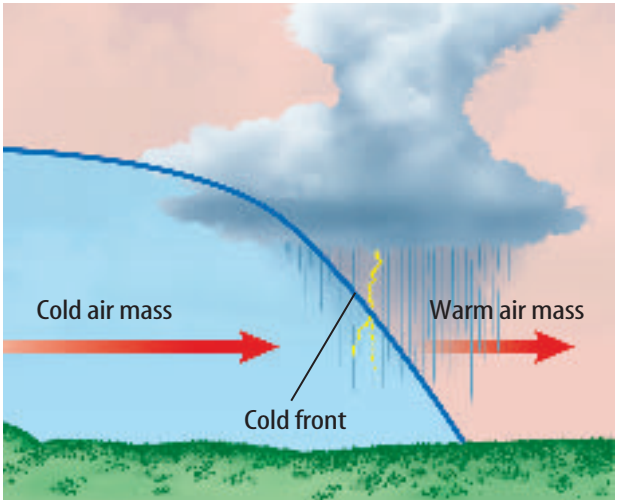
Science Online

Topic: Air Masses and Fronts

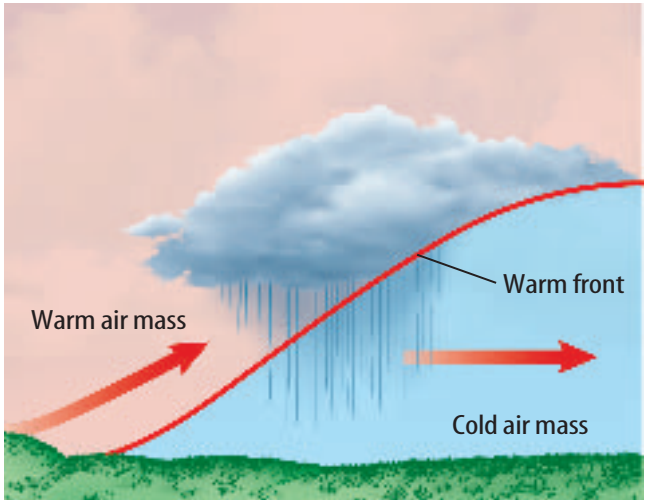
Visit red.msscience.com for Web links to information about air masses and fronts.

Activity Examine a current weather map. Identify any approaching fronts. Track the changes in temperature, pressure, precipitation, wind direction, and cloud cover as the front passes.

Figure 16 Cold and warm fronts always bring changes in the weather.



A cold front often produces short periods of storms with heavy precipitation. After the front passes, wind changes direction, skies begin to clear, and the temperature usually drops.



A warm front usually produces a long period of steady precipitation over a wide area. After the front passes, the sky clears, wind direction changes, and the temperature rises.

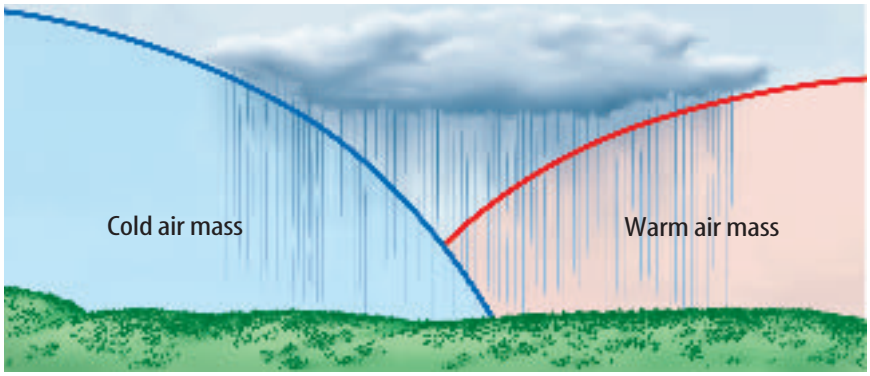


Figure 17 A stationary front can result in days of steady precipitation over the same area.

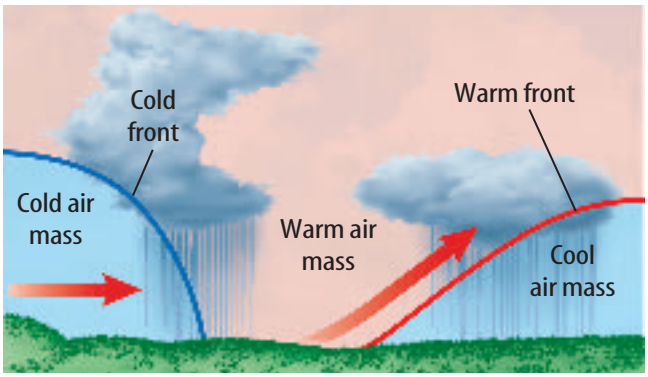
Stationary Fronts A stationary front, shown in **Figure 17,** is a front where a warm air mass and a cold air mass meet but neither advances. This kind of front can remain in the same location for several days. Cloudiness and precipitation occur along the front. Some precipitation can be heavy because the front moves so little.

Occluded Fronts **Figure 18** illustrates how an occluded front forms when a fast-moving cold front overtakes a slower warm front. Occluded fronts also form in other ways, but all types of occluded fronts can produce cloudy weather with precipitation.

High- and Low-Pressure Centers

In areas where pressure is high, air sinks. As it reaches the ground, it spreads outward away from the high-pressure center. As it spreads, the Coriolis effect turns the air in a clockwise direction in the northern hemisphere. Because the air is sinking, moisture cannot rise and condense, so air near a high-pressure center is usually dry with few clouds.

As air flows into a low-pressure center, it rises and cools. Eventually, the air reaches its dew point and the water vapor condenses, forming clouds and precipitation. Because of the Coriolis effect, air circulates in a counterclockwise direction in the northern hemisphere in a low-pressure center.



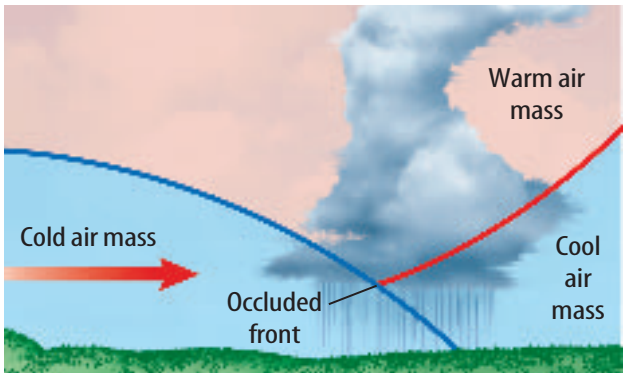


Figure 18 An occluded front produces weather similar to, but less severe than, the weather along a cold front.

Severe Weather

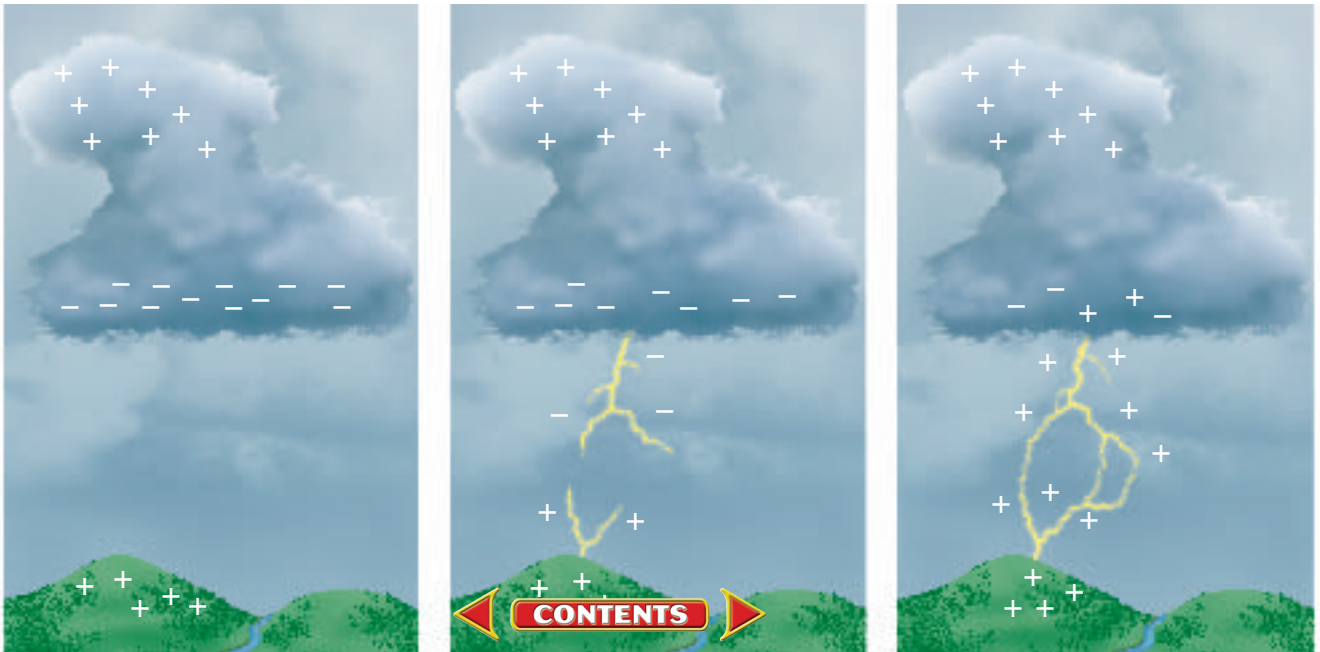
Severe weather causes strong winds and heavy precipitation. People can be injured and property can be damaged. How can you prepare for severe weather? To prepare, you must first understand it.

Thunderstorms Thunderstorms develop from cumulonimbus clouds. Recall that cumulonimbus clouds often form along cold fronts where air is forced rapidly upward, causing water droplets to form. Falling droplets collide with other droplets and grow bigger. As these large droplets fall, they cool the surrounding air, creating downdrafts that spread out at the surface. These are the strong winds associated with thunderstorms. Dangerous hail can develop in these storms.

Lightning and thunder also are created in cumulonimbus clouds. Where air uplifts rapidly, electric charges form, as shown in **Figure 19.** Lightning is the energy flow that occurs between areas of opposite electrical charge. A bolt of lightning can be five times hotter than the Sun's surface. Its extreme temperature heats the air nearby. The heated air expands faster than the speed of sound, which produces a sonic boom. This is the thunder that is heard after a lightning flash. Close to the lightning, the thunder sounds like a sharp bang. Farther away, the thunder is a dull rumble.

Reading Check *What causes thunder?*

Figure 19 During a thunderstorm, the bottom of the storm cloud has a negative charge. The ground has a positive charge. The negative charge rushes toward the ground. At the same time, the positive charge rushes toward the cloud.



Mini LAB

Creating a Low-Pressure Center

Procedure

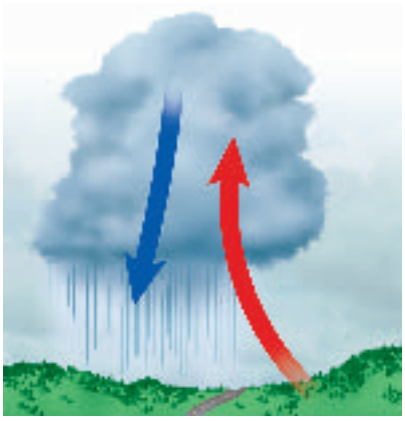
1. Fasten a **birthday candle** firmly to the bottom of a **pie pan or plate** with **clay.**
2. Fill a **tall, narrow jar** halfway with **water,** and pour the water into the pan or plate.
3. Light the candle. Invert the jar over the candle. Set the jar mouth down into the water and rest it on a **penny.**
4. In your **Science Journal,** write a brief description of what happens to the water level inside the jar when the candle goes out.

Analysis

1. Infer what happens to the air inside the jar when the candle is lit.
2. Infer what happens to air inside the jar when the candle goes out, and why water rises in the jar when this happens.

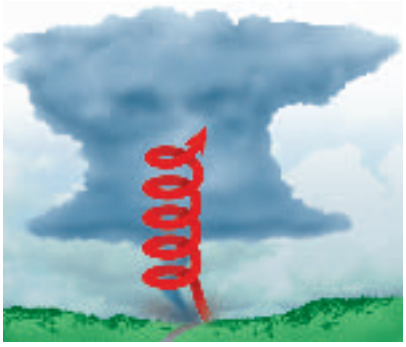
Tornadoes Along some frontal boundaries, cumulonimbus clouds create severe weather. If conditions are just right, updrafts of rising air can start to spin into a rotating vortex. This creates a funnel cloud. **Figure 20** shows the steps in the formation of a funnel cloud. If the funnel cloud reaches Earth's surface, it becomes a tornado like the one shown. A **tornado** is a violent, whirling wind that moves in a narrow path over land. Although tornadoes are usually less than 200 m in diameter, seldom travel on the ground for more than 10 km, and generally last less than 15 min, they are extremely destructive. The powerful updrafts into the low pressure in the center of a tornado act like a giant vacuum cleaner, sucking up anything in its path.

CLICK HERE



Strong updrafts and downdrafts develop within cumulonimbus clouds when warm, moist air meets cool, dry air.

Winds within the clouds cause air to spin faster and faster.

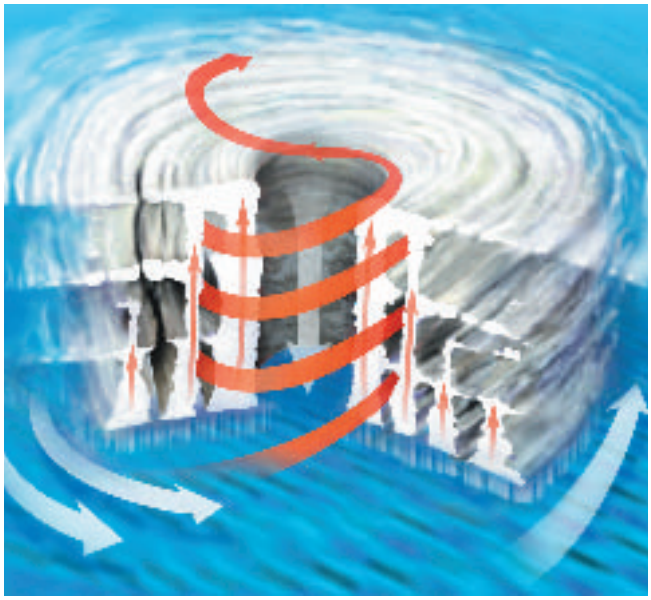


A funnel of spinning air drops downward through the base of the cloud toward the ground.

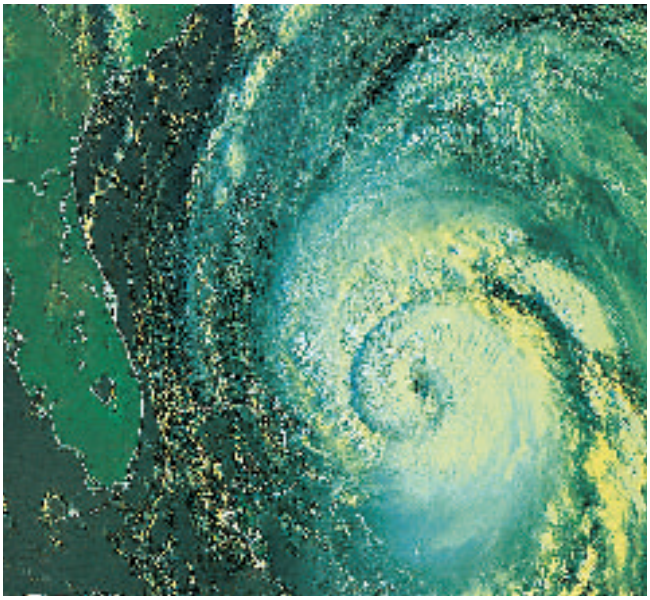
Figure 20 A tornado's winds can reach nearly 500 km/h, and it can move across the ground at speeds of up to 100 km/h.

Jim Zuckerman/CORBIS

Figure 21 Hurricanes begin as low-pressure areas over warm oceans.



Air circulation in a hurricane produces updrafts and downdrafts. The downdrafts prevent cloud formation, creating the calm eye of the storm.



As seen from a satellite, the swirling storm clouds of a hurricane are easy to spot.

Hurricanes

Unlike tornadoes, hurricanes can last for weeks and travel thousands of kilometers. The diameter of a hurricane can be up to 1,000 km. A **hurricane** is a large storm that begins as an area of low pressure over tropical oceans. The hurricanes that affect the East Coast and Gulf Coast of the United States often begin over the Atlantic Ocean west of Africa. Look at **Figure 21** as you read how a hurricane forms. The Coriolis effect causes winds to rotate counterclockwise around the center of the storm. As the storm moves, carried along by upper wind currents, it pulls in moisture. The heat energy from the moist air is converted to wind. When the winds reach 120 km/h, the low-pressure area is called a hurricane. The sustained winds in a hurricane can reach 250 km/h with gusts up to 300 km/h. **Figure 21** also shows a satellite photo of a hurricane over the ocean.

Sometimes a hurricane spends its entire existence at sea and is a danger only to ships. However, when a hurricane passes over land, high winds, tornadoes, heavy rains, and storm surge pound the affected region. Crops can be destroyed, land flooded, and people and animals killed or injured. After the storm begins traveling over land, however, it no longer has the warm, moist air to provide it with energy, and it begins losing power. Gradually, its winds decrease and the storm disappears.

Topic: Monitoring Hurricanes

Visit red.msscience.com for Web links to information about how meteorologists track and monitor hurricanes.

Activity Research the technology that is used to monitor hurricanes and predict where they might reach land. Make a poster with captions that shows how meteorologists use this technology.

Figure 22 These scientists are placing weather instruments in the path of a tornado. Their research helps forecasters better understand and predict tornadoes.

Weather Safety In the United States, the National Weather Service carefully monitors weather. Using technology such as Doppler radar, shown in **Figure 22,** as well as weather balloons, satellites, and computers, the position and strength of storms are watched constantly. Predicting the movement of storms is sometimes difficult because the conditions that affect them are always changing. If the National Weather Service believes conditions are right for severe weather to develop in a particular area, it issues a severe weather watch. If the severe weather already is occurring or has been indicated by radar, a warning is issued.

Watches and Warnings Watches and warnings are issued for severe thunderstorms, tornadoes, tropical storms, hurricanes, blizzards, and floods. Local radio and television stations announce watches and warnings, along with the National Weather Service's own radio network, called NOAA (NOH ah) Weather Radio.

The best preparation for severe weather is to understand how storms develop and to know what to do during watches and warnings. During a watch, stay tuned to a radio or television station and have a plan of action in case a warning is issued. If the National Weather Service does issue a warning, take immediate action to protect yourself.

section 3 review

Summary

Air Masses

- Air masses have the characteristics of the region where they developed.

Fronts

- Front types include cold, warm, stationary, and occluded.
- Precipitation often occurs along fronts.

High and Low Pressure Centers

- In the northern hemisphere, wind spirals clockwise around high pressure. It spirals counterclockwise around low-pressure regions.

Severe Weather

- If a severe weather warning is issued, take action to protect yourself.

Self Check

1. **Summarize** the characteristics of the four types of fronts.
2. **Explain** why thunderstorms often occur along cold fronts.
3. **Define** a severe weather watch and a severe weather warning.
4. **Explain** why technology is important for forecasting the weather.
5. **Think Critically** Why do southerly winds occur on the trailing side of a high pressure region?

Applying Math

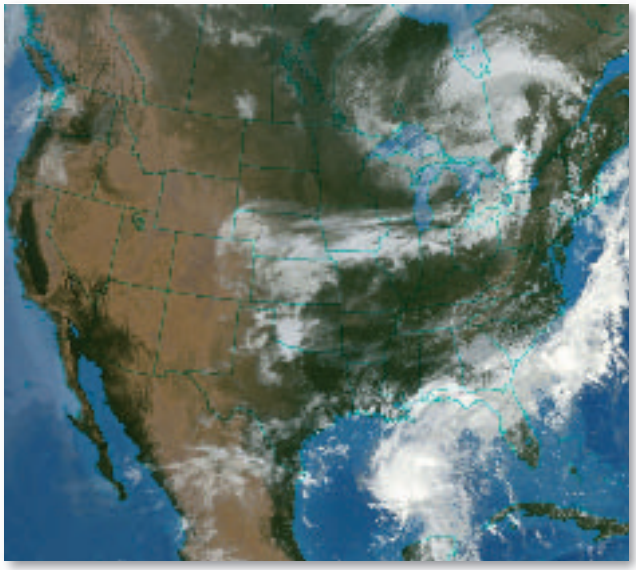
6. **Solve One-Step Equations** Calculate the average speed of a hurricane if it travels 3,500 km in nine days. What is the average speed of a tornado that travels 8 km in 10 min?

Howard Bluestein/Photo Researchers

LAB

Interpreting Satellite Images

Satellite images show clouds and weather systems across a large region. In this lab, you'll learn to interpret weather from a satellite image.



Real-World Question

What can you learn about the weather from satellite images?

Goals

- **Interpret** a satellite image.
- **Predict** future weather from the image.
- **Explain** the advantages of satellite technology for weather forecasting.

Materials

satellite image on this page

Procedure

1. Examine the satellite image shown on this page. Identify the color that represents clouds. What color is ocean water? Where is the United States in this image? Where is your state?
2. Describe which regions in the United States have clear skies. Which regions have cloud cover? How do you know?
3. Locate your town or city on the satellite image. What can you infer about the weather conditions at your location when this satellite image was made?

Conclude and Apply

1. **Identify** A tropical storm, named Bill, can be seen in this satellite image. Where is tropical storm Bill located? Which regions of the United States might be affected by this storm if it is moving toward the north? Will tropical storm watches and warnings be issued?
2. **Locate** A stationary front is causing some precipitation in the Midwest. Locate the stationary front on this map. How do you know its position? List some states that are receiving rainfall from this front. Which regions might receive rainfall tomorrow if the front is moving slowly toward the south?
3. **Observe** Find a region of low pressure in Canada. What shape can you see in the pattern of clouds?
4. **Explain** why satellite images are helpful for weather forecasters. What could you learn from the satellite image in today's newspaper?

CONTENTS

LAB

Design Your Own

CREATING YOUR OWN WEATHER STATION

Goals

- Use weather instruments for measuring air pressure, wind data, temperature, and precipitation.
- **Design** a weather station using your weather instruments.
- **Evaluate** current weather conditions and predict future conditions using your weather station.

Possible Materials

peanut butter jar
olive jar
permanent marker
metric ruler
meterstick
confetti
**shredded tissue paper*
wind vane
anemometer
compass
coffee can
barometer
thermometer
**Alternate materials*

Safety Precautions

Real-World Question

The weather can be very unpredictable. Being able to forecast severe weather such as thunderstorms, tornadoes, and flash floods can save property or lives. Weather stations use instruments to help predict weather patterns. Simple instruments that can be found in a weather station include thermometers for measuring temperature, barometers for observing changes in air pressure, anemometers for measuring wind speed, and rain gauges for measuring precipitation. How can you use weather instruments and design your own weather station to monitor and predict weather conditions?

Form a Hypothesis

Based on your reading in the text and your own experiences with the weather, form a hypothesis about how accurately you could predict future weather conditions using the weather instruments in your weather station.

Test Your Hypothesis

Make a Plan

1. **Decide** on the materials you will need to construct a rain gauge. A wide mouth jar is best for rain, and a small, tall jar is best for accurately measuring the rain collected in the larger jar. Decide how you will mark your jars to measure centimeters of rainfall.
2. To measure wind speed you can use an anemometer or you can make a wind-speed scale. Lightweight materials can be dropped from a specific height, and the distance the wind carries them can be measured with a meterstick. A compass can be used to determine wind direction. A wind vane also can be used to determine wind direction.
3. **Decide** where you will place your thermometer. Avoid placing it in direct sunlight.
4. **Decide** where you will place your barometer.

Doug Martin
CONTENTS

5. Prepare a data table in your Science Journal or on a computer to record your observations.
6. **Describe** how you will use your weather instruments to evaluate current weather conditions and predict future conditions.

Follow Your Plan

1. Ask your teacher to examine your plans and your data table before you start.
2. **Assemble** your weather instruments.
3. Use the weather instruments to monitor weather conditions for several days and to predict future weather conditions.
4. **Record** your weather data.

Analyze Your Data

1. **Compare** your weather data with those given on the nightly news or in the newspaper.
2. How well did your weather equipment measure current weather conditions?
3. How accurate were your weather predictions?
4. **Compare** your barometer readings with the dates it rained in your area. What can you conclude?

Conclude and Apply

1. **Determine** Did the results of your experiment support your hypothesis?
2. **Identify** ways your weather instruments could be improved for greater accuracy.
3. **Predict** how accurate your weather predictions would be if you used your instruments for a year.

Communicating Your Data

Post your weather forecast each day. How does your forecast compare to those of other students? Discuss any differences.

How Zoos Prepare for Hurricanes

Humans aren't the only ones to take cover when hurricanes strike

As you step into the rest room, you notice a crunch under your feet. When you look up expecting to see sinks and stalls, you see a flock of pink flamingos standing on a bed of straw. What's going on here?

The Miami Metrozoo is preparing for a hurricane, which means herding all of the flamingos into the shelter of the rest room. Why so much fuss?

In 1992, the Metrozoo was devastated by Hurricane Andrew, which killed five mammals and 50 to 75 birds. The zoo, along with many other Florida zoos, has since been forced to rethink how it gets ready for a hurricane and how to deal with its residents after the storm blows over.

Flamingos are herded into the zoo's rest room for safety.

Before the Storm

Where do the animals go before a storm at Metrozoo? The lions, tigers, bears, and monkeys are kept in their solid, strong, concrete overnight pens. Poisonous snakes must be bagged because it could be disastrous if they escaped. Other small animals are put into whatever containers can be found, including dog carriers and shipping crates. Some animals are shipped to warehouses or to other zoos that can care for them and are out of the hurricane's path.

Some animals can trust their instincts to tell them what to do. Larger animals may be given the option of coming under shelter or staying out and braving the storm. According to a spokesperson from Seaworld, "The killer whales stay under water longer," which is what they would do in the wild.

Even after the animals are locked up tight, zookeepers worry that the animals could be hurt psychologically by the storm. After Hurricane Andrew, some frightened animals were running around after the storm or just sitting alone. For many zookeepers, the most frustrating thing is being unable to go to an animal and hold it and say, "It's going to be okay."

Make a List List animal safety tips in case of severe weather in your area. What should you have on hand to keep your pets safe? What should you do with your pets during a weather disaster? If you live on a farm, how can you keep the livestock safe?

ScienceOnline
For more information, visit red.msscience.com/time

Ron Magill/Miami Metrozoo

Reviewing Main Ideas

Section 1 The Atmosphere

1. The atmosphere is made of gases, liquids, and solids.
2. The troposphere is warmest near the surface and grows cooler with height. Above the troposphere are four additional layers of the atmosphere, each with different characteristics.
3. Water circulates between Earth's surface and the atmosphere in the water cycle.

Section 2 Earth's Weather

1. Conduction and convection are two ways that heat is distributed on Earth.
2. Precipitation occurs when droplets or ice crystals become too heavy to be supported by the air.
3. Wind is air molecules moving from high-pressure centers to low-pressure centers.

Section 3 Air Masses and Fronts

1. Air masses are dry or moist and warm or cool, depending on where they originate.
2. Fronts develop where air masses of different temperatures collide, forming a boundary. The four kinds of fronts are cold, warm, stationary, and occluded.
3. Severe weather develops from low-pressure centers. Thunderstorms and tornadoes often form near fronts. Hurricanes develop from lows over tropical waters.
4. Knowing what to do when weather watch and warning advisories are made can save your life.

Visualizing Main Ideas

Copy and complete the following concept map about air masses and fronts.

chapter 12 Review

Using Vocabulary

aerosol p. 343
air mass p. 356
atmosphere p. 342
dew point p. 350
front p. 357
humidity p. 350
hurricane p. 361
precipitation p. 352
relative humidity p. 350
tornado p. 360
troposphere p. 344
water cycle p. 347
weather p. 348

Fill in the blanks with the correct word or words.

1. The _____ describes the current condition of the atmosphere.

2. The boundary between different air masses is called a(n) _____.

3. A(n) _____ is a violent, whirling wind that forms over land.

4. Dust, salt, pollen, and acid droplets in the atmosphere are called _____.

5. A large body of air that develops over a particular region of Earth's surface is called a(n) _____.

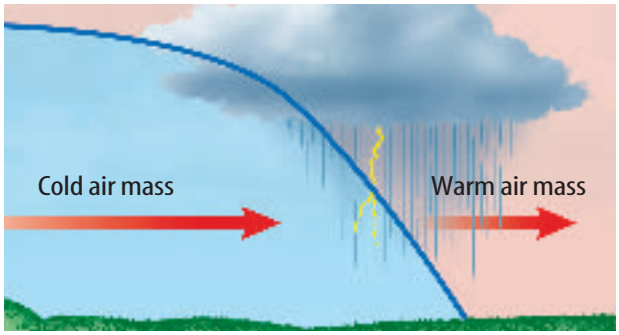
Checking Concepts

6. Which layer of Earth's atmosphere contains the ozone that protects living things from too much ultraviolet radiation?
A) thermosphere **C)** stratosphere
B) ionosphere **D)** troposphere

7. Air at 30°C can hold 32 g of water vapor per cubic meter of air. If the air is holding 16 g of water vapor, what is the relative humidity?
A) 15 percent **C)** 50 percent
B) 30 percent **D)** 100 percent

8. Which atmospheric layer is farthest from Earth's surface?
A) troposphere **C)** stratosphere
B) exosphere **D)** ionosphere

Use the illustration below to answer question 9.



9. Which type of front is shown above?
A) warm **C)** cold
B) stationary **D)** occluded

10. What causes low-pressure centers to rotate counterclockwise in the northern hemisphere?
A) trade winds
B) prevailing westerlies
C) Coriolis effect
D) jet stream

11. Who first proved that air has weight?
A) Robert Hooke
B) Evangelista Torricelli
C) Robert Boyle
D) Galileo Galilei

12. Which step in the water cycle occurs when water vapor changes to liquid water?
A) condensation **C)** precipitation
B) evaporation **D)** transpiration

13. What kind of cloud touches the ground?
A) altostratus **C)** stratocumulus
B) stratocirrus **D)** fog

14. Which occurs when colliding molecules transfer energy?
A) precipitation **C)** radiation
B) conduction **D)** convection

15. What occurs when strong winds toss ice crystals up and down within a cloud?
A) rain **C)** snow
B) freezing rain **D)** hail

Thinking Critically

16. **Explain** why hurricanes are dangerous to people.

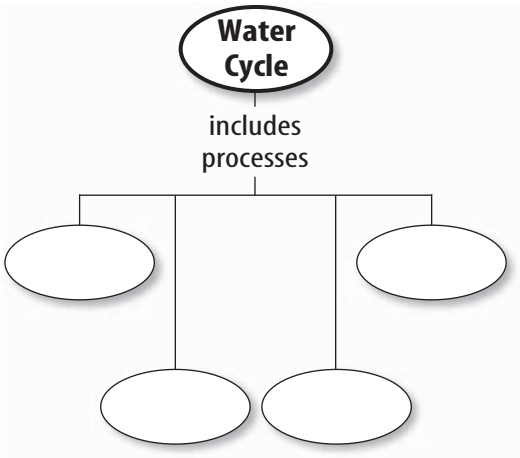
17. **Infer** why air pressure is higher at sea level than on top of a mountain.

18. **Compare and contrast** condensation and precipitation.

19. **Describe** what happens to gas molecules when air is heated.

20. **Recognize Cause and Effect** How can a cloud produce both rain and hail?

21. **Concept Map** Copy and complete the concept map of the water cycle below.



22. **Classify** You observe a tall, dark, puffy cloud. Rain is falling from its lower surface. How would you classify this cloud?

23. **Use Scientific Explanations** Explain why thunder is heard after a flash of lightning.

24. **Venn Diagram** Make a Venn diagram to compare and contrast tornadoes and hurricanes.

25. **Research Information** Do research to learn how sleet forms. Write a paragraph about sleet in your Science Journal.

Performance Activities

26. **Pamphlet** Research three destructive hurricanes and make a pamphlet using the information you collect. Discuss the paths the hurricanes took, how fast they moved, and the damage they caused.

27. **Oral Presentation** Imagine that you work for a television network. Prepare a weather advisory message and announce your watch or warning to the class. Discuss what actions people should take to stay safe.

28. **Poem** Write a poem about the water cycle. Display your poem with those of your classmates on a decorated bulletin board.

Applying Math

Use the equations below to answer questions 29–33.

$$°F = 9/5°C + 32$$
$$°C = 5/9(°F - 32)$$

29. **A Hot Summer Day** The Sun is shining and the temperature is a sweltering 95°F. What is the temperature in degrees Celsius?

30. **A Frigid Winter Morning** The thermometer shows a temperature of −10°C. What's the temperature in degrees Fahrenheit?

31. **A Pleasant Day** A gentle breeze is blowing and the temperature is a comfortable 78°F. What's the temperature in degrees Celsius?

32. **Record Cold** The coldest temperature recorded on Earth occurred at Vostok, Antarctica on July 21, 1983. It was −89.4°C. What was the temperature in degrees Fahrenheit?

33. **Record Heat** The hottest temperature occurred in El Azizia, Libya on September 13, 1922. A scorching 136°F was recorded. What was the temperature in degrees Celsius?

Part 1 Multiple Choice

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

Use the table below to answer questions 1 and 2.

Layers of the Atmosphere

Thermosphere	Filters out gamma rays
Ionosphere	Reflects AM radio waves
Mesosphere	Contains little ozone
Stratosphere	UV radiation-absorbing ozone
Troposphere	Contains most clouds

1. In which layer does Earth's atmosphere absorb most of the Sun's UV radiation?
- **A.** troposphere
- **B.** stratosphere
- **C.** mesosphere
- **D.** thermosphere

2. Solar radiation causes ions to continually form in Earth's ionosphere. Which has been one of the greatest benefits of ions in the ionosphere?
- **A.** They reflect radio waves.
- **B.** They absorb ozone.
- **C.** They filter out gamma rays.
- **D.** They form rain clouds.

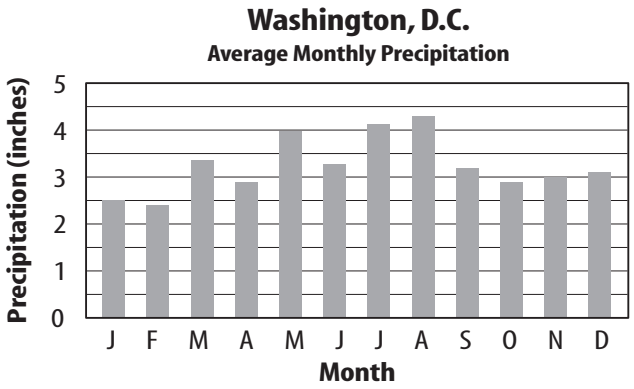
3. Which of the following is the most abundant gas found in the atmosphere?
- **A.** oxygen
- **B.** nitrogen
- **C.** helium
- **D.** hydrogen

Test-Taking Tip

Check Your Answers Never leave any answer blank.

4. Which of the following describes a stationary front?
- **A.** A front formed when warm air advances into a region of colder air.
- **B.** A front formed when a fast-moving cold front overtakes a slower warm front.
- **C.** A front formed when a warm air mass and a cold air mass meet but neither advances.
- **D.** A front formed when a cold air mass advances and pushes under a warm air mass.

Use the graph below to answer question 5.



5. During which month did Washington, D.C. receive the most precipitation?
- **A.** May
- **B.** June
- **C.** July
- **D.** August

6. Which of the following describes humidity?
- **A.** The measure of the amount of water vapor that is present compared to the amount that could be held at a specific temperature.
- **B.** The amount of water vapor in the atmosphere.
- **C.** The temperature at which air is saturated and condensation occurs.
- **D.** The current condition of the atmosphere.

Part 2 Short Response/Grid In

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

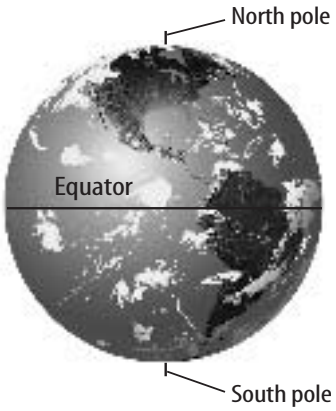
7. By what processes does water return to atmosphere after precipitation occurs?

8. How does temperature affect the amount of water vapor air can hold?

9. Describe how clouds form.

10. Air moves from an area of high pressure to an area of low pressure. The wind created by this moves 78 km in 2.5 h. What is the wind speed?

Use the figure below to answer question 11.



11. Copy the diagram of Earth on a separate sheet of paper. Add labels to the diagram indicating which areas have a heat gain and which areas experience a heat loss. Why does this imbalance occur? Explain what happens to air flow as a result of this heat imbalance? Add arrow labels that indicate where air flows.

12. Your area is experiencing a thunderstorm. What kind of clouds are producing the storm?

13. What are the four main types of precipitation? Describe the differences between each type.

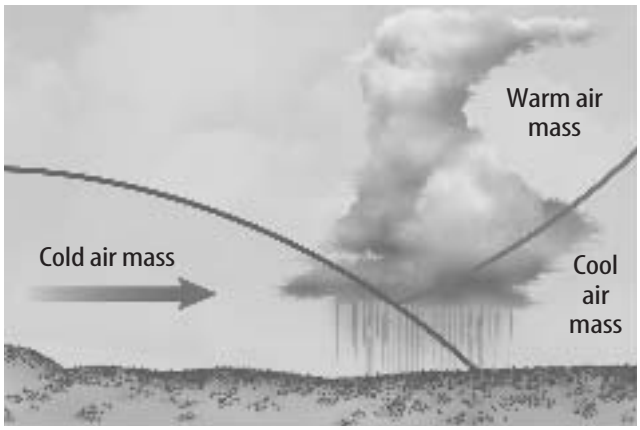
Part 3 Open Ended

Record your answers on a sheet of paper.

14. What are aerosols? Explain how the different aerosols—dust, salt, and pollen—enter the atmosphere.

15. Explain how the trade winds are created.

Use the figure below to answer question 16.



16. What type of front is shown here? How does this type of front form? What kind of weather does this type of front create?

17. Summarize how a tornado forms.

18. Can you have thunder without lightning? Explain why or why not.

19. The morning weather forecast indicates that a cold front is moving toward your area. The current temperature is about 27°C. Predict what changes will occur in the weather as a result of this front.

20. What are weather satellites? How do they help weather forecasters predict the weather?

21. Hurricanes can be dangerous to people and can cause a high amount of property damage when they reach land. Explain why hurricanes are so dangerous and destructive.