11.3 Weather Patterns

We can learn about today's or tomorrow's weather by listening to a *meteorologist*—a person who forecasts the weather. You can also find out about weather on your own by looking at clouds in the sky and by taking your own weather data. Read on to find out more about weather and storms.

VOCABULARY

front - the border between two different air masses.

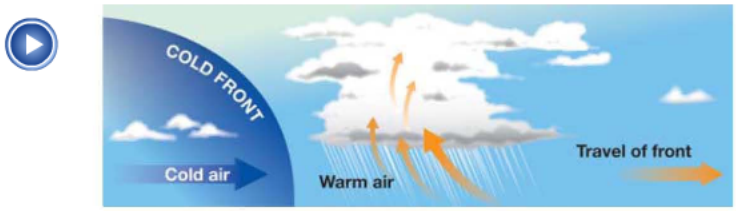
cold front - a front that occurs when a cold air mass moves in and replaces a warm air mass.

Fronts

Large bodies of air Air masses form when air is stationary over an area long enough to take on the characteristics of the surface below. Two common air masses affecting the United States are the *continental polar air mass*, which forms over the Canadian plains, and the *maritime tropical air mass*, which forms over the Gulf of Mexico (Figure 11.17). The continental polar air mass contains cold, dry air. In contrast, the maritime tropical air mass contains warm, moist air.

Moving air and fronts Changing atmospheric conditions and global wind currents cause air masses to move. The continental polar air mass tends to slide south or southeast, while the maritime tropical air mass tends to slide north or northwest. When two different moving air masses collide, the border between them is called a **front**.

Cold fronts A **cold front** occurs when cold air moves in and replaces warm air. The warm air is forced sharply upward by the cold, denser air. The rising warm air cools. This causes condensation. Often, rain or snow showers that can be shorter in duration but intense, accompany a cold front. As a cold front moves through an area, the temperature and water content of the air decrease rapidly. The temperature can sometimes cool as much as 15°F in one hour.



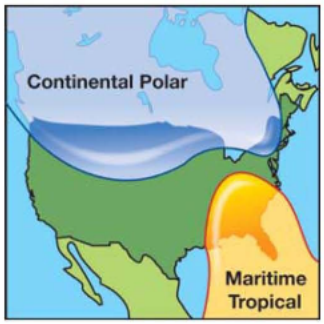


Figure 11.17: *Two air masses that affect the weather in the United States.*

Warm fronts A **warm front** occurs when warm air moves in and replaces cold air. The warm air slides up over the colder air. The warm air rises and cools, but in this case the lifting is very gradual and steady. As a result, long bands of light precipitation often move ahead of a warm front. As a warm front moves through an area, there will be a noticeable increase in temperature and moisture in the air.

Jet streams High-altitude, fast-moving winds are called **jet streams**. There are two big jet streams in each hemisphere, formed where there are sharp boundaries between cold and warm temperatures. A jet stream acts as a border between cold and warm air masses. When the jet stream changes its path, air masses to either side of it tend to move too.

Speed and path of a jet stream The jet stream winds are found near the top of the troposphere, and have speeds of at least 87 kilometers (54 miles) per hour, and sometimes as great as 320 kilometers (200 miles) per hour. The jet streams flow around the globe from west to east. A jet stream attains its fastest speeds during the winter of its hemisphere when the temperature difference between that pole and the equator is greatest. The path and speed of a jet stream can be altered by land features such as mountain ranges, or by giant cumulus clouds that act like boulders in a rushing river.

VOCABULARY

warm front - a front that occurs when a warm air mass moves in and replaces a cold air mass.

jet streams - high-altitude, fast-moving winds.

Weather Map Symbols for Fronts

On a weather map, a cold front is shown using a line marked with blue triangles. The triangles point in the direction the front is moving. A warm front is shown using a line marked with red semicircles, which point in the direction the front is moving.

Low- and high-pressure areas

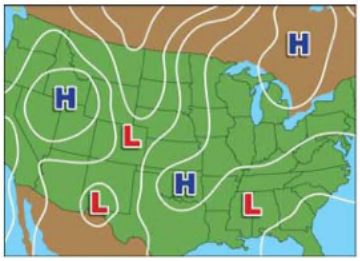
Low-pressure centers

When a cold front moves into a region and warm air is forced upward, a **low-pressure center** is created near Earth's surface at the boundary of two air masses (Figure 11.18). Cold air rushes in to fill that low-pressure region. This cold air forces more warm air to be pushed upward. A cycle begins to develop. Due to the Coriolis effect, the air masses move in curved paths. As a result, the moving air begins to rotate around the low-pressure center (Figure 11.18). In the northern hemisphere, the moving air rotates counterclockwise, while in the southern hemisphere, the air rotates clockwise. Strong winds and precipitation often accompany these rotating systems.

High-pressure centers

A **high-pressure center** tends to be found where a stable, colder air mass has settled in a region. Colder air is denser than warm air, and therefore creates higher atmospheric pressure. Sinking air in a high-pressure center inhibits the development of the upward air movement needed to create clouds and precipitation. High-pressure centers, therefore, are associated with fair weather and blue skies. Winds rotate clockwise in the northern hemisphere and counterclockwise in the southern hemisphere. This is the opposite of what happens in a low-pressure center.

Isobars



The wavy lines on a weather map are often associated with high- (H) and low- (L) pressure centers. Each line, called an **isobar**, connects the places that have the same atmospheric pressure. Isobars help meteorologists pinpoint the location of high- and low-pressure centers, and provide information about the movement of weather systems.

VOCABULARY

low-pressure center - a low-pressure area created by rising warm air.

high-pressure center - a high-pressure area created by sinking cold air.

isobar - a line on a weather map that connects places that have the same atmospheric pressure.

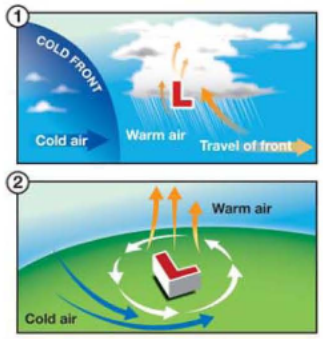


Figure 11.18: *(1) Warm air is forced upward when a cold front moves into an area. A low-pressure center is created. (2) The cold air moving toward the low-pressure center begins to rotate around it in a counterclockwise direction.*

Clouds

What is a cloud? When more water in the atmosphere is condensing than evaporating, we begin to see *clouds*. A **cloud** is a group of water droplets or ice crystals that you can see in the atmosphere. The flat bottom of the cloud marks the level of the atmosphere where condensation first exceeds evaporation (when the dewpoint has been reached). Clouds are divided into two broad categories: cumuliform clouds (*cumulus* means "piled up") and stratiform clouds (*stratus* means "layer").

Cumuliform clouds *Cumuliform clouds*, which look like heaps of popcorn, form as an air mass rises because of convection (Figure 11.19). Air is commonly warmed over a dark surface (like a road) that absorbs a lot of heat. It is rare to see a line of these clouds right above a dark surface though, because wind currents blow the rising air masses around before they condense and form clouds.

Cirrocumulus: Small, puffy, "cotton ball" type clouds high in the atmosphere (above 6,000 meters) are called *cirrocumulus*. They usually indicate fair weather.

Altocumulus: *Altocumulus clouds* form between 2,000 and 6,000 meters high. They usually form larger, darker puffs than cirrocumulus clouds. Sometimes they appear in rows. If the altocumulus clouds look like towers, they are called *altocumulus castellatus*. These clouds often appear before a storm.

Cumulus: *Cumulus clouds* are the tall, puffy clouds that form when the air over land is heated. As a result, these clouds often break down as the Sun sets. Often, cumulus clouds have a flat base. They are found below 2,000 meters.

Cumulonimbus: A dark and stormy cumulus cloud is called *cumulonimbus*. Thunderstorms develop from cumulonimbus clouds. These clouds are between 2,000 and 15,000 meters high.

VOCABULARY

cloud - a group of water droplets or ice crystals that you can see in the atmosphere.

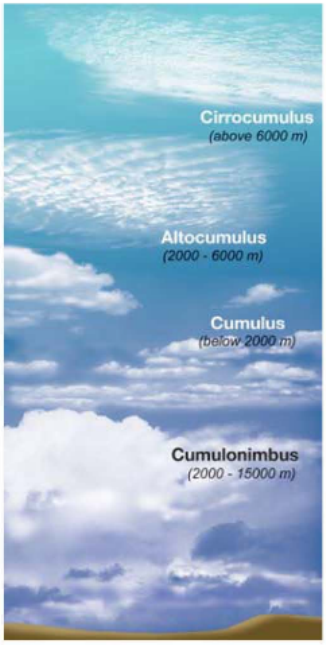


Figure 11.19: *Cumuliform clouds.*

Stratiform clouds

Stratiform clouds form when a large mass of stable air gradually rises. As this air rises, it expands and cools, allowing condensation to spread evenly throughout the layer. Stratiform clouds look like smooth, flattened blankets (Figure 11.20). They can cover as much as 300,000 square miles! A sky with stratiform clouds appears uniformly gray.

Cirrostratus: *Cirrostratus clouds* look like a translucent white coating across the sky. They are high clouds, located at least 6,000 meters above the ground. These clouds are made of ice crystals. As a result, sunlight shining through the crystals is refracted (bent) causing a halo-like effect around the Sun.

Altostratus: *Altostratus clouds* are the most easily recognizable stratiform clouds. If the sky looks like a smooth gray sheet and no shadows form on the ground, you are seeing altostratus clouds located between 2,000 and 6,000 meters high.

Stratus: *Stratus clouds* form below 2,000 meters. Stratus clouds look like fog that doesn't quite reach the ground.

Nimbostratus: When a stratus cloud turns dark gray, it signals the approach of rain. These rain clouds are called *nimbostratus*.

Figure 11.20: *Stratiform clouds.*

Stratocumulus clouds

Stratocumulus clouds have aspects of both cumuliform and stratiform clouds (Figure 11.21). They form when convection occurs inside a stratiform cloud. As rising air cools, the water in the cloud condenses, creating a cumuliform cloud within the stratiform cloud. This causes the smooth cloud to look lumpy.

Figure 11.21: *Stratocumulus clouds.*

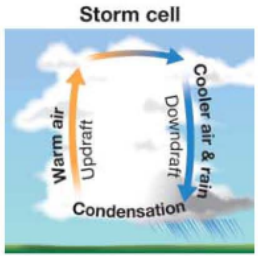
Cirrus clouds

Cirrus clouds are thin lines of ice crystals high in the sky, above 6,000 meters (Figure 11.22). A curved cirrus cloud is commonly called a "mare's tail." The curving is due to a change in wind direction, and might indicate that the weather is going to change.

Figure 11.22: *Cirrus clouds.*

Thunderstorms

Storm cells Thunderstorms occur because of convection in the atmosphere. Warm air rises from the ground to the top of the troposphere. This is called an *updraft*. As the updraft rises, it cools and condenses. This condensation releases heat, which warms the surrounding air, allowing it to rise and condense. This process forms a towering cumulonimbus cloud. Eventually, some of the cloud droplets become large enough to fall as rain. Cold air from the top of the troposphere is dragged down along with the rain. This cold, dense air is called a *downdraft*. The downdraft and updraft form a type of convection cell called a **storm cell** within the cloud (see diagram at right). A storm ends when cool air from the downdraft replaces all the warm air on the ground. The updraft stops flowing. Next, the rain stops and the thunderstorm ends.



Lightning and thunder **Lightning** is a bright spark of light that occurs within a storm cloud, between a cloud and Earth's surface, or between two storm clouds. Lightning occurs when the bottom of a storm cloud becomes negatively charged (–) and the top becomes positively charged (+). The negative charges on the bottom of the cloud repel negative charges on the ground so the ground becomes positive (Figure 11.23). In this situation, a spark can travel between the negatively and positively charged surfaces. **Thunder** is the sound we hear that is associated with lightning. Thunder is caused by the rapid heating and expanding of air that is near lightning.

Hail *Hail* is a form of precipitation consisting of chunks or balls of ice called hailstones. Hail forms in very tall thunderstorm clouds that have strong updrafts, where part of the cloud is below freezing (0°C), and when water droplets freeze on contact with dust particles. The hailstones are carried upward in the updraft and fall back down in the downdraft of the storm, gaining a layer of ice in each cycle. When hailstones become too heavy to be carried up by the storm's updraft, they fall out of the cloud to the ground.

VOCABULARY

storm cell - a convection cell within a cloud that is associated with a storm.

lightning - a bright spark of light that occurs inside a storm cloud, between a cloud and Earth's surface, or between two clouds.

thunder - a sound that occurs when a lightning spark heats and expands air.

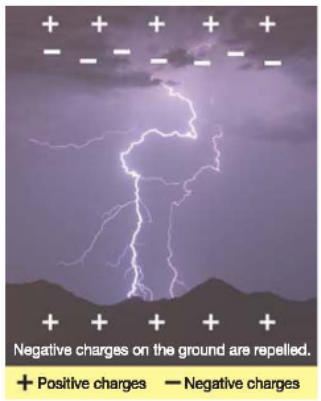


Figure 11.23: *Lightning occurs when a spark travels between negative and positive charges.*

Hurricanes

Cyclones and hurricanes

A **cyclone** is a low-pressure center that is surrounded by rotating winds. The Coriolis effect causes these winds to rotate counterclockwise in the northern hemisphere and clockwise in the southern hemisphere. A **hurricane** is a tropical cyclone with wind speeds of at least 119 kilometers (74 miles) per hour. The Saffir-Simpson Hurricane Scale is one scale used for rating hurricanes (Figure 11.24).

VOCABULARY

cyclone - a low-pressure center surrounded by rotating winds.

hurricane - a tropical cyclone with wind speeds of at least 119 kilometers per hour.

How hurricanes form

Warm, moist air over the tropical ocean provides the initial energy source for a hurricane. As the warm air rises, the water vapor in it condenses. Clouds and thundershowers form. The condensation releases heat, warming the surrounding air even more. As all of this air expands and rises, it creates an area of low pressure at the surface of the water. This pressure difference causes the surrounding air to rush toward the center. The path of this rushing air curves because of the Coriolis effect, and a rotating system forms.

Hurricane conditions

Image courtesy of NOAA

On August 28, 2005, Katrina, one of the deadliest hurricanes on record, became a category 5 hurricane (photo, left). Several conditions must be present for a rotating system to become a hurricane. First, the ocean water must be warm (about 27°C). Second, the layer of warm ocean water must be deep enough so that cooler water does not get stirred up to the surface by the storm. Cooler water decreases the strength of the storm. Next, the air must be warm and moist to a point high above sea level. Water vapor from high-level air is pulled into the storm. When it condenses, heat is released, and the storm strengthens. Finally, the wind conditions must also be just right. The storm breaks apart when the source of warm, moist air is removed, mostly by moving over land.

Saffir-Simpson Hurricane Scale

Name	Wind Speed	Damage	Storm Surge
Tropical depression	< 63 km/h	Little	None
Tropical storm	63–117 km/h	Minor flooding	Very minor
Category 1 hurricane	119–153 km/h	Minimal damage	1.2–1.5 m
Category 2 hurricane	154–177 km/h	Moderate	1.6–2.4 m
Category 3 hurricane	178–209 km/h	Extensive	2.5–3.7 m
Category 4 hurricane	210–249 km/h	Extreme	3.8–5.5 m
Category 5 hurricane	> 250 km/h	Catastrophic	> 5.6 m

km/h = kilometers per hour

Figure 11.24: *The Saffir-Simpson Hurricane Scale.*

Tornadoes

Comparing hurricanes and tornadoes

A **tornado**, like a hurricane, is a system of rotating winds around a low-pressure center. An average tornado is less than 200 meters in diameter—tiny, compared with the 640 kilometer (640,000 meter) average diameter of a hurricane! However, the wind speeds of a tornado are much greater than those of a hurricane. A tornado's wind speed can reach 400 kilometers per hour.

How tornadoes form

A tornado begins to form when the updrafts in a storm cell reach more than 160 kilometers per hour. Winds near the top of the cumulonimbus cloud begin rotating at a high speed. As more air flows into the low-pressure center of the storm, the rotation extends downward. The diameter of the rotating wind pattern narrows, causing the wind to speed up. As the rotating wind pattern narrows and lengthens, it forms a *funnel cloud* (Figure 11.25). If the funnel cloud reaches the ground, it becomes a tornado.

High wind speeds cause damage

The rushing wind of a tornado can flatten houses and even lift cars completely off the ground. A tornado in Broken Bow, Oklahoma once carried a motel sign 48 kilometers and dropped it in Arkansas! Most tornadoes last around 10 to 20 minutes, although the strongest tornadoes can last an hour or more. They travel along the ground at speeds of about 40 to 60 kilometers per hour.

Photo courtesy of NOAA/OAR/ERL/NSSL

VOCABULARY

tornado - a system of rotating winds around a low-pressure center; a tornado is smaller than a hurricane, but has faster winds.

How a Funnel Cloud Forms

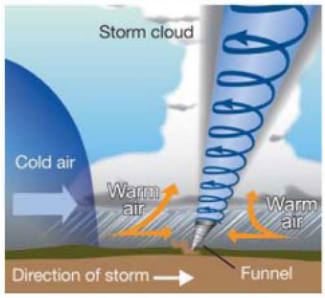
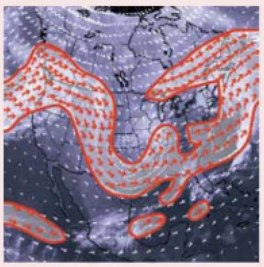


Figure 11.25: *A funnel cloud forms when updrafts in a storm cell reach high speed and begin to rotate. As the diameter of the rotation narrows and extends downward, a funnel cloud takes shape.*

Section 11.3 Review

1. How is the weather associated with a cold front different from the weather associated with a warm front?
2. What are jet streams and where do they form?
3. Indicate which characteristics below apply to a high-pressure center and which apply to a low-pressure center.
   a. rising warm air
   b. sinking cold air
   c. wind rotates counterclockwise around this pressure center in the northern hemisphere
   d. precipitation
   e. dry and clear
4. Name one type of cloud you would expect to see on a day when the weather is cool, dry, and clear. Name one type of cloud you would expect to see if a thunderstorm were about to happen.
5. Which kind of cloud has the characteristics of both cumuliform and stratiform clouds? Describe this cloud.
6. How is convection of air involved in the development of a thunderstorm?
7. What conditions are necessary for hail to form?
8. What conditions are needed for a hurricane to develop?
9. List three differences between a hurricane and a tornado.
10. On the Saffir-Simpson Hurricane Scale, what is the difference between a Category 1 hurricane and a Category 5 hurricane?

CHALLENGE



This photo of the jet stream was taken by the GOES-8 satellite in orbit 36,000 kilometers above Earth. Arrows were added to indicate wind direction. Research one important aspect of the jet stream and write a short report about what you learn.

SOLVE IT!

When Hurricane Andrew hit Florida in 1992, its winds were 265 km/h and it produced a storm surge of 5.2 meters. What category was Hurricane Andrew on the Saffir-Simpson Scale?

Research the answer to the following question. How does Hurricane Katrina, which hit New Orleans in 2005, compare to Hurricane Andrew?