6.2 Weather Patterns

As you have learned, our weather is part of Earth's atmosphere. We can learn about today's or tomorrow's weather by listening to a meteorologist. You can also find out about weather on your own by looking at clouds in the sky and by taking your own weather data. This section is all about observing weather patterns.

Meteorology

What is a meteorologist?

A **meteorologist** is a person who uses scientific principles to explain, understand, observe, or forecast Earth's weather. Many meteorologists have college degrees in physics, chemistry, or mathematics. Radio and television weathercasters are often professional meteorologists.

Tools used by meteorologists to help people

Meteorologists use satellite and computer technology to inform people about the weather. For example, meteorologists can use data to predict hurricanes. Before 1960, a hurricane could hit without warning. Since 1960, weather satellites have helped predict and track hurricanes. Figure 6.6 shows a satellite image of Hurricane Hugo about to make landfall on the coast of South Carolina in 1989. Government organizations like the National Hurricane Center (NHC) monitor storms that might become hurricanes. The NHC issues hurricane watches and warnings so that people can evacuate a threatened area.

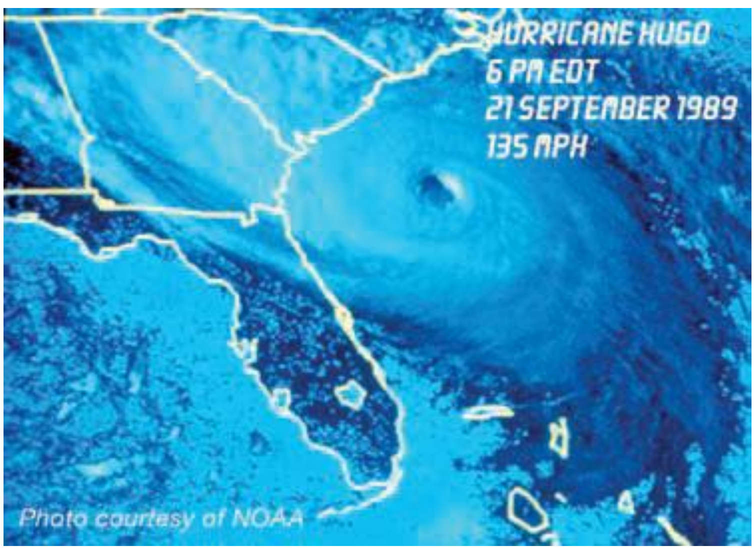


Figure 6.6: *A weather satellite image of Hurricane Hugo making landfall on the coast of South Carolina in 1989.*

Water in the atmosphere

Water in the atmosphere

Rain, snow, sleet, and hail occur because water exists in the atmosphere. Even when the skies are blue, there is water present. The amount varies from just 0.1 percent in the atmosphere above Antarctica to as much as 3 percent above a tropical rainforest.

Three phases of water in the atmosphere

Water in the atmosphere exists in all three phases (solid, liquid, and gas). Ice crystals occur high in the troposphere. Tiny water droplets, much too small to see, are suspended throughout the troposphere virtually all the time. They are considered liquid water and not gas because they are made of microscopic "clumps" of water molecules. Water in the atmosphere also occurs as water vapor— water in the gas phase.

Temperature and pressure

As temperature *increases*, the rate of evaporation *increases* (Figure 6.7). Higher temperatures cause the liquid water molecules to move fast so they have enough energy to break free of their bonds with each other. These water molecules become water vapor in the atmosphere. In contrast, as atmospheric pressure *increases*, the rate of evaporation *decreases* (Figure 6.7). This is because the pressure makes it harder for water molecules to escape from the liquid to the gas phase.

Dew point

Both condensation and evaporation occur in the atmosphere all the time. However, each process may happen at different rates. When the rate of evaporation is greater than the rate of condensation, we see clearing skies. When the rate of condensation exceeds the rate of evaporation, we say that the air's **dew point** has been reached. This is the temperature at which more water vapor is condensing than evaporating in an air mass. The water in the air mass is getting colder, slowing down, and forming "dew" or droplets.

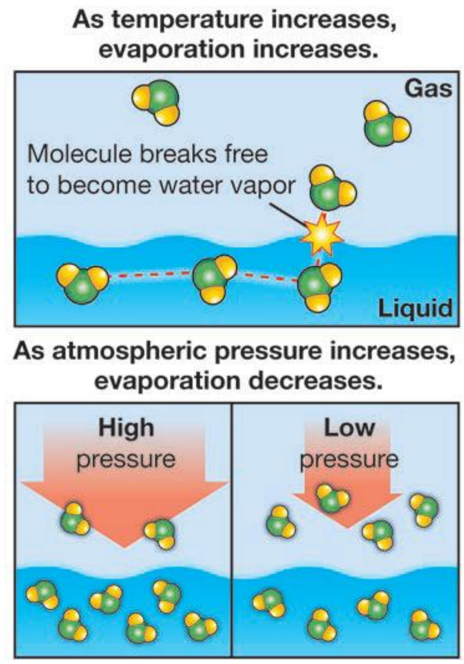


Figure 6.7: *The relationship between temperature and pressure when evaporation occurs.*

Cloud formation

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. 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 6.8). 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 row . If the altocumulus clouds look like towers, they are called *altocumulus castellatus*. These clouds often appear before a storm.

Cumulus:

The base of a cumulus cloud can occur anywhere from 1,000 meters to 5,800 meters high. *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.

Cumulonimbus:

When a cumulus cloud is dark and stormy looking, it is called *cumulonimbus*. Thunderstorms develop from cumulonimbus clouds.

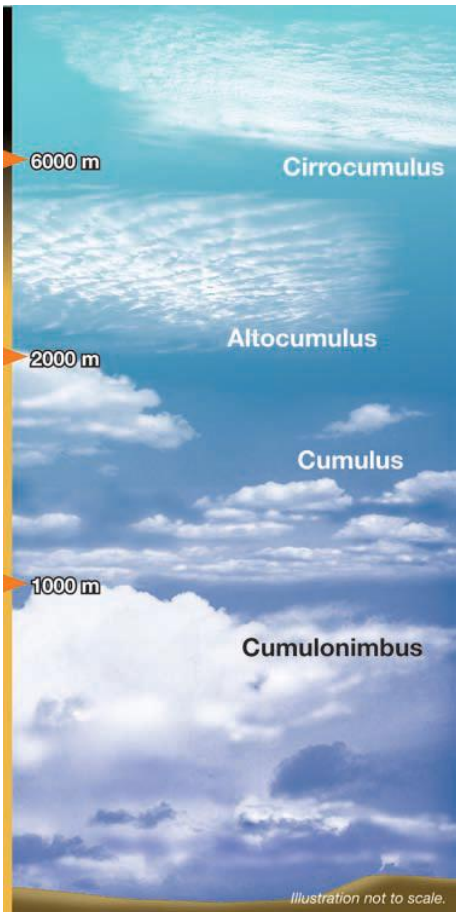


Figure 6.8: *Cumuliform clouds.*

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 6.9). 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*.

Stratocumulus clouds

Stratocumulus clouds have aspects of both cumuliform and stratiform clouds (Figure 6.10). 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.

Cirrus clouds

Cirrus clouds are thin lines of ice crystals high in the sky, above 6,000 meters (Figure 6.11). A curved cirrus cloud is commonly called a "mare's tail." The curving is due to a change in wind direction, and as a result may indicate that the weather is going to change.

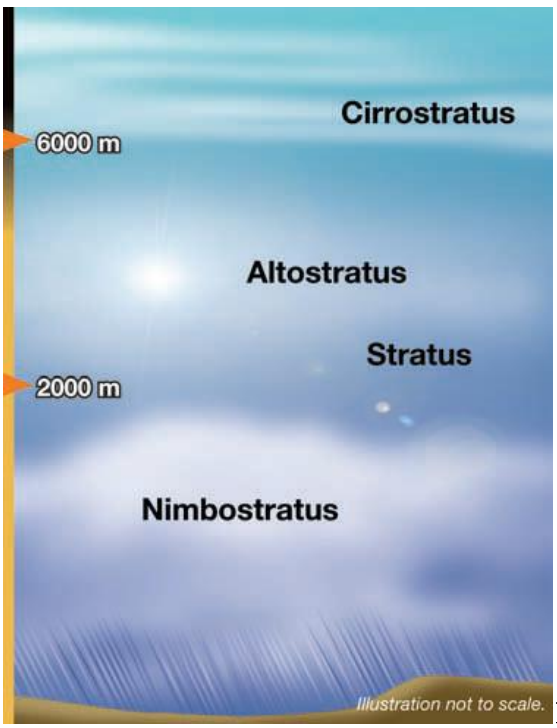


Figure 6.9: *Stratiform clouds.*


Figure 6.10: *Stratocumulus clouds.*

Figure 6.11: *Cirrus clouds.*

Precipitation

Rain

If air cools to a temperature lower than the dew point, and the pressure remains constant, water vapor condenses into liquid. At first, the water molecules condense on particles such as dust, pollen, or volcanic ash. Once a few water molecules condense, they create a site for other molecules to condense too. What starts as just a few water molecules quickly grows to millions of molecules that form water droplets. If the droplets become big enough, they form visible clouds. Clouds will produce *rain* when the drops get even bigger and have a volume of about 1 milliliter. At this size, they become heavy enough to fall as raindrops.

Snow and sleet

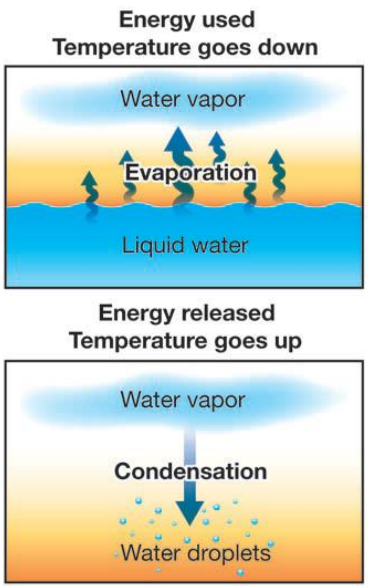
Snow usually forms when both ice crystals and water droplets are present in the sky. The water droplets attach to ice crystals and freeze there. When the ice crystals are large enough, they will fall to the ground as snow. However, if the air temperature near the ground is warm, the crystals will melt and the precipitation will fall as rain. Sometimes very cold air lies below warmer air, causing the water to refreeze and hit the ground as *sleet*.

Dew and frost

Because the ground cools quickly, the temperature of the ground is often below the dew point late at night or early in the morning. Air near the ground gets cooled and some water vapor condenses in the form of *dew*. If the temperature is low enough, the dew freezes and turns to *frost*.

Fog

If air within a few hundred meters of the ground is cooled below the dew point, *fog* will form. Fog can form under two conditions. Warm moist air could move over a cooler surface, or the ground below could cool below the dew point at night. Either way, fog consists of suspended water droplets. Fog is a ground-level cloud.



Condensation warms the air

Condensation is actually a warming process. Why? Energy was needed when the water changed from a liquid to a gas. This energy is released when the water changes back into the liquid form. As a result, if it is not too windy, you can sometimes feel the air warm up a few degrees when precipitation begins to fall.

Fronts

Large bodies of air

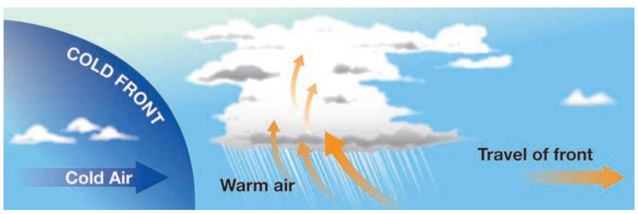
As you learned in Section 6.1, air masses are large bodies of air sometimes covering thousands of square kilometers. Air masses form when air is stationary over an area long enough to take on the characteristics of the surface below. Two common air masses affecting the United States are the *continental polar air mass*, which forms over the Canadian plains, and the *maritime tropical air mass*, which forms over the Gulf of Mexico (Figure 6.12). 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 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 cools as much as 15 °F in one hour.



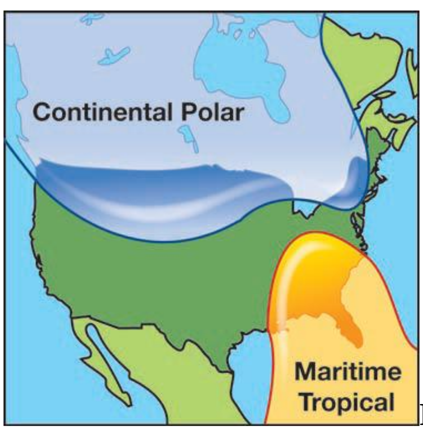
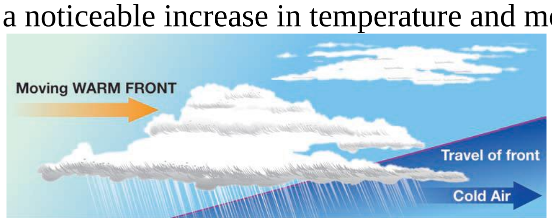
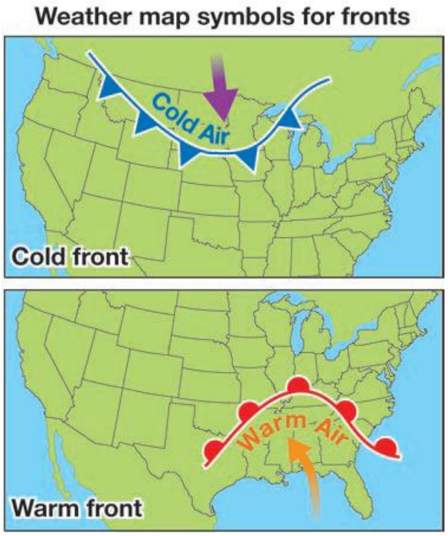


Figure 6.12: *Two air masses that affect the weather in the United States.*

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.





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

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 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.

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 6.13). 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 6.13). 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.

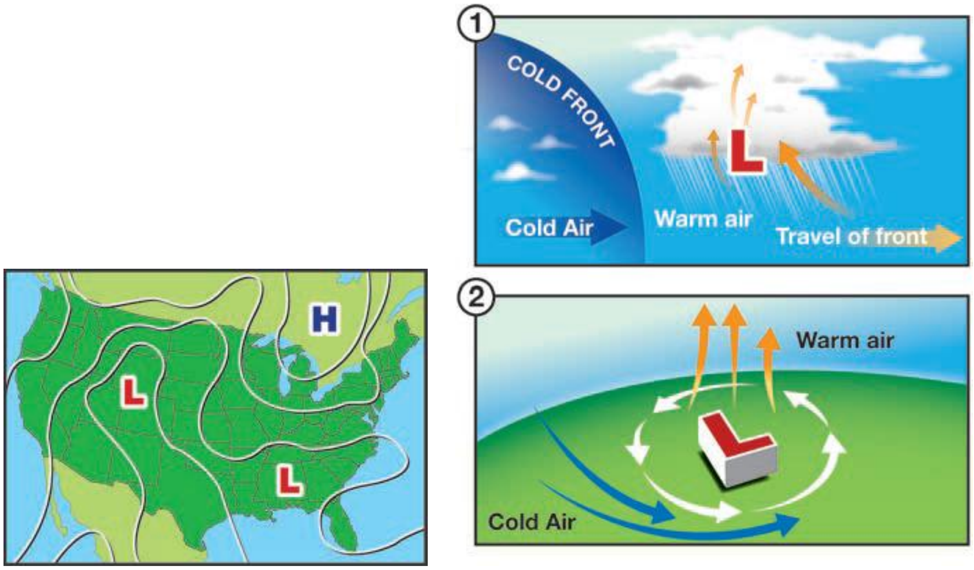


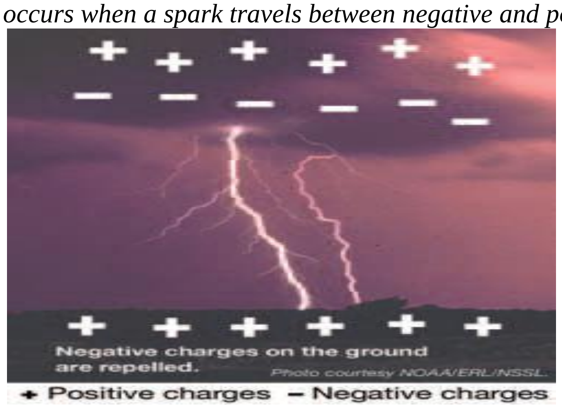
Figure 6.13: *(1) Warm air is forced upward when a cold front moves into an area. A low-pressure center is created. (2) The cold air moving toward the lowpressure center begins to rotate around it in a counterclockwise direction.*

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, forming 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. 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 (+) (Figure 6.14). When this happens, a spark travels between 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. **Figure 6.14 below:** *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 74 miles (119 kilometers) per hour. The Saffir- Simpson Hurricane Scale is one scale used for rating hurricanes (Figure 6.15).

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 due to the Coriolis effect, and a rotating system forms.

Hurricane conditions

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. Winds blowing from different directions or at different speeds can break the storm apart. **Figure 6.15 below :** *The Saffir-Simpson Hurricane Scale.*

Saffir-Simpson Hurricane Scale

Name	Wind speed	Damage	Storm surge
Tropical depression	> 63 km/h	Little	None
Tropical storm	63–119 km/h	Minor flooding	Very minor
Category 1 hurricane	120–153 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

Tornadoes

Comparing hurricanes and tornadoes

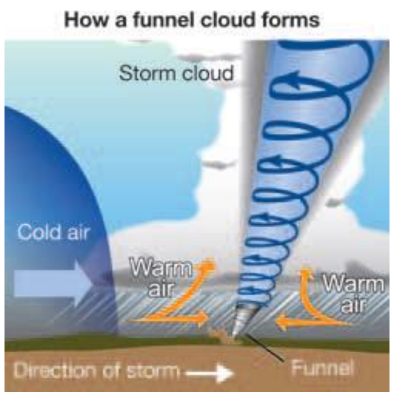
A **tornado**, like a hurricane, is a system of rotating winds around a low-pressure center. An average tornado is less than 200 meters in diameter—tiny, compared with the 640 kilometer (640,000 meter) average diameter of a hurricane! However, the wind speeds of a tornado are much greater than those 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 in to 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 6.16). 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. **Figure 6.16 below:** *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.*



El Niño Southern Oscillation

A storm pattern in the Pacific

Storm patterns across the globe can happen in cycles. One such pattern is in the tropical Pacific. Usually, the trade winds blow warm water from east to west across the Pacific Ocean, from Peru on the ocean's eastern coast toward Indonesia on the western coast (Figure 6.17). As a result, the average water temperature off the coast of Indonesia is 6 °C warmer than the average water temperature off the coast of Peru. The warm water of the western Pacific typically generates thunderstorms of greater frequency and intensity than what is normally seen near Peru.

El Niño Southern Oscillation

For reasons not fully understood, every so often the trade winds weaken and the warm water reverses direction, flowing from the western Pacific toward South America (Figure 6.17). Along with that warm water comes greater thunderstorm activity across the Pacific. Indonesia and other western Pacific nations experience drier than normal conditions, while the eastern Pacific countries get more precipitation. This change in wind flow, air pressure, and thunderstorm activity is known as the *El Niño Southern Oscillation*.

El Niño Peruvian fishermen were among the first to notice the change in water temperature along their shores. When the warm water from the west flows toward South America, it cuts off a normal pattern in which cold water from the ocean depths flows up to the surface along the coast of Peru. The upwelling cold water brings nutrients necessary for fish and other aquatic life to flourish. During an El Niño event, the warm water flowing over the cold water acts like a lid (Figure 6.18). It prevents the cold water from reaching the surface. As a result, nutrients are not available for aquatic life and the fish population declines.

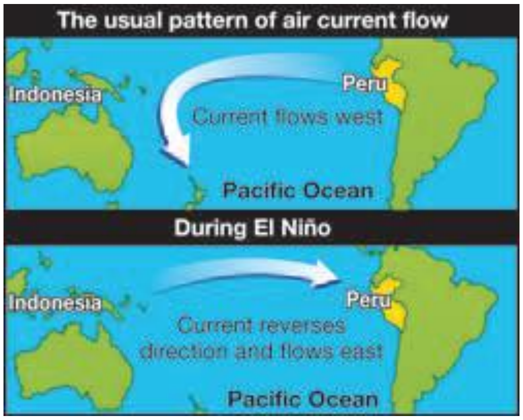


Figure 6.17: *The usual pattern of air current flow compared to what happens during El Niño.*

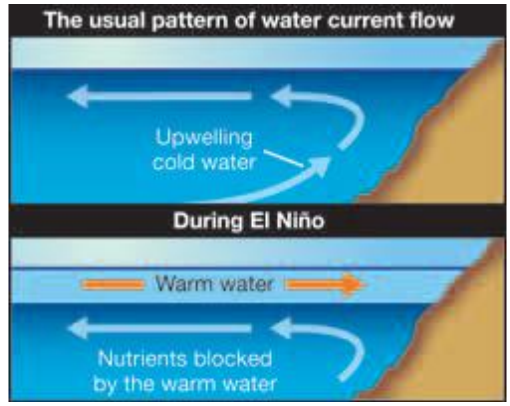


Figure 6.18: *The usual pattern of water current flow compared to what happens during El Niño.*

VOCABULARY

meteorologist - an individual who uses scientific principles to forecast the weather.
dew point - the temperature at which more water condenses than evaporates in an air mass at a constant atmospheric pressure.
cloud - a group of water droplets or ice crystals that you can see in the atmosphere.
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.
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.
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.
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 air and the air expands.
cyclone - a low-pressure center surrounded by rotating winds.
hurricane - a tropical cyclone with wind speeds of at least 74 miles per hour (119 kilometers per hour).
tornado - a system of rotating winds around a low-pressure center; a tornado is smaller than a hurricane, but has faster winds.

6.2 Section Review

1. What does a meteorologist do?

2. If you wanted to increase the rate of evaporation of water, how would you change the temperature and pressure?

3. 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 see if a thunderstorm were about to happen.

4. Which kind of cloud has the characteristics of both cumuliform and stratiform clouds? Describe this cloud.

5. What causes frost to form?

6. How is the weather associated with a cold front different from the weather associated with a warm front?

7. 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

8. How is convection of air involved in the development of a thunderstorm?

9. What conditions are needed for a hurricane to develop?

10. List three differences between a hurricane and a tornado.

11. On the Saffir-Simpson Hurricane Scale, what is the difference between a Category 1 hurricane and a Category 5 hurricane?

12. Fish populations decline as a result of the El Niño Southern Oscillation. Why?