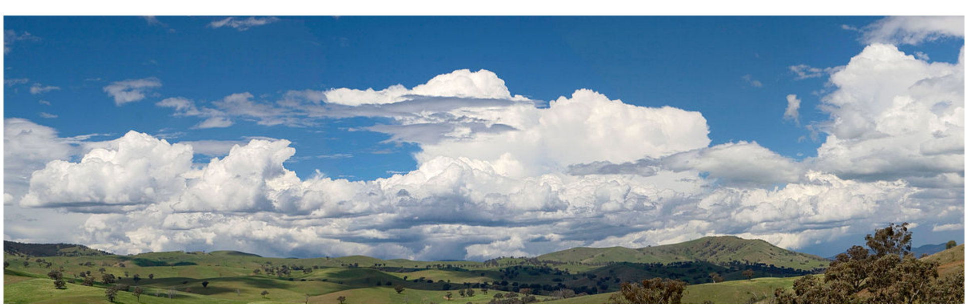
Chapter 4 Strand 3: Weather Patterns

Chapter Outline

Strand 3: Earth's Weather Patterns and Climate



All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. Heat energy from the Sun, transmitted by radiation, is the primary source of energy that affects Earth's weather and drives the water cycle. Uneven heating across Earth's surface causes changes in density, which result in convection currents in water and air, creating patterns of atmospheric and oceanic circulation that determine regional and global climates.

4.1 Water Cycle (6.3.1)

Explore This Phenomena

Every school has drinking fountains. You need water. Think about the water that you drink. Where did the water come from before you drank it? Where will it go when you are done with it? How long has the water been here on Earth?

Where do you think the water you are drinking today has been? Draw a model that shows where your water has been.

Standard 6.3.1

Develop a model to describe how the cycling of water through Earth's systems is driven by energy from the Sun, gravitational forces, and density.

TABLE 4.1:

	In this section, focus on energy. Think about how the transfer of energy drives the motion and cycling of water throughout the water cycle.

The Water Cycle

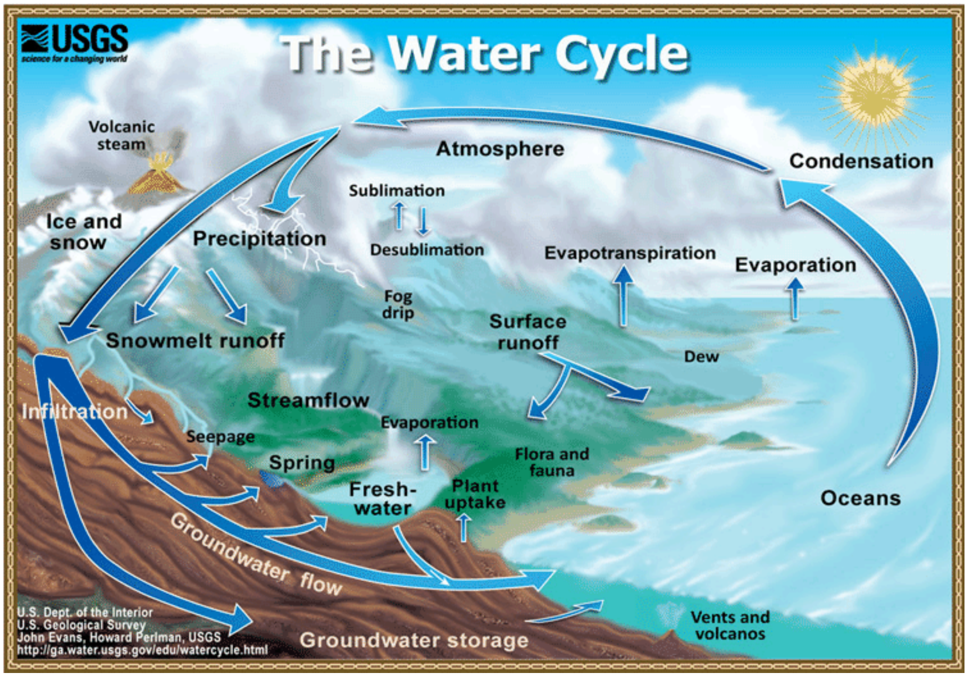
The water molecule found in your glass of water today could have erupted from a volcano early in Earth's history. In the intervening billions of years, the molecule probably spent time in a glacier or far below the ground. The molecule surely was high up in the atmosphere and maybe deep in the belly of a dinosaur. Because of the unique properties of water, water molecules can cycle through almost anywhere on Earth. Where will that water molecule go next?

Water continuously moves between living organisms, such as plants, and non-living things, such as clouds, rivers, and oceans.The water cycle does not have a starting or ending point. It is an endless recycling process that involves oceans, lakes and other bodies of water, as well as the land surfaces and the atmosphere. One possible pathway water could follow is:

- Water evaporates from the surface of the ocean. As the water vapor rises, it collects and is stored in clouds .
- As water cools in the atmosphere it condenses to form clouds. Condensation is when water vapor turns into liquid water.
- Water leaves the atmosphere as precipitation. Precipitation includes rain, snow, hail, and sleet. Precipitation returns the water to the Earth's surface.
- When precipitation falls to the surface, the water can sink into the ground to become part of the underground water reservoir, also known as groundwater. Much of this underground water is stored in aquifers, which are porous layers of rock that can hold water.

Most precipitation that occurs over land is not absorbed by the soil. This water remains on the surface and is called runoff. Runoff collects in streams and rivers and eventually flows back into the ocean.

Water also moves through the living organisms. Plants soak up large amounts of water through their roots. The water then moves up the plant and evaporates from the leaves in a process called transpiration. Another name for transpiration is evapotranspirtation. The process of transpiration, like evaporation, returns water back into the atmosphere.



Forces that Drive the Water Cycle

Solar Energy

The Sun provides the energy that drives the water cycle. For water to evaporate it requires an input of energy. The Sun directly impacts the water cycle by supplying the energy needed for evaporation .

Density

As clouds accumulate more water they become more dense. Water will fall from the clouds as precipitation to the surface of the Earth.

Gravity

Clouds will move water from the ocean to the tops of the mountains. Water evaporated from the ocean will be deposited on land as precipitation. Gravity pulls the water down to the oceans where the process continues.

Earth's Water Reservoirs

Water can be found in many different locations on the Earth. It can be found in oceans, clouds, puddles or living things. Each of these locations is called a reservoir.

Oceans

Most of Earth's water is stored in the oceans. In fact, 97% of the Earth's water is in this reservoir. Water can remain in the ocean for hundreds or thousands of years. Or it can evaporate in days or hours.

Atmosphere

When water absorbs energy it will change from a liquid to water vapor. The Sun's energy can evaporate water from the ocean surface or from lakes, streams, or puddles on land. The water vapor remains in the atmosphere until it condenses to become tiny droplets of liquid. The droplets gather in clouds, which are blown about the globe by wind. As the water droplets in the clouds collide and grow, they fall from the sky as precipitation. Precipitation can be rain, sleet, hail, or snow. Sometimes precipitation falls back into the ocean and sometimes it falls onto the land surface.

Streams and Lakes

When water falls from the sky as rain it may enter streams and rivers that flow downward to lakes and oceans. Water that falls as snow may sit on a mountain for several months. Snow may become ice in a glacier, where it will remain for hundreds or thousands of years. Snow and ice slowly melt over time to become liquid water, which provides a steady flow of fresh water to streams, rivers, and lakes. A water droplet falling as rain could also become part of a stream or a lake. At the surface, the water will eventually evaporate and reenter the atmosphere.

Soil

A significant amount of water seeps into the ground. Soil moisture is an important reservoir for water (Figure below). Water trapped in soil is important for plants to grow.

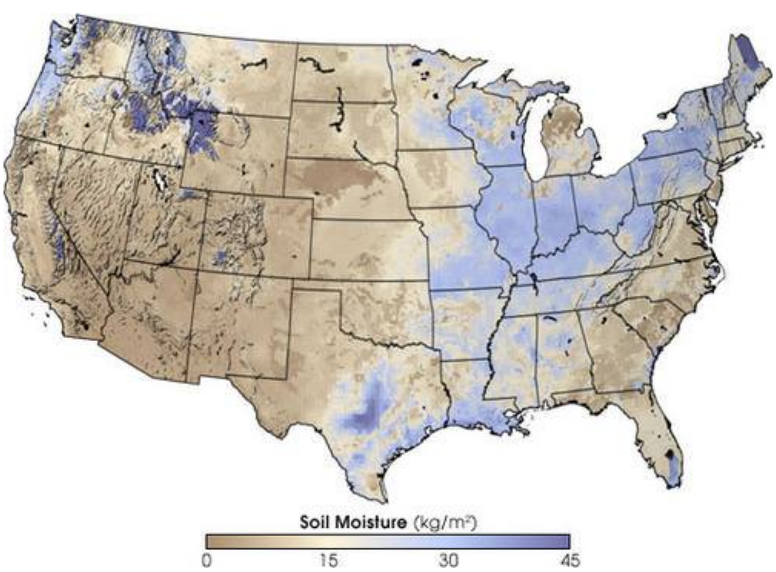


FIGURE 4.1

The moisture content of soil in the United States varies greatly.

Groundwater

Water may seep through dirt and rock below the soil and then through pores infiltrating the ground to go into Earth's groundwater system. Groundwater enters aquifers that may store fresh water for centuries. Alternatively, the water may come to the surface through springs or find its way back to the oceans. Water can remain in this reservoir for hundreds or even thousands of years.

Biosphere

Plants and animals depend on water to live. Plants and animals are another place water is stored. Plants take up water from the soil and release large amounts of water vapor into the air through their leaves in transpiration. Water will move quickly through this reservoir.

Focus Questions

- Explain how energy from the Sun affects the movement of water through the water cycle.
- What is a water reservoir? List 3 examples of water reservoirs.
- Describe how water can change states as it moves through the water cycle?

Putting it Together

Every school has drinking fountains. You need water. Think about the water that you drink. Where did the water come from before you drank it? Where will it go when you are done with it? How long has the water been here on Earth?

Where do you think the water you are drinking today has been?

Review your initial model, now draw a revised model that shows where your water has been based on what you have learned.

4.2 Pressure and Air Masses (6.3.2)

Explore This Phenomena

Everybody loves a picnic. Your friends and you are headed up the canyon to enjoy the mountains. While driving you feel a slight discomfort in your ears which goes away as soon as your ears "pop". What happened? Why were your ears hurting?

Write an explanation for why your ears were hurting as you drove into the mountains and stopped hurting once they "popped".

Pressure and Air Masses

Standard 6.3.2: Investigate the interactions between air masses that cause changes in weather conditions. Collect and analyze weather data to provide evidence for how air masses flow from regions of high pressure to low pressure causing a change in weather. Examples of data collection could include field observations, laboratory experiments, weather maps, or diagrams.

TABLE 4.2:

	In this section, focus on cause and effect. Analyzing cause and effect relationships help us to predict natural phenomena, such as changes to the weather.

Air Pressure

Pressure in the atmosphere is created by the weight of the atmosphere pushing down on the surface. Air heated at the surface rises, creating a low pressure zone. Air from the surrounding area is rushes into the space left by the rising air. As air cools it sinks back to the surface. When the air reaches the ground, it creates a high pressure zone. Air flowing from areas of high pressure to low pressure creates winds. The greater the pressure difference between the pressure zones, the stronger the wind blows.

Warm air can hold more moisture than cool air. When warm air rises and cools in a low pressure zone, it may not be able to hold all the water it contains as vapor. Some water vapor may condense to form clouds and precipitation . When cool air descends, it warms. Since it can then hold more moisture, the descending air will evaporate water on the ground.

Gases at sea level are also compressed by the weight of the atmosphere above them. The force of the air weighing down over a unit of area is known as its atmospheric pressure, or air pressure. Why are we not crushed? The molecules inside our bodies are pushing outward to compensate. Air pressure is felt from all directions, not just from above.

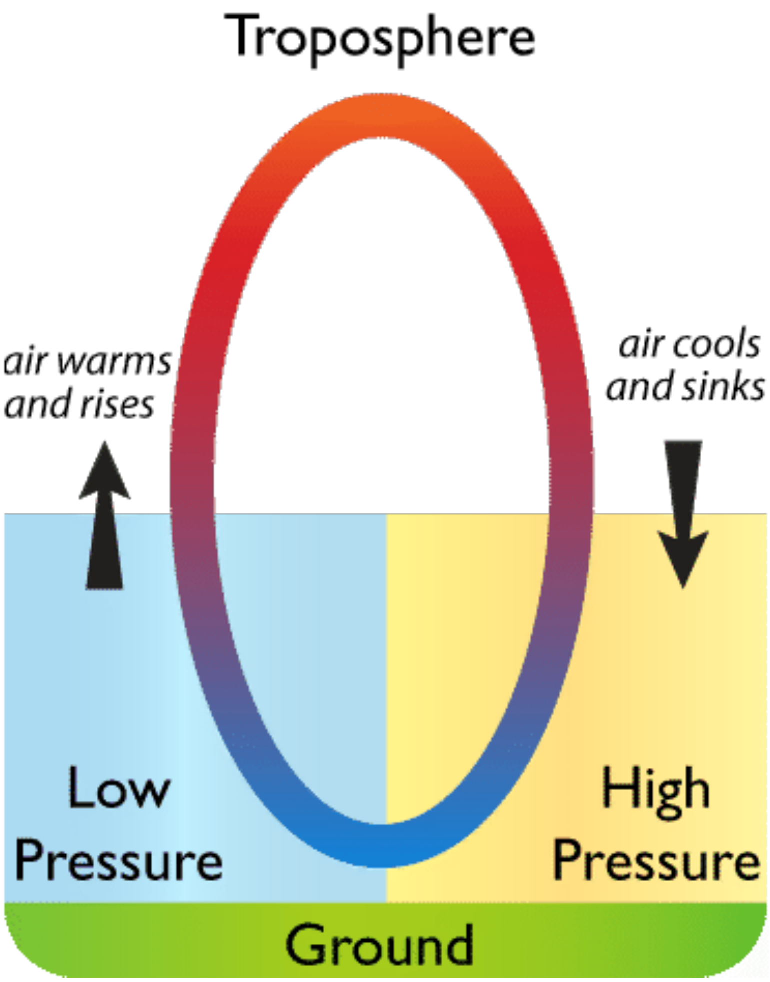


FIGURE 4.2
Warm air rises, creating a low pressure zone; cool air sinks, creating a high pressure zone.

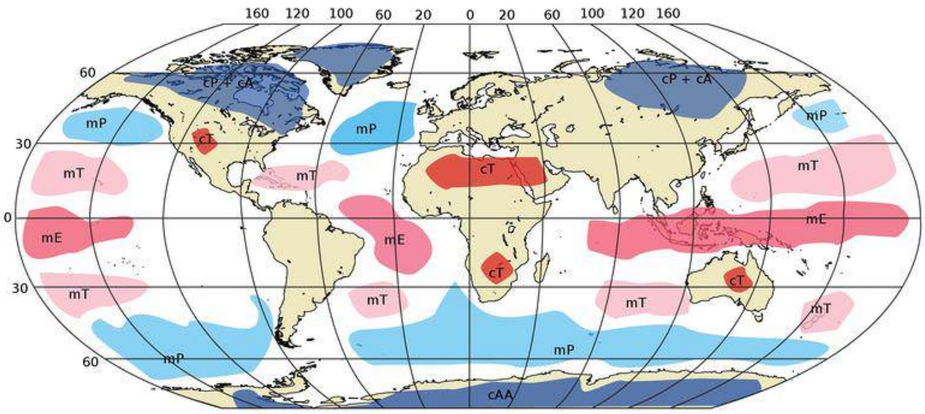
This bottle was closed at an altitude of 3,000 meters where air pressure is lower. When it was brought down to sea level, the higher air pressure caused the bottle to collapse.

At higher altitudes the atmospheric pressure is lower and the air is less dense than at lower altitudes. That's what makes your ears pop when you change altitude. Gas molecules are found inside and outside your ears. When you change altitude quickly, like when an airplane is descending, your inner ear keeps the density of molecules at the original altitude. Eventually the air molecules inside your ear suddenly move through a small tube in your ear to equalize the pressure. This sudden rush of air is felt as a popping sensation.

Air Masses

An air mass is a body of air that has nearly the same temperature and humidity . When the air mass sits over a region for several days or longer, it picks up the distinct temperature and humidity characteristics of that region.

Air masses form over a large area. They can be 1,600 km (1,000 miles) across and several kilometers thick. Air masses form primarily in high pressure zones, most commonly in polar and tropical regions. Temperate zones are ordinarily too unstable for air masses to form. Instead, air masses move across temperate zones, so these areas are prone to having more varied weather.



This picture shows where different types of air masses form. Some form over land and some form over water. They are also named for the area they form.

Air masses are slowly pushed along by high-level winds. When an air mass moves over a new region, it shares its temperature and humidity with that region. So the temperature and humidity of a particular location depends partly on the characteristics of the air mass that sits over it.

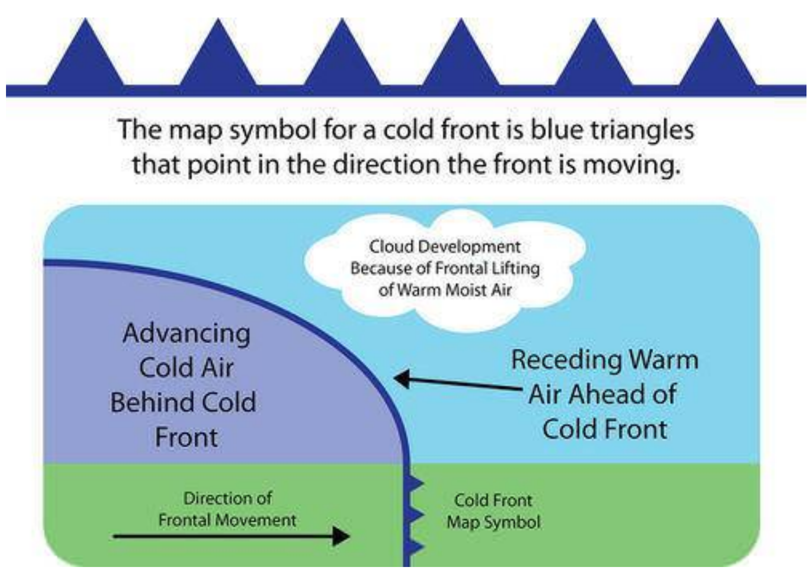
Fronts

Two air masses meet at a front. At a front, the two air masses have different characteristics and do not easily mix. One air mass is lifted above the other, creating a low pressure zone. If the lifted air is moist, there will be condensation and precipitation. Winds are common at a front. The greater the temperature difference between the two air masses, the stronger the winds will be. Fronts are the main cause of stormy weather.

There are four types of fronts, three moving and one stationary. With cold fronts and warm fronts, the air mass at the leading edge of the front gives the front its name. In other words, a cold front is right at the leading edge of moving cold air and a warm front marks the leading edge of moving warm air.

Cold Fronts

When a cold air mass takes the place of a warm air mass, there is a cold front (Figure below).



The cold air mass is slides beneath the warm air mass and pushes it up.

Imagine that you are standing in one spot as a cold front approaches. Along the cold front the cold air pushes up the warm air, causing the air pressure to decrease (Figure above). If the humidity is high enough clouds will develop. High in the atmosphere, winds blow ice crystals from the tops of these clouds. At the front, there will be a line of rain showers, snow showers, or thunderstorms with blustery winds. Behind the front is the cold air mass. This mass is drier, so precipitation stops. The weather may be cold and clear or only partly cloudy. Winds may continue to blow into the low pressure zone at the front.

A developing thunderstorm

The weather at a cold front varies with the season.

- Spring and summer: the air is unstable so thunderstorms or tornadoes may form.
- Spring: if the temperature variation is high, strong winds blow.
- Autumn: strong rains fall over a large area.
- Winter: the cold air mass is likely to have formed in the frigid arctic, so there are frigid temperatures and heavy snows.

Warm Fronts

At a warm front, a warm air mass slides over a cold air mass (Figure below). When warm air moves over the colder air the atmosphere is relatively stable.

Imagine that you are on the ground in the wintertime under a cold winter air mass with a warm front approaching. The transition from cold air to warm air takes place over a long distance, so the first signs of changing weather appear long before the front is actually over you. Initially, the air is cold: the cold air mass is above you and the warm air mass is above it. High clouds mark the transition from one air mass to the other.

Over time, the clouds become thicker. As the front approaches clouds appear and the sky turns gray. Since it is winter precipitation falls as snow. Winds grow stronger as the low pressure approaches. As the front gets closer, the

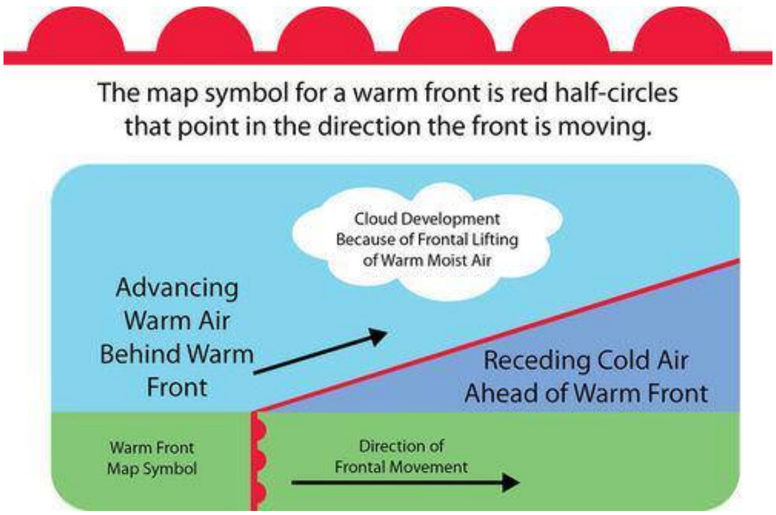


FIGURE 4.3
Warm air moves forward to take over the position of colder air.

cold air mass is just above you but the warm air mass is not too far above that. The weather worsens. As the warm air mass approaches, temperatures rise and snow turns to sleet and freezing rain. Warm and cold air mix at the front, leading to the formation of clouds and fog .

Stationary Fronts

At a stationary front the air masses do not move (Figure below). A front may become stationary if an air mass is stopped by a barrier, such as a mountain range. A stationary front may bring days of rain, drizzle, and fog. Winds usually blow parallel to the front, but in opposite directions. After several days, the front will likely break apart.

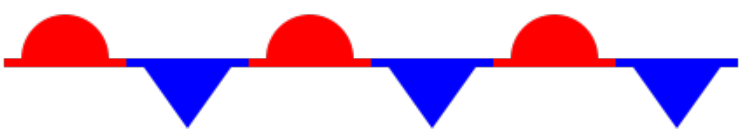


FIGURE 4.4
The map symbol for a stationary front has red domes for the warm air mass and blue triangles for the cold air mass.

Occluded Fronts

An occluded front usually forms around a low pressure system (Figure below). The occlusion starts when a cold front catches up to a warm front. The air masses, in order from front to back, are cold, warm, and then cold again.

FIGURE 4.5
The map symbol for an occluded front is mixed cold front triangles and warm front domes.

The weather at an occluded front is especially fierce right at the occlusion. Precipitation and shifting winds are typical. The Pacific Coast has frequent occluded fronts.

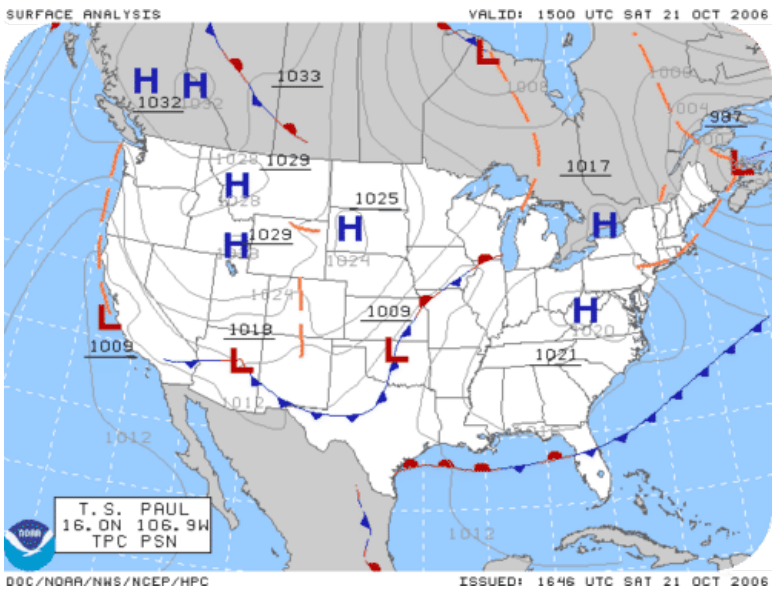


FIGURE 4.6

Surface analysis maps may show sea level mean pressure, temperature, and amount of cloud cover.

Focus Questions:

- Describe how the air masses move.
- What type of weather is associated with a warm front?
- Look for patterns in the weather map from NOAA, what type of weather would you expect around low pressure areas? Why?

Putting It All Together:

Everybody loves a picnic. You and your friends are headed up the canyon to enjoy the mountains. While driving you feel a slight discomfort in your ears which goes away as soon as your ears "pop". What happened? Why were your ears hurting?

Review your initial explanation about why your ears stop hurting once they popped. Based on what you have learned, write a revised explanation for why your ears were hurting as you drove into the mountains and stopped hurting once they "popped".

4.3 Climate (6.3.3)

Explore this Phenomena

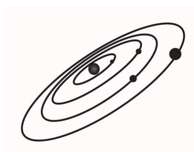
The sun shines on the entire Earth. The sun is the same.

Explain why these two areas have such different climates.

Climate

Standard 6.3.3: Develop and use a model to show how unequal heating of the Earth's systems causes patterns of atmospheric and oceanic circulation that determine regional climates. Emphasize how warm water and air move from the equator toward the poles. Examples of models could include Utah regional weather patterns such as lake-effect snow and wintertime temperature inversions.

TABLE 4.3:



As you read this section, focus on systems. Think about both the atmosphere and the ocean as systems as you learn about how heat energy is distributed around Earth by these two systems.

Energy and Latitude

Different parts of Earth's surface receive different amounts of sunlight (Figure below). The Sun's rays strike Earth's surface most directly at the Equator. Near the poles, the Sun's rays strike the surface less directly. This spreads the rays over a wide area. The more focused the rays are, the more energy an area receives, and the warmer it is.

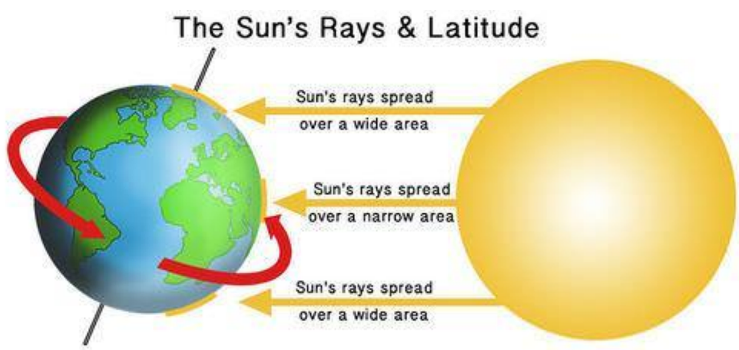


FIGURE 4.7
The lowest latitudes get the most energy from the Sun. The highest latitudes get the least.

The difference in solar energy received at different latitudes caused unequal heating of Earth's surface. Places that get more solar energy will be warmer. Places that get less solar energy will be be cooler. Warm air rises and cool air sinks. This principle means that air moves around the planet. The Earth's atmosphere carries heat, therefore the heat moves around the globe in ways that affect weather patterns.

Circulation of the Atmosphere and the Ocean

It may not look like it, but various processes work to moderate Earth's temperature across the globe. Atmospheric circulation brings warm air towards the poles and cold polar air towards the Equator. If the Earth's atmosphere didn't move the temperature differences would be much greater. In general, cold air masses tend to flow toward the Equator and warm air masses tend to flow toward the poles. This brings heat to cold areas and cools down areas that are warm. It is one of the many processes that act to balance out the planet's temperatures.

Ocean water moves in predictable ways along the ocean surface. Surface currents can flow for thousands of kilometers and can reach depths of hundreds of meters. These surface currents do not depend on the weather; they remain unchanged even in large storms because they depend on factors that do not change. Surface currents are created by global wind patterns and the rotation of the Earth. Surface currents are extremely important because they distribute heat around the planet and are a major factor influencing climate around the globe.

Winds on Earth are either global or local. Global winds blow in the same directions all the time and are related to the unequal heating of Earth by the Sun and the rotation of the Earth. These predictable wind patterns allowed early sailing ships to travel around the globe. Ocean currents created by these wind patterns move ocean water around the planet. Normally warm water at the Equator will be pushed to the polar areas and colder water will be pushed to the equator.

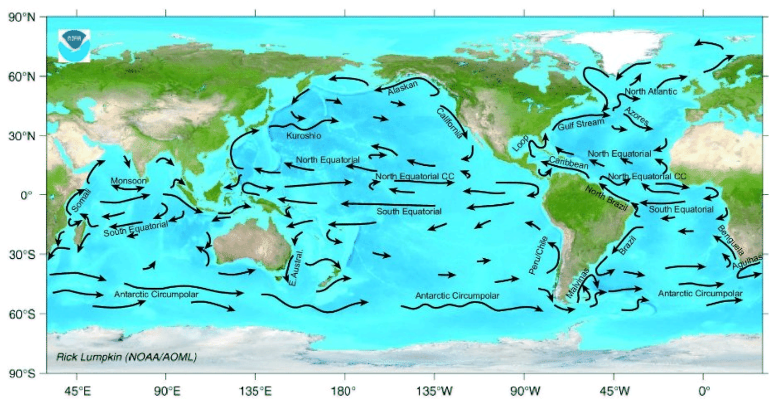


FIGURE 4.8

Major ocean surface currents

Surface currents play an enormous role in Earth's climate. Even though the Equator and poles have very different climates, these regions would have extremely different climates if ocean currents did not transfer heat from the equatorial regions to the higher latitudes.

An example of how ocean current effect an area's climate is the Gulf Stream. The Gulf Stream is a river of warm water in the Atlantic Ocean, about 160 kilometers wide and about a kilometer deep. Water that enters the Gulf Stream is heated as it travels along the Equator. The warm water then flows up the east coast of North America and across the Atlantic Ocean to Europe. The energy the Gulf Stream transfers is more than 100 times the world's energy demand.

The Gulf Stream's warm waters raise temperatures in the North Sea, which raises the air temperatures over land between 3 to 6°C (5 to 11°F). London is at about six degrees further south than Quebec. However, London's average January temperature is 3.8°C (38°F), while Quebec's is only -12°C (10°F). Because air traveling over the warm water in the Gulf Stream picks up a lot of water, London gets a lot of rain. In contrast, Quebec is much drier and receives its precipitation as snow.

Focus Questions

- What causes Earth's poles to be much cooler than the Equator?
- How do surface currents form?
- Describe the Earth systems that are responsible for moving heat energy from the Equator to the poles.

Putting it all together:

The sun shines on the entire Earth. The sun is the same.

Review what you wrote about the climates in these two pictures. Based on what you have learned,explain why these two areas have such different climates.

4.4 The Greenhouse Effect (6.3.4)

Explore this Phenomena

Summer is a great time of year. The weather is warm. People spend a lot of time outside. Eventually you have to return home. Imagine you have spent the entire day playing outside, while your car was parked in a parking lot. You open the door to climb in your car. It feels like you are climbing into an oven!

Based on your own experiences record observations and questions about this phenomena.

TABLE 4.4:

Observations	Questions

Explain why the inside of a car that is parked outside during the summer can become so hot.

The Greenhouse Effect

Standard 6.3.4: Construct an explanation supported by evidence for the role of the natural greenhouse effect in Earth's energy balance, and how it enables life to exist on Earth. Examples could include comparisons between Earth and other planets such as Venus and Mars.

TABLE 4.5:

	As you read this section, focus on how energy from the Sun interacts with Earth and the atmosphere. Think about how the natural greenhouse effect contributes to Earth's energy balance, and allows for life to exist on Earth.

What is the Greenhouse Effect?

When sunlight heats Earth's surface, some of the heat radiates into the atmosphere. Some of this heat is absorbed by gases in the atmosphere. This is the greenhouse effect, and it keeps Earth warm. The greenhouse effect allows Earth to have temperatures that can support life.

Gases that absorb heat in the atmosphere are called greenhouse gases. They include carbon dioxide and water vapor. Like a blanket on a sleeping person, greenhouse gases act as insulation for the planet. The warming of the atmosphere is because of insulation by greenhouse gases. Greenhouse gases are the component of the atmosphere that moderate Earth's temperatures.

The greenhouse effect is a natural feature of Earth's atmosphere. Without the greenhouse effect, Earth's surface temperature would average -18ºC (0ºF) a temperature far too cold to support life as we know it. With the greenhouse effect, Earth's surface temperature averages 15ºC (5ºF), and it is this temperature range to which today's diversity of life has adapted.

The movement of energy due to the greenhouse effect is summarized in the figure below . Of the solar radiation which reaches the Earth's surface, as much as 30% is reflected back into space. About 70% is absorbed as heat , warming the land, waters, and atmosphere. If there were no atmosphere, most of the heat would radiate back out into space as infrared radiation. Earth's atmosphere contains molecules of water (H_2O), carbon dioxide (CO_2), methane (CH_4), and ozone (O_3), which absorb some of the infrared radiation. Some of this absorbed radiation further warms the atmosphere, and some is emitted, radiating back down to the Earth's surface or out into space. A balance between the heat which is absorbed and the heat which is radiated out into space results in an equilibrium which maintains a constant average temperature for the Earth.

If we compare Earth's atmosphere to the atmospheres which surround Mars and Venus (Figure below) we can understand why the composition of the Earth's atmosphere is important. Mars ' atmosphere is very thin, exerting less than 1% of the surface pressure of the Earth. As you might expect, the thin atmosphere cannot hold heat and the average surface temperature is -55ºC (-67ºF) - even though that atmosphere is 95% CO_2 and contains a great deal of dust. Daily variations in temperature are extreme, because the atmosphere cannot hold heat.

In contrast, Venus ' atmosphere is much thicker than Earth's, exerting 92 times the surface pressure of our own. Moreover, 96% of the atmosphere is CO_2, so a strong greenhouse effect heats the surface temperature of Venus as high as 500ºC, hottest of any planet in our solar system. The thick atmosphere prevents heat from escaping at night, so daily variations are minimal.

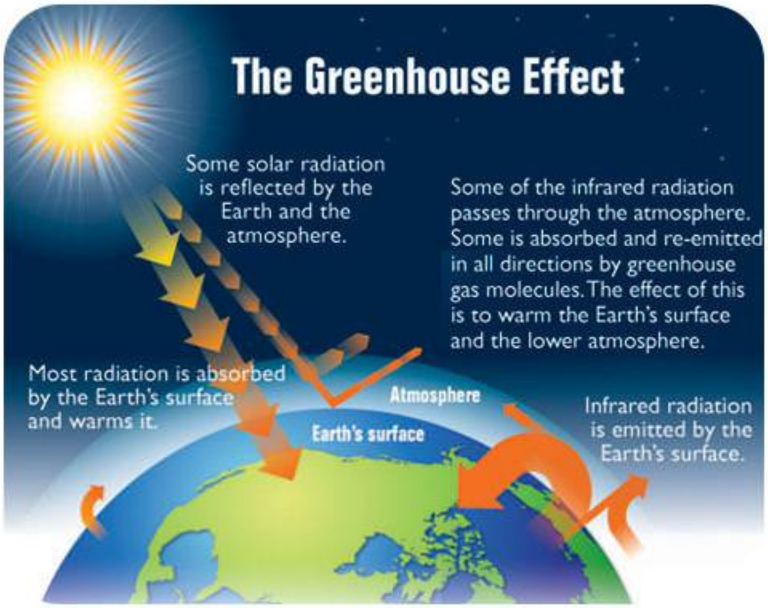


FIGURE 4.9

Without greenhouse gases, most of the sun's energy (transformed to heat) would be radiated back out into space. Greenhouse gases in the atmosphere absorb and reflect back to the surface much of the heat which would otherwise be radiated.

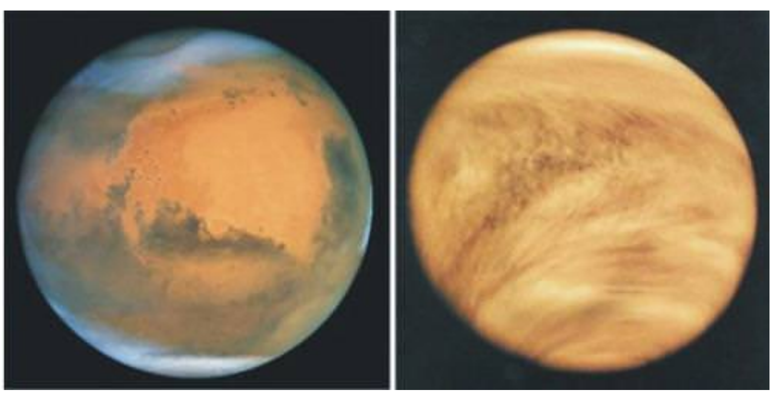


FIGURE 4.10

The thickness of a planet's atmosphere strongly influences its temperature through the greenhouse effect. Mars (left) has an extremely thin atmosphere, and an average temperature near -55ºC. Venus (right) has a far more dense atmosphere than Earth, and surface temperatures reach 500ºC.

Focus Questions:

- Explain how the atmosphere keeps the Earth warm?
- Draw a Venn diagram comparing the atmosphere of Mars and Venus.
- How would Earth's temperature be affected if the greenhouse gases in the atmosphere decreased? How would Earth's temperature be affected if the greenhouse gases in the atmosphere increased?

Putting it all together:

Summer is a great time of year. The weather is warm. People spend a lot of time outside. Eventually you have to return home. Imagine you have spent the entire day playing outside, while your car was parked in a parking lot. You open the door to climb in your car. It feels like you are climbing into an oven!

Review your explanation for why a car parked outside during the summer can become so hot. Based on what you have learned, revise your explanation for why a car can become so hot, and explain what you can do to prevent a car from becoming too hot during the summer.