

Chapter 6

Earth's Surface and Heat

How does Earth stay warm in cold, empty space? Most of Earth's heat energy comes from the Sun by the process of radiation. Energy from the Sun enters Earth's atmosphere and some gets trapped. This trapped energy warms the planet. In this chapter you will learn that ocean currents, wind, and weather are all related to heat energy at Earth's surface.



Key Questions

1. *Why is Earth's atmosphere important?*
2. *Why do palm trees grow in Scotland?*
3. *What causes wind?*



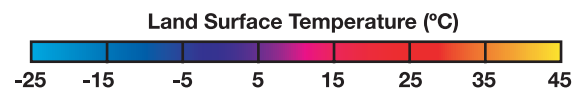
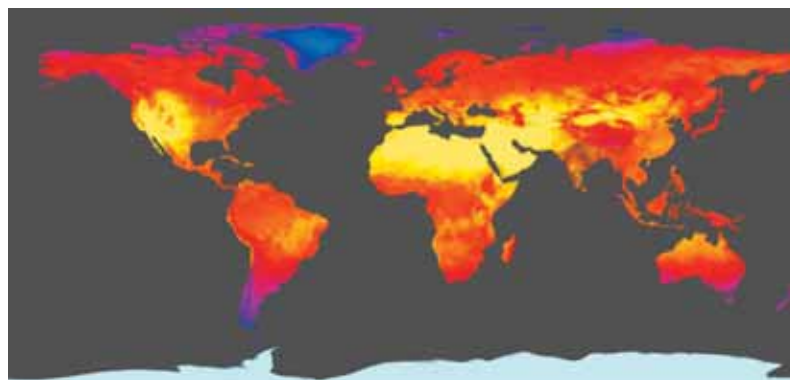
6.1 Earth Is Just Right

Earth is “just right” because its temperature is not too hot or too cold (Figure 6.1). Metals like lead melt on the hot surface of Venus, but not on Earth. Some gases freeze solid on Pluto, but not on Earth. Earth’s temperature is especially nurturing for living things. This section is about how Earth’s temperature stays “just right.”

Temperature

Water for life The temperature range on Earth’s surface is just right for water to be a liquid. Liquid water is extremely important for living things. For example, an adult human body is 60% to 75% water. You need water to keep your blood, brain, and lungs working properly!

Earth’s temperature range Earth’s surface temperature stays within a narrow range—it is not too hot or too cold. The average temperature of Earth’s surface is about 15°C. This temperature is maintained because Earth has an atmosphere which traps some of the Sun’s energy. Without an atmosphere, Earth’s surface temperature would be about -18°C.



July 2003. Image based on data from NASA’s Moderate Resolution Imaging Spectroradiometer (MODIS) Sensor. Credit: NASA

	Surface temperature (°C)
Mercury	-170 to 390
Venus	450 to 480
Earth	-88 to 48
Mars	-89 to -31
Jupiter	-108
Saturn	-139
Uranus	-197
Neptune	-201
Pluto	-223

Figure 6.1: *The surface temperatures for planets in our solar system.*

STUDY SKILLS

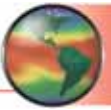
How to “read” diagrams

How do you read a diagram?

(1) Study the diagram to determine what information it is showing you.

(2) Read the caption and title.

(3) **Question:** Refer to the diagram at the left. In your estimation, what was the most common land surface temperature for July 2003?



Energy and motion

The Sun's energy Almost all of the heat energy on Earth's surface comes from the Sun. Hot spots like volcanoes and hot springs add some heat, but not as much as the Sun. At the same time that the Sun adds heat to Earth's surface, heat is being lost to space. The balance between the Sun's heat and heat lost into space is what determines Earth's surface temperature.

Earth's motion The motion of Earth also helps to balance its surface temperature. Read on to find out how two of these motions, rotation and revolution, affect the temperature of every place on Earth.

Rotation **Rotation** is the turning motion of a planet as it spins. It takes one day for Earth to make one complete spin. For half of a day, your side of Earth faces the Sun and experiences daytime. For the other half of the day, your side of Earth faces away from the Sun and experiences nighttime. The trick of spinning a basketball on your finger is a good example of rotation (Figure 6.2).

Revolution **Revolution** is the motion of a planet around its star, like a race car that moves around and around a circular track (Figure 6.2). One complete trip around the track would be one revolution. It takes about 365.25 days for Earth to make one revolution or one trip around the Sun. Later in this chapter we'll learn how the revolution of Earth is related to the seasons.



VOCABULARY

rotation - the motion of Earth spinning on its axis; one rotation is called a *day*.

revolution - the motion of Earth moving around the Sun; one revolution is called a *year*.

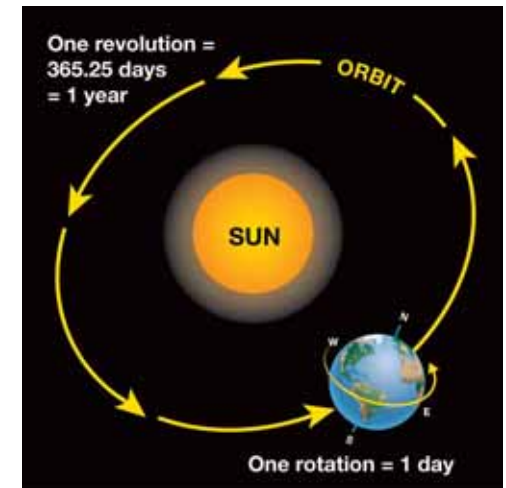
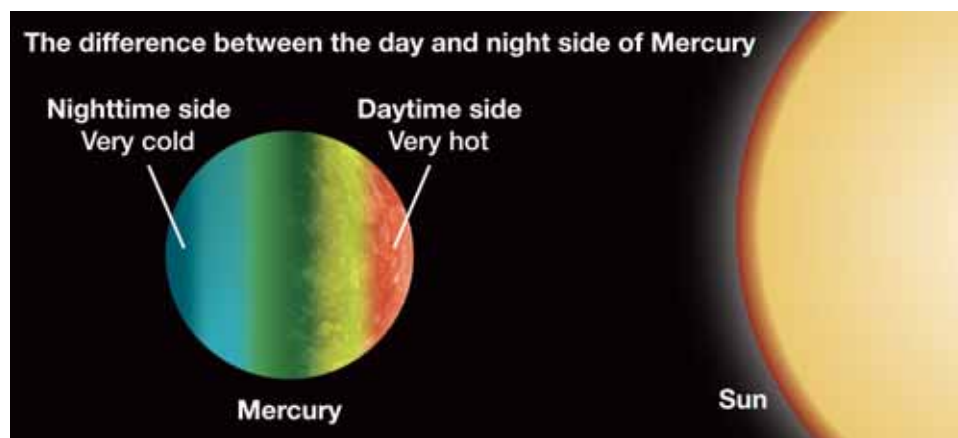


Figure 6.2: Earth rotates on its axis and revolves around the Sun.

Temperature and Earth's rotation

Mercury is too hot and too cold!

It may seem strange to compare a planet to a grilled burger, but what happens if you put a burger on a hot grill and forget to turn it? The bottom will be burned to a crisp, and the top will be undercooked. The planet Mercury is like that. One day on Mercury lasts for about 58 Earth days! The long day causes the temperature on the Sun-facing side of Mercury to reach about 400°C. Something made out of the metal lead would melt at this temperature! At the same time, the dark nighttime side plunges to -170° Celsius. That's so cold that the liquid in a thermometer would freeze.



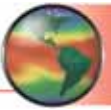
The Earth is just right—not too hot or too cold!

Even though Earth is farther away from the Sun than Mercury, our night side never gets as cold as Mercury's night side. Why not? Think about burgers again. A good chef turns the burger so it browns nicely on both sides. Similarly, the Earth turns rapidly enough so that there isn't enough time for our night temperature to sink too low. In the same way, there isn't enough time for Earth's day temperature to rise extremely high.

Greenhouse Gases



A greenhouse is a glass building where plants can be grown in a warm, moist environment. Scientists use the term "greenhouse gases" to describe certain gases in Earth's atmosphere. Like the glass in a greenhouse, greenhouse gases can slow down Earth's natural heat-loss processes. These gases are useful because they keep Earth warm. However, the amount of these gases is increasing in our atmosphere. Due to the increase, less heat energy will be able to leave Earth. Scientists are concerned that the resulting rise in Earth's average surface temperature might alter climates and other aspects of our environment.



Revolution and Earth's seasons

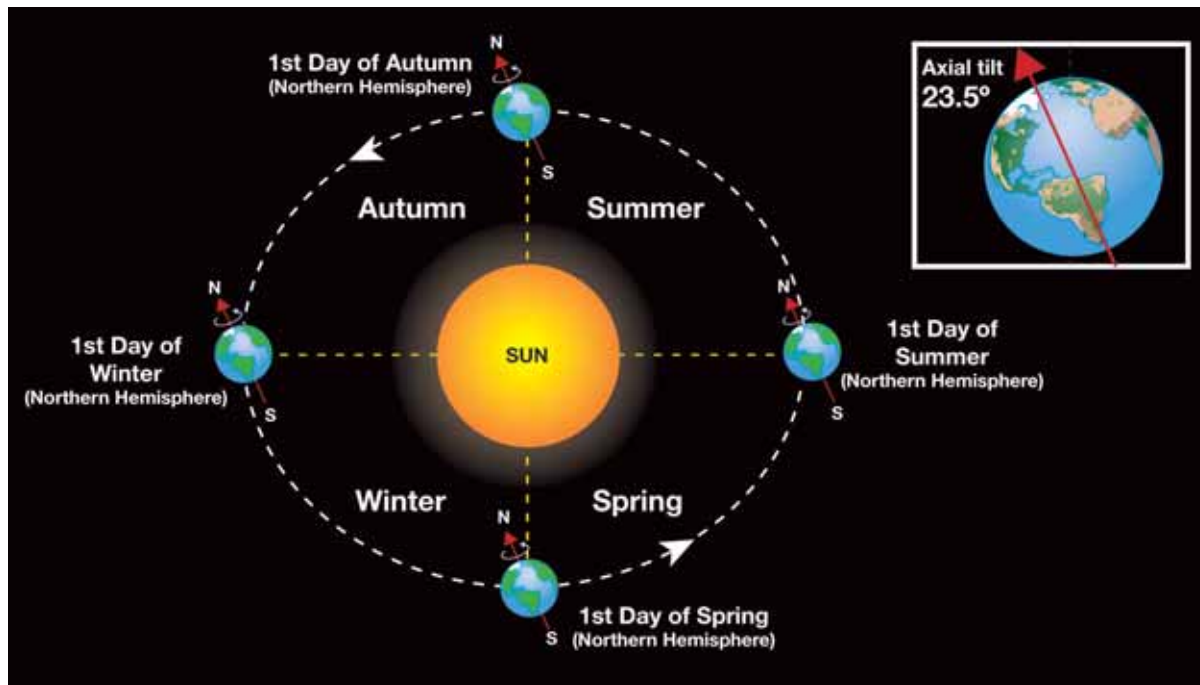
Why does Earth have seasons? The diagram below shows Earth at four different places in its revolution around the Sun. Why is it warmer in summer and cooler in winter in the northern hemisphere? In other words, why do seasons occur?

Earth is tilted One guess might be that Earth is closer to the Sun during summer. But this isn't the correct answer! Earth has seasons because it is tilted on its axis. During our summer, the northern hemisphere receives sunlight that is more direct than it is in the winter, and in summer there are more hours of daylight. This means we have warmer temperatures in summer than we do in winter.

Earth's axis

Earth rotates about an imaginary axis that goes through its center. This axis is drawn on Earth images in the diagram at the left. The diagram shows that Earth is tilted at 23.5° as it revolves around the Sun.

The axis connects the north and south poles. The north end of the axis points toward the North Star throughout the year.



SOLVE IT!

Make your own sketch of the diagram at the left. Based on today's date, indicate on your diagram where Earth is on its path around the Sun.

6.1 Section Review

1. Describe two ways that make Earth's climate "just right" for life on Earth.
2. What is the source of most of Earth's heat energy?
3. Some of Earth's heat energy is lost to space. Why is this important?
4. Define the term *rotation*. How long is one rotation of Earth?
5. Define the term *revolution*. How long is one revolution of Earth around the Sun?
6. Earth's surface does not get too hot or too cold compared to Mercury's surface. What difference between the two planets makes this possible?
7. What role do greenhouse gases play in keeping Earth warm?
8. Why does Earth have seasons?
9. Refer to the diagram on the previous page. During winter in the northern hemisphere, is the southern hemisphere tilted toward or away from the Sun?
10. How many degrees is Earth's axis tilted?
11. There are more hours of sunlight and more direct sunlight during summer. How does winter compare to summer in terms of hours of sunlight?
12. Research: You will need to do research on the Internet or at the library to answer these questions.
 - a. What are the main greenhouse gases?
 - b. Where do these gases come from?
 - c. Which planet—Venus or Earth— exhibits a stronger greenhouse effect? Why?

MY JOURNAL

Water is everywhere!

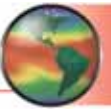
1. Look indoors and outdoors and list everything you see that contains water. Remember to include food, drinks, things in nature, and even YOU!
2. Make a second list of every activity, job, or process you do throughout a usual day where water is used.

Compare your journal lists with your classmates. Are your lists complete?

CHALLENGE

Why is January a *winter* month in the northern hemisphere but a summer month in the southern hemisphere?





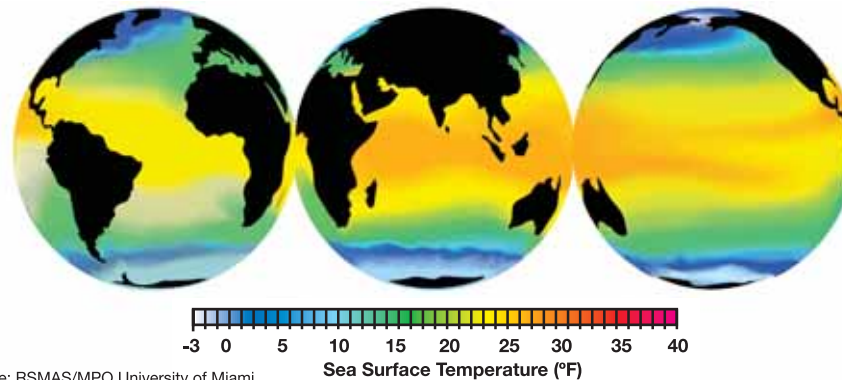
6.2 Ocean Currents

Cooks sometimes wrap warm food in a piece of aluminum foil to keep it warm. Aluminum foil helps spread the heat energy around the food. Our atmosphere and oceans act like foil because they spread heat around our planet. In this section, you will learn how heat is spread around by ocean currents.

Oceans

Water covers most of Earth's surface Oceans are massive bodies of seawater that cover much of Earth's surface. Land only covers about one-quarter of Earth's surface. The rest is covered with water, especially ocean water. About 97% of Earth's water is contained in oceans.

Oceans spread heat energy If Earth was the same temperature everywhere, the winds and ocean currents would be very weak. In Chapter 4 you learned that heat could spread from one place to another as a moving group of warm atoms. Oceans spread heat too. Oceans spread enormous amounts of energy from the hot equator toward the cold north and south poles. Earth has five major oceans (Figure 6.3). Can you name them? One of them was just named in the year 2000!



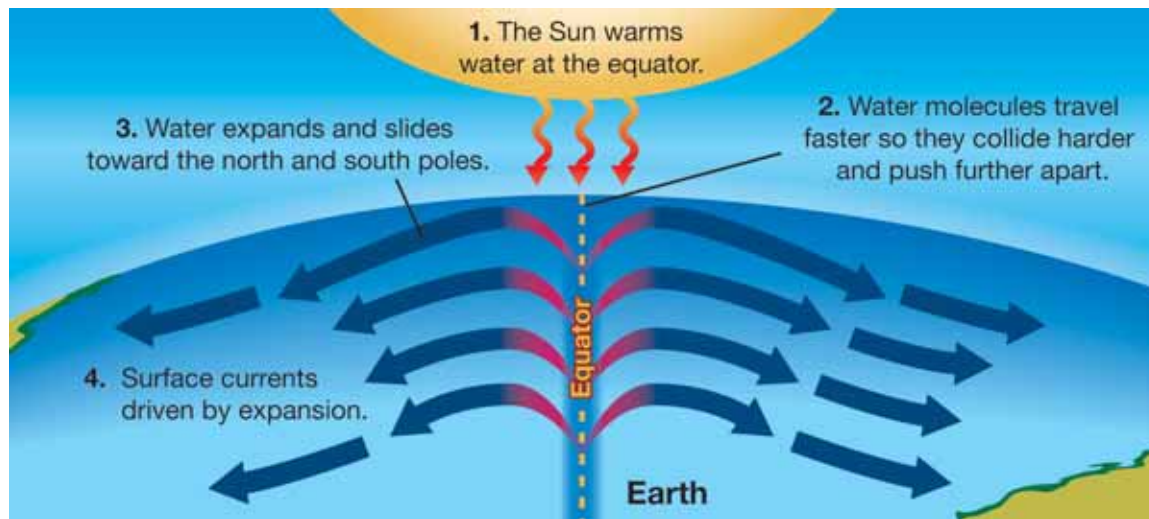
Source: RSMAS/MPO University of Miami

Figure 6.3: Earth's five major oceans. The Southern Ocean was recently named as a separate ocean in 2000 by the International Hydrographic Organization (IHO). The IHO includes representatives from 68 countries that border the world's oceans.

What causes surface ocean currents?

Wind creates currents Energy from the Sun creates permanent belts of wind that blow over large parts of Earth. When wind moves over an ocean, it pushes water along its path. The moving water forms patterns called **surface ocean currents**. One well-known surface ocean current is called the Gulf Stream (Figure 6.4). The Gulf Stream moves northward from Mexico all the way to the British Isles!

Water expansion also drives surface currents Ocean surface currents are also driven by a process called expansion. *Expansion* occurs when something increases in size. The climate at the equator (Figure 6.5) is hot all year long and warms the ocean surface. This makes the surface water expand so that the water level is a little higher at the equator. The force of gravity causes the expanded surface water to slide toward the north and south poles. This effect helps to drive the surface ocean currents. The diagram below shows why water expands when it is heated.



VOCABULARY

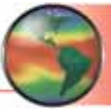
surface ocean currents - wind-driven currents that move at the ocean surface, often for very long distances.



Figure 6.4: The Gulf Stream is a surface ocean current.



Figure 6.5: The equator is an imaginary line that forms a circle around Earth, dividing it into the northern and southern hemispheres.



Ocean gyres

Rotation of Earth Surface ocean currents do not simply flow in a straight line away from the equator. The rotation of Earth causes the flow to curve to the right above the equator, and to the left below the equator. This natural phenomenon is called the *Coriolis effect*. Because of this effect, surface ocean currents can flow in a circular pattern called a **gyre**. Each ocean basin contains a gyre. Gyres north of the equator—like the North Atlantic Gyre below—turn in a clockwise direction. Gyres south of the equator turn in a counter-clockwise direction. It takes about three years for water to complete the path of the North Atlantic Gyre. This rate was determined by tracking bathtub toys that had spilled into the Atlantic Ocean (Figure 6.6)!

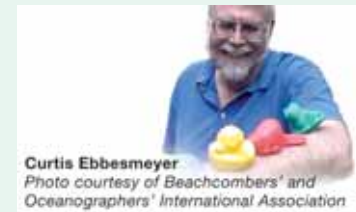
Heat energy Surface ocean currents move an enormous amount of heat energy away from the equator. Find New York and England on the map below. You can see that England is farther north of the equator than New York. Find the Gulf Stream part of the North Atlantic Gyre. The Gulf Stream carries so much heat energy that England is as warm as New York! Moving this amount of heat energy is incredible. With all our modern technology, we can't come close to producing this much heat energy.



VOCABULARY

gyre - a circular motion, such as a circular ocean current.

Tracking Ocean Currents



Sometimes, ships spill interesting things into the ocean. Since 1991, Oregon scientist Curtis Ebbesmeyer has tracked spilled objects to learn about surface ocean currents. He has tracked 60,000 sneakers spilled in the North Pacific. He followed 29,000 bathtub toys, and over 4.5 million plastic bricks spilled off the coast of Britain. He records and maps where these objects wash ashore. His data can be used to find out how fast currents travel and to make predictions. If there is an oil spill, it can be cleaned up more quickly using knowledge of the paths of surface ocean currents.

Figure 6.6: *Tracking ocean currents.*

Deep ocean currents

What are deep ocean currents? **Deep ocean currents** move within the ocean and are slower than the surface currents. Another name for deep ocean currents is *thermohaline currents*. *Thermo* means temperature and *haline* means salt. Deep ocean currents can't be driven by the wind. They are driven by differences in temperature and saltiness, which is why they are called thermohaline currents.

Two things happen at the equator As surface ocean currents flow near the equator, the Sun warms the water and the water expands. This means that the surface water becomes less dense. At the same time, these warm currents lose water due to evaporation. **Evaporation** occurs when a liquid, like water, changes into a gas. As water evaporates from these currents they become saltier and denser.

A giant conveyor belt of water As long as salty currents are warm, their expansion keeps them near the ocean's surface. But as they flow toward the poles, these currents cool down and the expansion effect is lost. The cooler, saltier water sinks toward the ocean floor—like an underwater waterfall. Deep ocean current water eventually returns toward the surface forming a huge, slow “conveyor belt” of moving water. It takes 1000 years for water to travel the path shown below. The surface water of the North Atlantic Gyre is on a much quicker circulation pattern taking only three years.



VOCABULARY

deep ocean currents - density- and temperature-driven currents that move slowly within the ocean; also called thermohaline currents.

evaporation - occurs when a liquid changes to a gas.

STUDY SKILLS

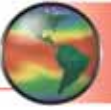
Learning new words

A good way to learn new words is to break down the word into parts.

Thermohaline has two parts:

Thermo- = temperature

-haline = salt



6.2 Section Review

1. The Sun is important in creating wind and ocean currents. Is this statement true or false? Explain your answer.
2. What role do ocean currents play in weather patterns? (Hint: Why is the weather in England similar to the weather in New York?)
3. What is the Coriolis effect? How does it affect paths of surface ocean currents?
4. Name the five major oceans. How much of Earth's surface is covered by ocean water?
5. Define surface ocean currents. From what two processes are they created?
6. Describe the process of expansion.
7. What is a gyre?
8. In what direction do gyres move in the southern hemispheres?
9. The surface ocean currents move heat energy away from where?
10. What is another name for deep ocean currents? What two factors drive them?
11. If a mass of ocean water is cold and salty, what will it do? Where on Earth's surface is this event common?
12. If a mass of ocean water is heated by the Sun and some water evaporates, what happens? Where on Earth's surface is this event common?
13. Research the answers these questions.
 - a. In Early American history, how was mail service *expedited* (made quicker) between Europe and America once ocean currents were observed and studied?
 - b. Where is the Sargasso Sea and what is interesting about it?



Palm Trees in Scotland?



Palm trees are common in Southern California, Florida, and other tropical locations—but could there be palm trees in a country as far north of the equator as Scotland? Scotland is a very small country located in the northern third of Great Britain's islands. Do some research to find out if there are palm trees in Scotland, and if so, explain how this could happen.

6.3 Wind and Weather

The combination of wind, water, and temperature creates Earth's weather patterns. The Sun is the major source of energy for weather. **Weather** is a term that describes the condition of the atmosphere in terms of temperature, wind, and atmospheric pressure. What is the weather like today in your town?

Wind

What is wind? **Wind** is the flow of air that occurs as a result of unequal pressure in the atmosphere. Wind flows from an area of high pressure to an area of low pressure.

Heating and cooling The Sun warms Earth's surface. Air near the warmed ground expands and becomes less dense. The less-dense air rises. Surrounding air is drawn in to take the place of the air that rose from the ground. Eventually the warm, less-dense air from the surface cools. The same chain of events that made the air rise now works in reverse and the air sinks back to the ground.

Unequal pressure When warm air rises from Earth's surface, an area of low pressure is created. This lower-pressure area draws in air from surrounding higher-pressure areas. Eventually the warm air that rose from the surface cools and becomes denser. This dense, cool air sinks back to the surface causing an area of high pressure. This new high pressure may become the source of more wind.

Thermals A small upward flow of warm air is called a **thermal**. Gliding birds like hawks often ride a thermal as they hunt for food. Pilots of sailplanes (which lack an engine) fly by riding the same thermals that gliding birds do (Figure 6.7). In fact, the pilots look for gliding birds to find these invisible air currents. Thermals are usually not stable and come and go over a short period of time.

VOCABULARY

weather - the condition of the atmosphere as it is affected by wind, water, temperature, and atmospheric pressure.

wind - air that flows, often because of heating and cooling of air or unequal air pressure.

thermal - a small heat-driven air current.

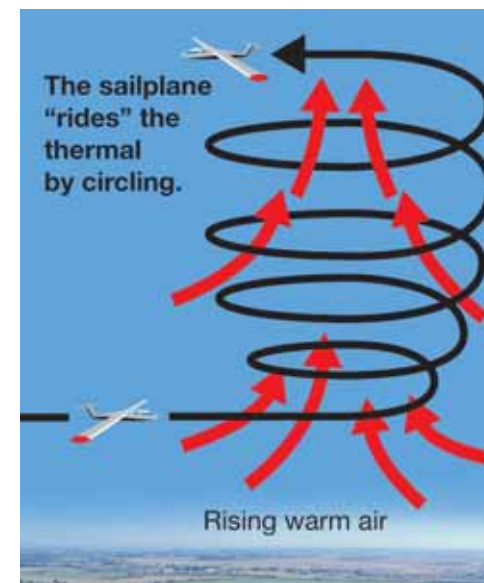
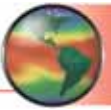


Figure 6.7: A thermal is a rising column of warm air. Gliding birds and sailplanes "ride" thermals.



Convection in the atmosphere

Small convection currents Thermals can be described as small convection currents in the atmosphere. Heated air near a surface becomes less dense than the colder air above it. The heated air rises, forcing the colder air to move aside and sink toward the ground. Then this colder air is warmed by the surface, and it rises. A thermal is created. As you learned on the previous page and in Chapter 4, hawks often ride these convection currents (Figure 6.8).

Global convection currents Thermals form on a local level. Convection currents form on a global scale. These form as a result of the temperature difference between the equator and the poles. Warm, less-dense air at the equator tends to rise and flow toward the poles. Cooler, denser air from the poles sinks and flows back toward the equator.

Convection cells The giant circles of air from the equator to the poles are complicated by Earth's rotation. Because of the rotation, the warm air from the equator doesn't make it all the way to the poles. The combination of global convection and Earth's rotation sets up a series of wind patterns called **convection cells** in each hemisphere. The turning Earth also changes the direction of airflow causing the path of the wind to be curved as it moves from high to low pressure.

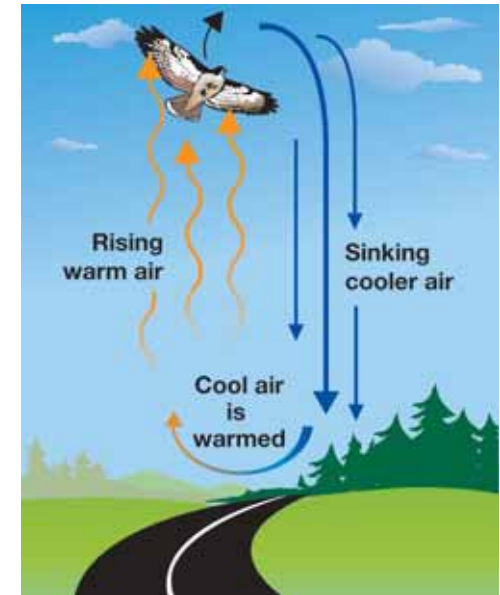
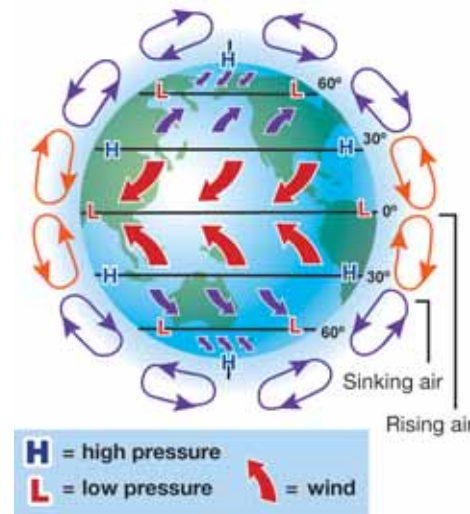


Figure 6.8: A thermal is the result of convection.

VOCABULARY

convection cells - large wind patterns in Earth's atmosphere caused by convection.

Air and water vapor

Water vapor Water in gas form is called **water vapor**. During a rainstorm, puddles often form on sidewalks and streets. The puddles eventually “disappear.” Where does the liquid water go? The liquid water changes to a gas and mixes with the air (Figure 6.9).

How much water vapor can air hold? Since air often contains water vapor it is helpful to compare an air mass to a sponge. Warm air is like a big sponge that can contain a lot of water vapor. Cold air is like a small sponge that can contain less water vapor. Air that contains the maximum amount of water is *saturated*. Like a soggy sponge, saturated air can’t hold anymore water vapor. If more water vapor is added to saturated air, the water vapor will turn back into liquid and form droplets.

Relative humidity *Relative humidity* is a measure of how much water vapor an air mass contains relative to the total amount of water vapor it could contain at a certain temperature. Let’s say a warm air mass contains twenty-five percent of the total amount of water vapor it could contain. If this warm air mass cools, its volume will get smaller. However, the air mass will have the same amount of water vapor. Therefore, the relative humidity value increases.

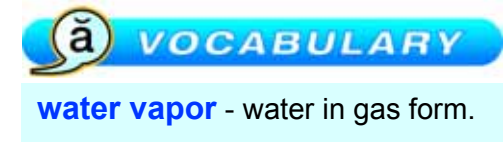
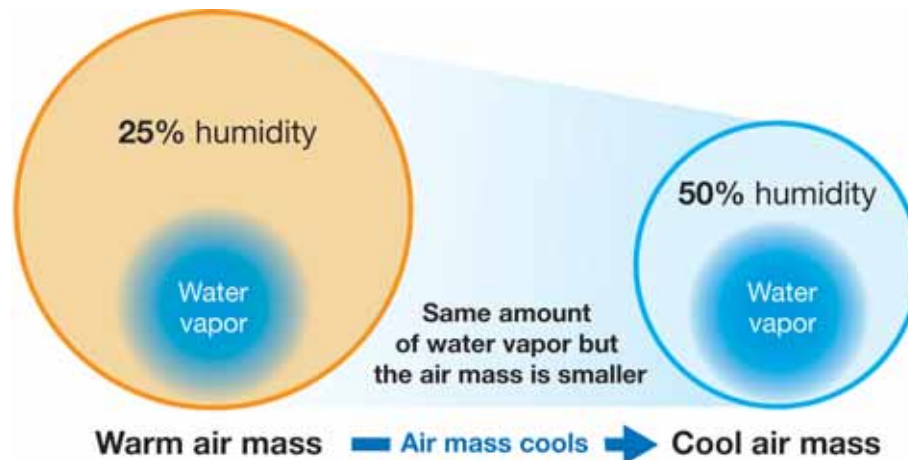
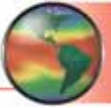


Figure 6.9: When a puddle dries, the water becomes water vapor in the atmosphere.

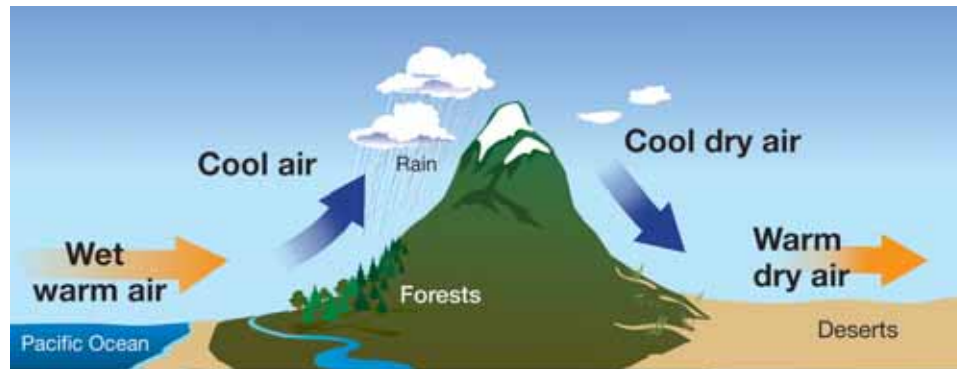


Rain

How does rain form? Rain is the result of a cooling air mass. As the temperature of the air mass decreases, it gets smaller. At some temperature, the air mass humidity is 100% and it is *saturated* with water vapor. If the air mass cools even more, the water vapor will form water droplets. Tiny droplets form a cloud or fog. Larger droplets fall as rain. Cooling an air mass is like wringing out a wet sponge.

After rain Suppose an air mass passes over warm ground after it has rained a lot of water. The air mass now contains only a little water vapor. As the temperature of the air mass increases, it gets bigger but the amount of water vapor it has stays the same. Therefore, the humidity of the air mass is extremely low.

From the ocean over a mountain Warm, moist air crosses over the Pacific Ocean and reaches the coast. At first the air mass flows up the western side of a mountain which has a lot of trees and plants. Cool temperatures at the top of the mountain cause the mass to decrease in size so that water vapor becomes first a cloud and then rain droplets. The resulting cool, dry air mass sinks down the eastern side of the mountain into warm temperatures. The land that this dry air passes over will have a dry climate.



SOLVE IT!

A cool (10°C) air mass contains 80% of the water it could contain. The air mass warms to 30°C .

1. Does the volume of the air mass decrease or increase when the temperature goes up?
2. Does the relative humidity of the air mass increase or decrease when the temperature goes up? (Assume that the amount of water in the air mass stays the same.)

Hint: draw a diagram similar to the one on page 126 to help you answer these questions.

Weather

What is weather? *Weather* is caused by the effects of wind, water, temperature, and atmospheric pressure. The weather in a certain location is another way of describing what the atmosphere is doing at a certain time.

Weather transports heat energy The oceans are the most important source of water vapor in the atmosphere. Huge amounts of water vapor formed by evaporation near the equator carry tremendous amounts of heat energy. The water vapor forms clouds and releases heat energy wherever it changes back into rain (liquid water). In this way, wind systems carry moisture and work with surface ocean currents to move large amounts of heat energy all over Earth.

Weather vs. climate What is the difference between weather and climate? Both terms describe the temperature, precipitation, and wind that we feel. The main difference is time. Weather can change daily. **Climate** describes the long-term record of temperature, precipitation (rain or snow), and wind for a region. Climate changes slowly and is nearly the same from one year to the next. What is the climate like where you live? What is today's weather report? How are your answers to these questions similar and different?

What is a meteorologist? When you hear the word *meteorologist*, do you think of a television weather reporter? Many radio and television weathercasters are professional meteorologists, but others are reporters who are passing on information provided by the National Weather Service or private weather forecasters. A **meteorologist** is a person with specialized education who uses scientific principles to explain, understand, observe, or forecast Earth's weather. A meteorologist has a bachelor's degree (or higher) from a college or university. Many meteorologists have degrees in physics, chemistry, mathematics, and other fields.

VOCABULARY

climate - the long-term record of temperature, precipitation, and wind for a region.

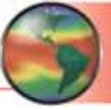
meteorologist - an individual who uses scientific principles to forecast the weather.

Surviving a desert climate

Did you know that the desert is home to more different types of animals than any other place except the rainforest? How can animals survive in such a hot climate?



Jackrabbits have big ears. When the rabbit sits in the shade, the blood running under the surface of the ears is cooled, lowering the animal's body temperature. Use the library or Internet to learn how other animals are able to survive in this climate.



6.3 Section Review

1. Define wind. Draw a diagram that illustrates how wind is created.
2. What are small-scale and large-scale wind currents called?
3. Do convection currents connect the poles all the way to the equator?
4. What is water vapor?
5. Which holds more water vapor, a warm air mass or a cold air mass?
6. When the air is filled to capacity with water vapor, it is said to be _____.
7. What does it mean for the relative humidity of an air mass to be 70%?
8. If the temperature of an air mass increased by 20°C, would the relative humidity increase or decrease? Explain your answer.
9. An air mass cools to the point where it becomes saturated. What might happen next?
10. Draw a diagram of what happens when an air mass moves from the ocean over a mountain.
11. What is the most important source of water vapor in the atmosphere?
12. What is the main difference between weather and climate?
13. What is a meteorologist?
14. Research: What is a rainshadow desert? Where is one located in the United States?

! CHALLENGE

Look at the illustration below. Which city would receive more rain per year—Olympia or Yakima? Explain your answer. Go to the Internet and find out what the average rainfall actually is for each of these cities.





Weather Forecasting: The Heart of Meteorology

Neither rain nor sleet nor cold shall keep a mail carrier from doing his job (or you from walking the dog). The same can be said of your local meteorologist. Every day meteorologists broadcast weather reports. Millions of people plan what they will wear, what they will do after work or on the weekend, and if they will carry their umbrellas based on those reports.

But only a very few meteorologists in the United States wear a microphone or appear on camera at work. Most meteorologists work for the National Weather Service (NWS), a government agency that is part of the National Oceanic and Atmospheric Administration (NOAA).



NOAA was formed in 1970, and its mission is to predict changes in the atmosphere and ocean environments. This task includes predicting the weather.

Meteorologists observe and study Earth's atmosphere and its phenomena. Many work to forecast the weather and changing climate conditions, while others do scientific research. They try to understand how atmosphere affects environment. They study the constant changes in our atmosphere. They create computer models to predict how storms will form, when rivers will flood, and what areas will suffer droughts. Their work can go far beyond telling an audience whether it will be sunny or cloudy tomorrow.

Meteorologist at work

Julie Dian is a meteorologist who works at the National Weather Service Ohio River Forecast Center in Wilmington, Ohio. One of her responsibilities is to compare readings of temperature, winds, atmospheric pressure, precipitation

patterns, and other variables. She draws conclusions and makes predictions about local weather with this data.

Dian and other meteorologists use many tools of their trade. They gather information in many different ways.

- More than 11,000 volunteers from all over the United States and beyond provide daily reports. They phone their reports to warning and forecast centers.
- Satellites collect data and record images. The TV images you see of hurricanes in the Gulf of Mexico or Caribbean Sea, for instance, are provided by cameras on satellites high above Earth.
- Ground-based radar scans for precipitation and clouds.
- Weather balloons are launched to gather data.

Up, up, and away

Wind direction, air pressure, temperature, and humidity of air masses high in the sky all affect our weather down on the ground. Weather balloons can monitor these conditions.

Weather balloons are released at least twice a day from a structure (like the one at right) at the National Weather Service office in Wilmington. Additional balloons are released more often during severe weather.

The balloons are filled with helium. When they are inflated on the ground, they are about 2 meters across. As they rise, they grow to a diameter of about 6 meters. This is because the air pressure is lower at higher altitudes, so the gas inside the balloon expands.



One type of balloon carries a *radiosonde*, which is a miniature radio transmitter with instruments on it. The balloon rises 27,400 meters (90,000 feet) or higher. All along the way, the radiosonde measures data such as temperature, air pressure, and humidity and transmits the measurements to a ground receiver or satellite.



Dian uses a theodolite to track balloons that have been launched from her center. A *theodolite* is a surveyor's instrument for measuring angles and, in this case, for

following the altitude and movement of the balloon. In this photo, Dian shows a student the radio theodolite at the NWS office. In her left hand she holds an unopened weather balloon. The theodolite in the photo shows the wind speed at different altitudes. Some theodolites contain telescopes, others have radio receivers.

Methods for predicting

There are several different ways to predict the weather. All of the information collected—from volunteers, radar, satellites, and weather balloons—is used in different models. Some of the older methods use historical information to predict future weather events. The most complex of these involves finding very similar conditions at some point in the past. Then the weather is predicted based on what happened in the “same” situation back then.

Today, computers have made forecasting much more successful. Numerical weather prediction, or NWP, is used to create computer models of the atmosphere. With NWP, many variables are considered. Air temperatures at different altitudes, wind speeds, humidity, high and low pressure areas—all this is fed into a computer. The computer creates a complex model of the atmosphere and provides the most accurate forecasts available.



Questions:

1. What is the mission of the National Oceanic and Atmospheric Administration?
2. What causes weather balloons to grow in diameter from 2 to 6 meters?
3. Why are today's weather forecasts more accurate than in the past?



CHAPTER ACTIVITY

Circumnavigating the Globe

The map on this page shows the world surface currents. Cold currents are marked in blue and warm currents are marked in red. You will use this map to plot a sailboat route for *circumnavigating* the globe from the coast of Massachusetts to the coast of California. This means you can't just go around North America. You need to go around the world!

Materials

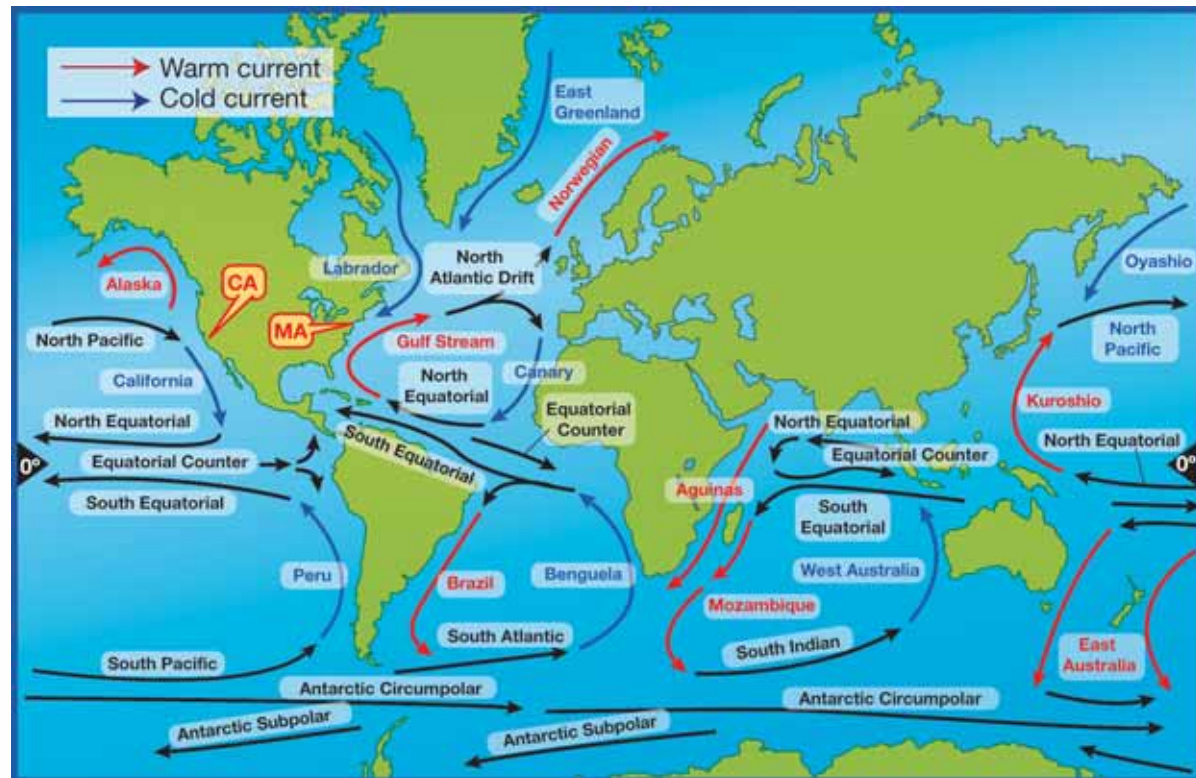
Bathymetric map and colored markers or pencils (red, blue, and black)

What you will do

1. With a partner, study the map on this page. Find the coast of Massachusetts. Then, find the coast of California.
2. Large surface currents are mostly driven by winds. With your partner, you need to decide what currents to use so that your sail takes you from Massachusetts to California. Before you get started on "sailing around the world" come up with a name for your sailboat.
3. As you choose currents, draw them on your bathymetric map. Use a red to indicate a warm current, blue to indicate a cold current, and black to indicate other currents. Also use your black pencil or marker to label each current you draw.

Applying your knowledge

- a. Do the warm currents flow towards or away from the equator? Do the cold currents flow towards or away from the equator?
- b. On which side of the ocean basins are warm currents found? On which side of the ocean basins are cold currents found?
- c. List any uninterrupted currents (they flow around the globe without being blocked by land)?
- d. How many currents did you need to use to sail from Massachusetts to California? How does your route compare with the routes used by other teams?



Chapter 6 Assessment

Vocabulary

Select the correct term to complete the sentences.

surface ocean current	rotation	thermals
evaporation	convection cells	deep ocean currents
water vapor	revolution	meteorologist
climate	weather	
gyre	wind	

Section 6.1

1. Earth spinning once on its axis is a _____.
2. One Earth _____ represents a year.

Section 6.2

3. The Gulf Stream is an example of a _____.
4. In the ocean, _____ causes tropical waters to become more salty.
5. A current that moves within the ocean is called a _____. Another name for this kind of current is thermohaline current.
6. A circular ocean current is called a _____.

Section 6.3

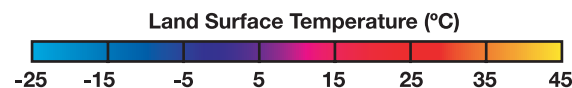
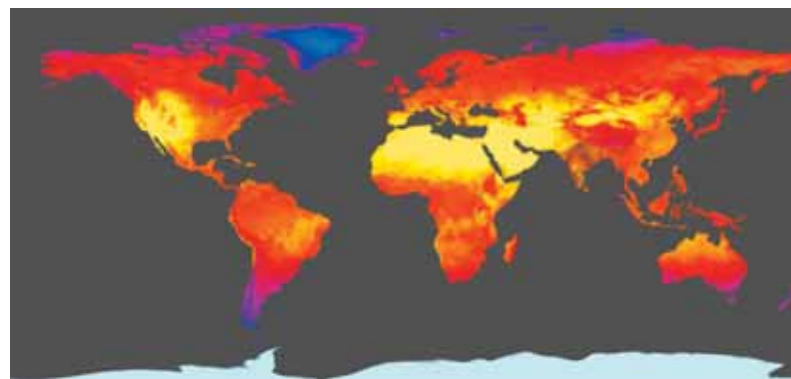
7. _____ is water in gas form.
8. The long-term record of temperature, precipitation, and wind for an area is known as _____.
9. Air that flows, often because of unequal heating, is called _____.
10. Gliding birds use small heat-driven airflows called _____ to hunt for food.
11. _____ describes changes in temperature, precipitation, and wind for an area over a few days.

12. _____ are large wind loops that are heated and rise at the equator and cool and sink at higher latitudes.
13. A _____ uses scientific principles to forecast Earth's weather.

Concepts

Section 6.1

1. Why is it important that Earth have an atmosphere?
2. Could water exist as a liquid on Earth if it did not have an atmosphere?
3. According to this land surface temperature image (from the first page of Section 6.1), what large area of the United States had the highest temperatures in July 2003?



July 2003. Image based on data from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) Sensor. Credit: NASA

4. Earth's main source of heat energy is the Sun. Why doesn't Earth get too hot? List two reasons in your answer.
5. What are greenhouse gases?

6. Draw a diagram of Earth revolving around the Sun. Be sure to show Earth's axial tilt. Indicate on your diagram when it will be summer in the southern hemisphere.

Section 6.2

7. Name two ways that heat is moved around Earth.
8. Earth's oceans:
- Name Earth's five oceans.
 - How much of Earth's surface is covered by oceans.
 - How much of Earth's water is in the oceans?
9. Why does water expand at the equator?
10. What two factors cause the Gulf Stream to move away from the equator?
11. Which motion of Earth causes surface ocean currents to flow in a circular pattern: the rotation of Earth or the revolution of Earth?
12. Why are deep ocean currents also called thermohaline currents?

Section 6.3

13. What two factors cause wind?
14. A weather map shows a high pressure area located over Town A and a low pressure area located over Town B. Which direction will the wind blow? From Town A to Town B or from Town B to Town A?
15. Why is the equator a low air pressure area? Does air rise or sink at the equator?
16. What is a convection cell?
17. A weather report states that the relative humidity is forty percent. What does this value mean?

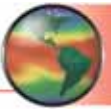
18. An air mass is described as being saturated. This means that the air mass contains _____ percent of the amount of water vapor it can hold.

- 100
- 1000
- 0
- 10

19. What is the relative humidity of an air mass that has just produced rain? High or low?

20. For each of the following statements write whether it describes the weather or the climate for an area:

- The temperature today is 40°C.
- In the northeastern United States, it often snows in the winter.
- It is supposed to rain tomorrow.
- Hurricanes commonly occur in tropical regions like the Caribbean and Florida.
- Where would you like to live: in a place where there are polar bears (the tundra) or in a place where you can see toucans (the tropical rainforest)?
- The desert southwest has very low humidity while the southeastern United States tends to have high humidity.
- Today's relative humidity was 80%.
- The average yearly temperature for Nome, Alaska is lower than the average yearly temperature for Paris, Texas.



Math and Writing Skills

Section 6.1

- What is the total range in surface temperature on Earth according to Figure 6.1?
 - 188 degrees Celsius
 - 136 degrees Celsius
 - 40 degrees Celsius
- What was the range of temperature for Earth's surface for July 2003 based on the Land Surface Temperature graph?
- In Section 6.1, you learned how long it takes for Earth to revolve around the Sun. Based on what you learned and doing conversion calculations, fill in the table below (one day = 24 hours).

Time for one revolution around the Sun	
Number of years	
Number of days	
Number of hours	

Section 6.2

- One of the deep ocean currents is called the Antarctic Circumpolar Current. It is so called because it circles Antarctica. It aids in the circulation of deep and middle-range waters between the Atlantic, Indian, and Pacific Oceans. The average speed is about 10 cm/s. How many kilometers would this represent for a year's time?

- Curtis Ebbesmeyer studies ocean currents by tracking different objects—like bathtub toys and sneakers—that have spilled into the ocean off of ships. In January of 1992, he tracked 28,800 rubber duckies and other floating toys in the mid-Pacific Ocean. Between the years of 1993 and 2004, 111 of these floating toys were found in Sitka, Alaska. They had been 2,200 miles adrift.

- If the floating toys traveled at 7 miles per day. How long would it take to travel 700 miles?



- It took the floating toys 3 years to complete the gyre in the Pacific—called the Subtropical Gyre—and the speed they traveled at was approximately 7 miles per day, then about how many miles does this gyre represent?

Section 6.3

- In what general direction does wind blow between the latitudes of 30 degrees and 60 degrees north?
- An air mass can hold at total of 20 grams of water vapor per kilogram of air. Right now the air mass has 5 grams of water vapor per kilogram of air. What is the relative humidity of this air mass?
- In the air mass described in question 7, the water vapor increased to 20 grams of water vapor per kilogram of air. What is the relative humidity now?

Chapter Project—Mobiles and Water Tricks

Project 1: A seasons mobile

Make a mobile that represents Earth's four major positions in relation to the Sun. Make an axis through each Earth, draw the equator, the Tropics of Cancer and Capricorn. Use the diagram at the end of Section 6.1 to help you design your mobile.

Project 2: A water trick

See if you can setup two jars inverted on one another such that the liquid in one jar does not mix with the liquid in the other. *Important hints:* Ask an adult to help you. Work in a tray to catch any spills. Use two same-sized baby food jars that have been cleaned. Fill them to the rims with water. Make choices about the temperature and saltiness of the water in each jar. Add red food coloring to jar A and blue food coloring to jar B. Place an index card over the mouth of the jar B. Using both hands to hold the card to the rim of jar B, invert it on top of jar A. Gently pull out the card. Do the two volumes of water mix or stay separated?

