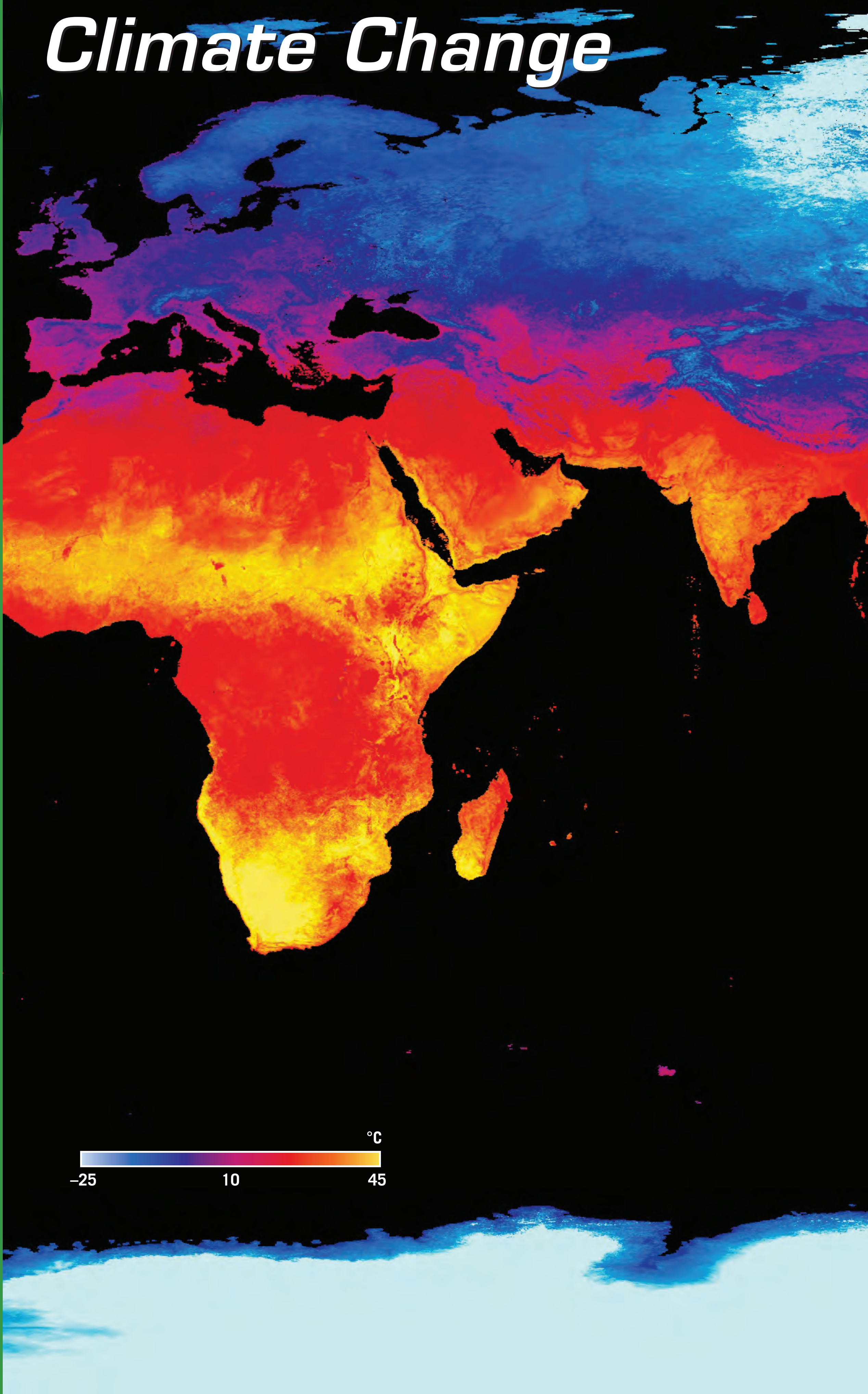
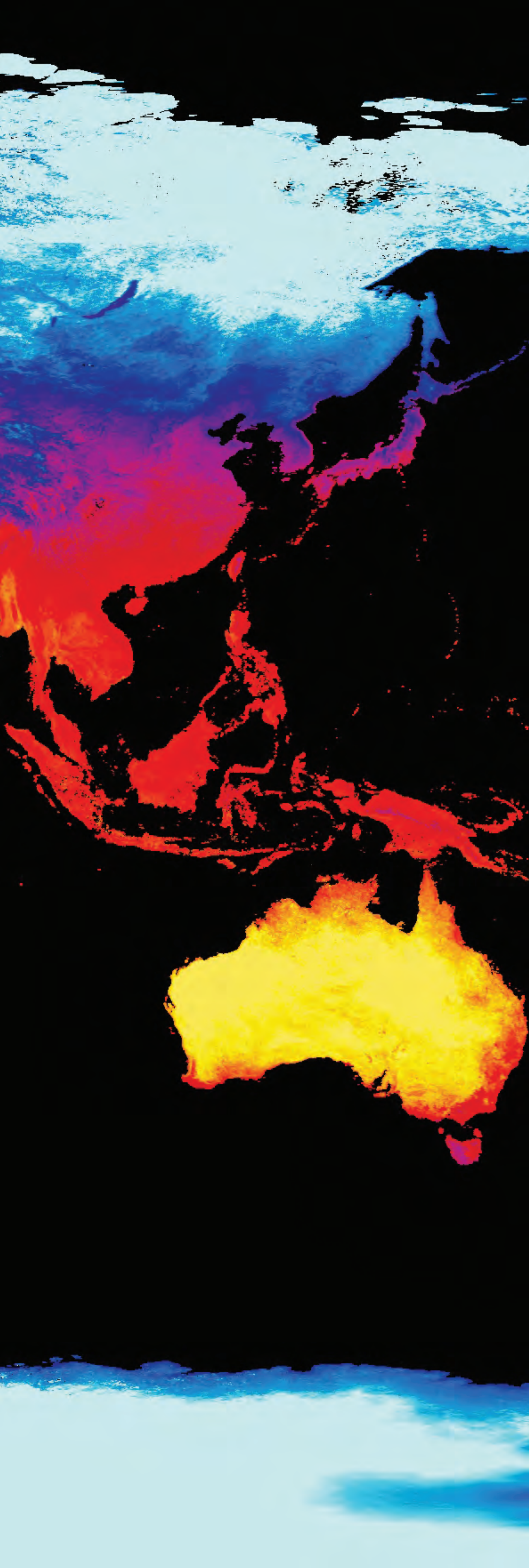
UNIT C

Climate Change



Satellites can detect Earth's surface temperatures. This NASA map shows the average daytime December temperatures between 2000 and 2008.



Contents

Unit Task

Climate change is a dynamic and rapidly evolving field of study, as well as a societal, economic, and political issue. Reducing our impact on Earth is essential to addressing climate change. Over the next few years, we may develop new ways to minimize our impact on Earth, while discovering as yet unknown effects of climate change on natural and human systems. Governments may also change their policies. International climate change organizations will continue to develop intensive mitigation and adaptation projects.

For your Unit Task, you will research a new technology, scientific study, economic event, or government policy related to climate change that has been highlighted in the media over the last 12 to 18 months. As you study this unit, you will assemble a portfolio of information that interests you. You will write a supplement to this unit that could be used by students taking this course next year.

Essential Question

How have technologies and issues related to climate change developed over the last 12 to 18 months?

Exploring

The Ward Hunt Island ice shelf, 20 km^2 in area, between Ellesmere Island and Ward Hunt Island (in the distance). This photo was taken in early July 2008.

Ice shelves are breaking off in both the Arctic and the Antarctic. In March 2008, over 400 km^2 of the Wilkins Ice Shelf broke away from Antarctica.

Disappearing Ice

In July 2008, a huge slab broke off the ice shelf attached to Ward Hunt Island off the coast of Ellesmere Island in Nunavut. This was one of the largest remaining ice shelves in the Arctic.

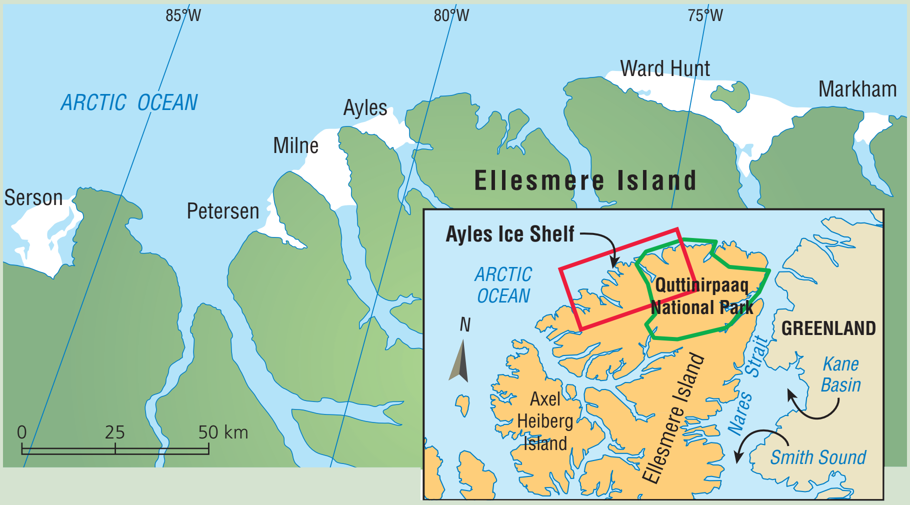
An ice shelf is a thick slab of ice that is attached to land. Part of it may float on the ocean or sit on the ocean bottom. Ice shelves form where sea ice piles up against a coastline or where glaciers flow past the coastline into the ocean. The bottom layers of ice of the Ward Hunt Ice Shelf were about 4500 years old, according to evidence collected by scientists. Usually, ice shelves melt slowly every summer, and small pieces fall off where the ice floats on the ocean. But rarely in the past have huge slabs, measuring several square kilometres in area, broken off completely and floated away. Scientists estimate that where there was once 9000 km^2 of ice shelves on Ellesmere Island, less than 1000 km^2 remain.

According to researchers, five ice shelves remain in the Canadian Arctic. All are retreating. Originally, these five ice shelves were one, called the Ellesmere Ice Shelf. In the early 20th century, the ice shelf extended about

Ward Hunt Island Ice Shelf in mid-August 2008, after the ice shelf broke off and floated away

500 km along the coastline of Ellesmere Island. Since then, over 90 percent of the ice shelf has disappeared. No new ice is forming, which is a sign that Earth is warming. As the ice melts, the white, sunlight-reflecting surface of the vast ice sheets is replaced by dark, sunlight-absorbing water.

Climate scientists are becoming concerned because the Arctic Ocean has changed dramatically. Over the past 30 years, the amount of summer ice cover has decreased by almost half. The Arctic Ocean and the oceans around Antarctica are warming. Thus, ice shelves are also melting more quickly. Because this is happening at both ends of Earth, scientists have determined that it is happening everywhere on Earth. They believe that the ice shelves are breaking because of a phenomenon called climate change, a gradual, long-term change in Earth's average weather conditions.



The north coast of Ellesmere Island showing the location of the ice shelves in 2008

C1 STSE Science, Technology, Society, and the Environment

The Message in the Media

Climate change is an issue that is often seen in the media. It appears in the news, in magazine articles, on Internet sites, and in television documentaries. You may have noticed that different media tell somewhat different versions of the same story. It is important to think critically about all media.

1. Form a group of 3–4 and gather markers, a piece of chart paper, and tape. Your teacher will give you newspaper and magazine articles.
2. Write the words "climate change" in the middle of the chart paper.
3. Discuss the implications of the Exploring section.
4. Discuss what the group members know about climate change and what their media sources were.
5. Create a collage of articles, drawings, and key words to represent the group's current knowledge of climate change.
6. Have each member of the group add at least one question that he or she would like to investigate during this unit.
7. What is the media's role in educating the public about climate change?
8. Do you think the general public is interested in stories about climate change? Why or why not?
9. What types of media do you think are the most effective in reaching the public with information about climate change?
10. Why is it important to consider different views about stories in the media?

7 Earth's climate system is a result of interactions among its components.

Today's weather can bring a sudden storm or a sunny day. Your area's climate, however, is the average temperature and amount of precipitation (rain, snow, and hail) over a long time.

Skills You Will Use

In this chapter, you will:

- build a model to illustrate the natural greenhouse effect
- investigate the effects of heat transfer within the hydrosphere and atmosphere
- investigate the influence of ocean currents on local and global heat transfer and precipitation patterns
- classify the climate of your region

Concepts You Will Learn

In this chapter, you will:

- describe the principal components of Earth's climate system
- describe and explain heat transfer in the hydrosphere and atmosphere and its effects on air and water currents
- describe the natural greenhouse effect and explain why it is important

Why It Is Important

People, including scientists, economists, and politicians, are discussing climate and climate change. An understanding of weather and climate, the natural greenhouse effect, and the global movement of heat will help you to participate in this discussion.

Before Reading

Thinking Literacy

Connecting to Prior Knowledge

Good readers recognize when a topic is familiar. They connect new information to things that they already know about the topic.

Preview the subheadings for Section 7.1, choosing one key word from each. Now, use the words to create a probable passage — a statement or prediction about the content of this chapter based on your prior knowledge.

Key Terms

• albedo • atmosphere • biome • biosphere • climate
• conduction • convection • Coriolis effect
• greenhouse gases • hydrosphere • insolation • lithosphere
• natural greenhouse effect • net radiation budget • radiation
• solar radiation • thermal energy • weather • wind

7.1 Climate

Here is a summary of what you will learn in this section:

- The climate of a region is the long-term average of regional weather conditions.
- Climate affects all organisms that live in that region.
- The Sun provides all of the energy necessary for life on Earth.
- Earth's biosphere provides conditions suitable to support life.
- Earth's climatic regions are classified into biomes.

Figure 7.1 It's best to plan a visit to an amusement park in good weather. Amusement parks shut down many of the open-air rides during rainstorms.

Weather Effects

Imagine that you and your friends are going to an amusement park today (Figure 7.1). You checked the weather forecast three days ago, and it said that today would be sunny and warm. All of you have lots of fun enjoying the rides in the great weather. But in mid-afternoon, dark clouds start to cover the Sun. First you hear thunder, a distance away. Then, the amusement park shuts down the rides you like best. As you make your way to the bus stop, the rain comes pouring down. You are drenched in seconds. Lightning flashes across the darkened sky, and the thunder booms.

Once you are on the bus, your friends accuse you of not checking the weather forecast. You say you did, but three days ago. A while later, you arrive at your stop and get off the bus, only to notice that the sky has cleared and the sun is reappearing. Luckily, you had your hands stamped at the park, so you can hurry back to enjoy the rest of your day.

Almost everyone uses weather forecasts to help plan daily activities. Weather changes quickly, so weather forecasters, called meteorologists, prepare forecasts at least three times a day for more than 160 communities in Ontario (Figure 7.2).

Figure 7.2 Sometimes, weather can change very quickly. Here, the coming storm creates a beautiful sky.

Sometimes, however, we need to plan events, such as skiing competitions and track-and-field days, weeks or even months in advance. Weather forecasts cannot help with these plans.

C2 Quick Lab

What Is the Weather Today?

Purpose

To determine the usefulness of different types of weather reports and forecasts

Materials & Equipment

- forecasts from several radio stations
- TV news weather reports
- forecasts from newspapers
- ***ScienceSource*** for Internet weather reports

Procedure

1. With a partner, choose one forecast from each source.
2. Using a checklist such as Table 7.1, compare the contents of the different forecasts.

Table 7.1 Comparison of Weather Reports

	Radio	TV	Newspaper	Internet
Number of days				
Temperature: High				
Temperature: Low				
Precipitation: Amount				
Precipitation: Type				
Wind Speed				
Wind Direction				
Wind Gusts				
Humidity				
Barometer Reading				

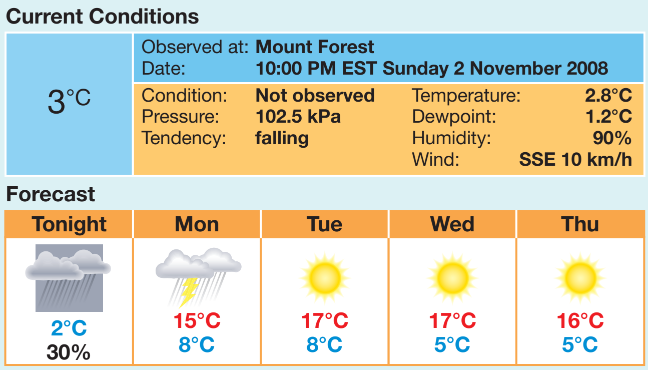


Figure 7.3 Local weather conditions can be predicted by meteorologists a few days in advance.

Questions

3. Which weather report is most useful in the following situations?
   - You are going to school.
   - You want to play soccer.
   - You want to go camping next weekend.
   - You are considering buying tickets to an outdoor concert.
   - You need to plant some trees.
   - You want to organize a car-wash fundraiser.
4. Why is one type of forecast more useful than another in the above situations? Which forecast is the most useful?
5. Weather forecasts typically extend about five days ahead. How would you plan an outdoor activity if you needed to pick a date a month in advance? A year in advance?
6. Describe the weather conditions that are typical for the season. Are today's predicted weather conditions typical for the season? Why or why not? Be prepared to share your analysis with the class.

Weather and Climate

Although weather and climate are related, they are not the same thing. Think of all the clothes you own. Your entire wardrobe is dictated by the climate in Ontario. Everything from shorts and T-shirts to a heavy parka deals with the range of climatic conditions we encounter over a year. The weather, however, dictated what you are wearing today.

Weather refers specifically to the environmental conditions that occur at a particular place at a particular time. These include temperature, air pressure, cloud cover, and precipitation. The morning weather forecast may predict sunny, warm conditions, while the afternoon forecast for the same area may call for increasing cloud cover overnight and the possibility of precipitation.

Most people are familiar with what weather is and how it affects their daily lives. The effects of weather are immediate and obvious. If a severe snowstorm is forecast, you may decide to stay at home. If a weather forecast calls for rain, you may decide to take an umbrella or wear a raincoat when you go out.

Climate, and how it affects your life and the lives of other organisms, may not be as familiar to you. Knowing that your community gets an average of 75 mm of rain in June and the average June temperature is 19.3 °C is of little use when planning a June birthday party. These data are part of the climate of your area. **Climate** is the average weather conditions that occur in a region over a long period of time, usually a minimum of 30 years. The description of the climate of a region includes average monthly temperatures and precipitation, average wind speed and direction, and a variety of other data. Climate is studied by climatologists, who also understand meteorology.

The climate of an area is affected by many factors. The four main factors are:

- latitude
- elevation
- the air masses that flow over the area
- the area's nearness to large bodies of water

WORDS MATTER

The word "weather" started with the early root *wē*, which means to blow. *Wedram*, an early German word, meant wind or storm. *Wedram* became *weder* in early English.

WORDS MATTER

"Climate" originates from the Greek word *klima*, which means surface of Earth or region. The Romans changed the word to *clima*, which you can see in both "climate" and "acclimatize," which means to get used to new surroundings — to a new *clima*.

During Reading — Thinking Literacy

Make a Text-to-Text Connection

As you read about weather and climate, think about other sources you use to get information about these two topics. How is information about weather and climate presented on television, on the Internet, or in newspapers?

Learning Checkpoint

1. In this section, weather and climate were compared using the analogy of a person's wardrobe. Think of another analogy to describe the difference between weather and climate.
2. Explain your analogy to a partner, and discuss in what ways the analogy works well and in what ways it is weak.
3. What is a weather forecast, and when could it be important to you?

(a) (b)

Figure 7.4 Wintertime in Canada. (a) In the north, people wear parkas for warmth.
(b) Although southern Ontario also has snow and cold, the parkas that people wear are not as thick as those in the north.

How Climate Affects Your Life

If you were planning to visit or move to another part of the world, you would want to have an idea of that region's climate. Perhaps you and your family immigrated to Canada from a country with a very different climate. You probably made some adjustments after you arrived. For example, if you came from a warmer climate, you may not have experienced snow before you arrived and did not understand the need for warm clothing and specialized footwear (boots, skates, skis), especially for outdoor winter activities (Figure 7.4(b)). The plants and animals you see around you here may also be different from what you are used to.

Suggested Activity •
C4 Inquiry Activity on page 270

People in some parts of the world inaccurately associate Canada exclusively with a harsh winter climate (Figure 7.4). But in fact, all Canadians enjoy warm temperatures and sunshine for significant portions of the year (Figure 7.5).

The climate of a region determines the basic needs of people who live there. Clothing, agriculture, and housing are affected by the region's climate. Ontarians generally experience hot summers, cold winters, and more moderate temperatures in fall and spring. To deal with this, Ontarians equip themselves with a variety of clothing. Instead of local fresh fruits and vegetables, they rely on frozen, canned, stored, or imported produce during the winter and early spring. And they use different systems to heat, ventilate, and cool their buildings.

(a) (b)

Figure 7.5 The climate is warm to hot in Canada's summer. (a) People in Nunavut can wear light clothing.
(b) The water is warm enough for swimming at Outlet Beach in southern Ontario but not in the north.

The Sun: Source of All Energy

Both weather and climate depend on the amount of energy in a region. Almost all the energy on Earth is initially **solar radiation** — transmitted as waves that radiate from the Sun. Life as we know it depends on solar radiation. Different regions on Earth's surface receive different amounts of solar radiation. In general, regions at or near the equator receive more solar radiation per square metre than regions closer to the poles do (Figure 7.6).

Some of the solar radiation that strikes Earth is absorbed by Earth's surface. This solar radiation is converted to thermal energy in everything it touches. **Thermal energy** is the total kinetic energy of the particles in a substance. A quantity of a substance at a high temperature has more thermal energy than the same quantity of that substance at a lower temperature. Heat flows from a substance at a high temperature to one at a lower temperature. A tiny amount of the solar radiation is converted to chemical energy through photosynthesis in plants.

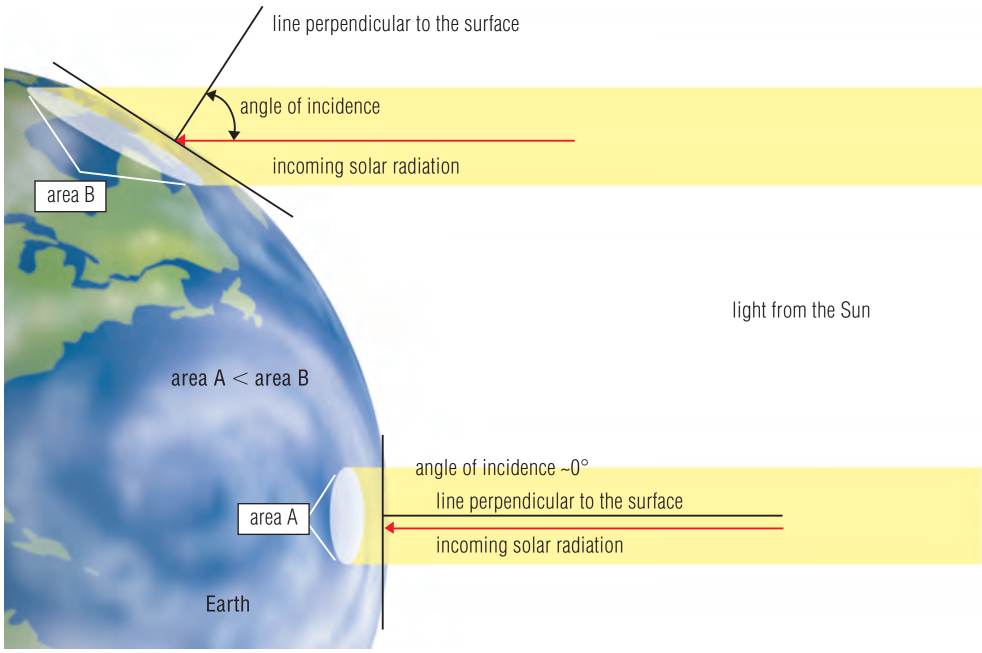


Figure 7.6 The angle of incidence of light from the Sun increases with distance from the equator. As a result, the same amount of solar radiation is spread out over a larger surface area at polar latitudes, such as area B, than at or near the equator, such as area A.

Earth's Biosphere

The climate of a region is affected not only by the amount of solar radiation it receives but also by interactions among components of Earth's biosphere. The **biosphere** is the relatively thin layer of Earth that has conditions suitable for supporting life. It is composed of all the living things on Earth and the physical environment that supports them. Other planets in our solar system do not appear capable of supporting life as we know it. Earth may be divided into four spheres for closer study (Table 7.2, Figure 7.7).

Table 7.2 The Spheres of Earth

Sphere	Explanation
Biosphere	bio = living, sphere = ball; the living layer around the planet; includes the atmosphere, lithosphere, and hydrosphere
Atmosphere	atmos = gas; the gas layer around the planet
Lithosphere	lithos = rock; the rock layer around the planet
Hydrosphere	hydro = water; the water layer around the planet

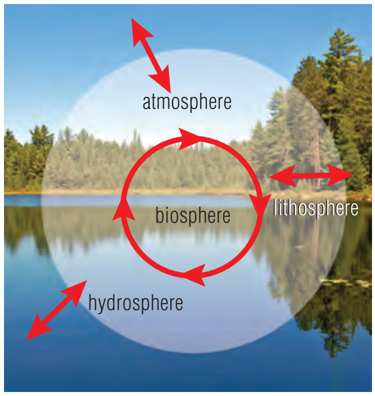


Figure 7.7 Earth's biosphere is home to all living things and the physical environment that supports them. All organisms live in the lower atmosphere, on the surface or just below the surface of the lithosphere, and in the hydrosphere.

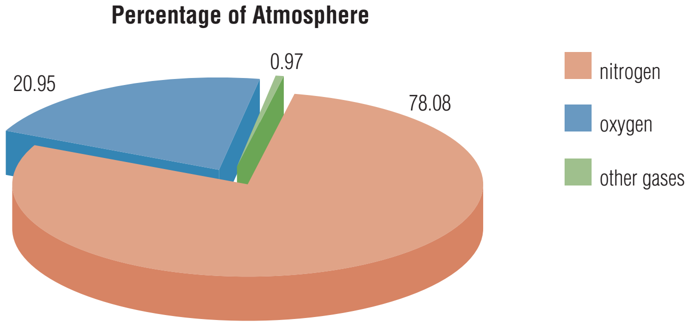


Figure 7.8 The main component of Earth's atmosphere is nitrogen gas. Because the amount of water vapour varies with temperature, it is not shown in this graph.

The Atmosphere

Air is the mixture of different gases found in Earth's atmosphere. The **atmosphere** is the layer of gases that extends outward about 300 km from the surface of Earth. The major gases found in this mixture are nitrogen and oxygen (Figure 7.8). Other gases found in trace amounts are argon, carbon dioxide, neon, helium, methane, and krypton. Water vapour is also a gas found in the atmosphere, but since levels of water vapour (humidity) can vary greatly, water vapour will be considered part of the hydrosphere in this book. Water vapour, oxygen, and carbon dioxide are essential for life.

In addition to these gases, the atmosphere also contains atmospheric dust, made up of abiotic (non-living) and biotic (living) particles. Examples of abiotic particles are soil particles and soot (sometimes called aerosols); examples of biotic particles are pollen and micro-organisms. Many of these particles are small (less than 0.66 mm in diameter) and solid. The amount of these particles in the air contributes to our air quality. Smog, a word combining "smoke" and "fog," occurs when soot particles combine with car exhaust in the air.

Just as the interior of Earth can be divided into the layers of core, mantle, and crust, the atmosphere can be subdivided into regions according to their distance from Earth's surface. These layers are described in terms of temperature, chemical composition, air movement, and density, which may differ from place to place. Figure 7.9 and Table 7.3 on the next page give information about these layers: the troposphere, stratosphere, mesosphere, and thermosphere.

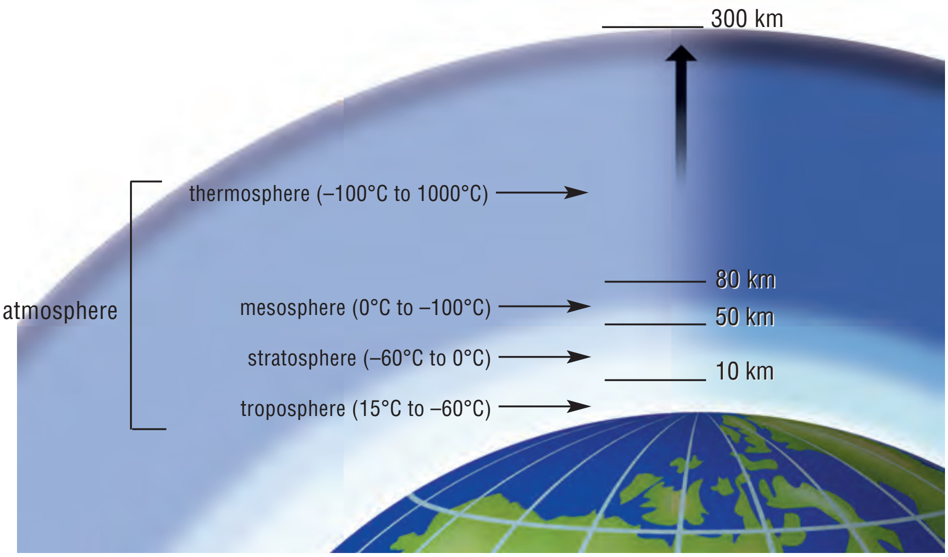


Figure 7.9 The layers of Earth's atmosphere do not have distinct boundaries but blend into one another. Values are the average altitudes for all of Earth as determined by the Centre of Atmospheric Science at the University of Cambridge, U.K.

Table 7.3 Summary of Earth's Atmospheric Layers

Layer	Average Altitude from Earth's Surface (km)	Temperature Range (°C)	Characteristics
Troposphere	0–10	20 to –60	• 80 percent of atmospheric gas by mass • can support life • contains most of the carbon dioxide and water vapour in the atmosphere • contains almost all of the atmospheric dust in the atmosphere • where weather takes place
Stratosphere	10–50	0 to –60	• contains most of the ozone gas in the atmosphere, which protects living organisms from damaging high-energy radiation • clumps of cells found but no other life • Air temperature increases with height as ozone gas absorbs ultraviolet solar radiation.
Mesosphere	50–80	0 to –100	• very little gas • Air is thin, and atmospheric pressure is low. • fewer oxygen molecules (O_2)
Thermosphere	80+	–100 to 1000	• very little gas • Gas particles are hot during the day and cold at night.

The Lithosphere

The **lithosphere** is the solid portion of Earth that floats on the semi-fluid portion of the mantle (Figure 7.10). The lithosphere is home to many micro-organisms, plants, and animals, including humans. It is the outer surface of Earth (its crust) plus the solid part of the upper mantle. It extends downward from Earth's surface and varies in thickness from as little as 5 km thick beneath parts of the oceans to as deep as 100 km beneath the continents. A few metres at the surface of the lithosphere are warmed by the incoming energy from the Sun. The rest is warmed mainly by the decay of radioactive elements in the lithosphere and mantle.

Movements in the lithosphere can affect climate. The science of plate tectonics describes how the different plates of Earth's lithosphere move over the mantle. When plates collide, they may push up mountains, although this can take many millions of years. The sides of mountains on which the wind blows receive most of the moisture from the clouds, while the leeward side can be dry (Figure 7.10). Also, most volcanoes occur where tectonic plates interact. Volcanic eruptions, such as the explosion of Mount St. Helens in Washington state in 1980, can spew millions of tonnes of ash high into the atmosphere, blocking the sun and cooling the global climate for a few years.

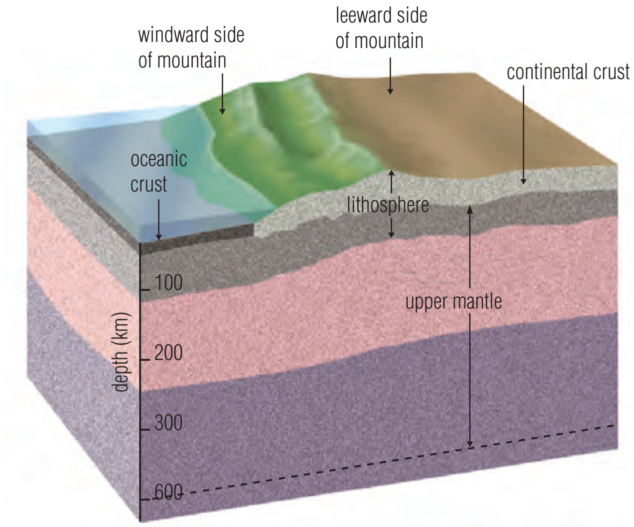


Figure 7.10 The lithosphere is the solid portion of Earth's crust and upper mantle.

The Hydrosphere

The **hydrosphere** includes all of the water on Earth. About 97 percent of this water is salt water in Earth's oceans. The other 3 percent is fresh water and includes liquid water, such as in groundwater, lakes, and streams, and frozen water, such as the ice in snow and glaciers.

Many different organisms, from whales to algae, live in the large water bodies of the hydrosphere. However, the vast majority of living organisms found in the lithosphere or atmosphere need water to survive and so also depend on the hydrosphere, even though they do not make their homes in it. The hydrosphere is warmed by incoming solar radiation.

During Reading — Thinking Literacy

Make a Connection to a Visual or Image

As you read about the biosphere, lithosphere, atmosphere, and hydrosphere, create an image or visual in your mind for each of these terms. Practise saying the term and naming your image to consolidate the concept or idea of each "sphere."

Interactions among the Biosphere's Components

Thinking about the atmosphere, lithosphere, and hydrosphere separately can help you understand the processes that occur on Earth. To get a better understanding of the systems of our planet, however, remember that these components continuously interact with one another. For example, water is present as water vapour in the atmosphere, where it plays a role in cloud formation and preciptation. It is also present in the soil and minerals of the lithosphere, where it erodes the rock and dissolves salts that plants can use as nutrients. Because these interactions are continuously changing, Earth is said to be dynamic.

Earth's Biomes

Although the biosphere provides environmental conditions that support life, these conditions are not the same everywhere on Earth. Thus, the types of life that can survive in different places are also not the same.

Take It Further

Choose a biome that interests you, and use Figure 7.11 to find out where it occurs in the world. Pick two or three of those places, and research the organisms that live there. Compare the organisms in these locations, and comment on how each is suited to live in that biome. Begin your research at ***ScienceSource***.

A **biome** is a large geographical region with a defined range of temperature and precipitation — its climate. Each biome is characterized by the plants and animals that are adapted to that climate. Figure 7.11 shows the land surface of Earth divided into 11 different terrestrial biomes. The oceans are considered a single biome — the marine biome — that covers about 70 percent of Earth.

Dividing Earth into biomes helps scientists study and understand how the biotic and abiotic components of each biome interact and how the biomes interact with each other. Biome divisions also make it easier for scientists to predict how different groups of organisms may be affected by changes in a region, such as a decrease in precipitation or an increase in summer temperatures.

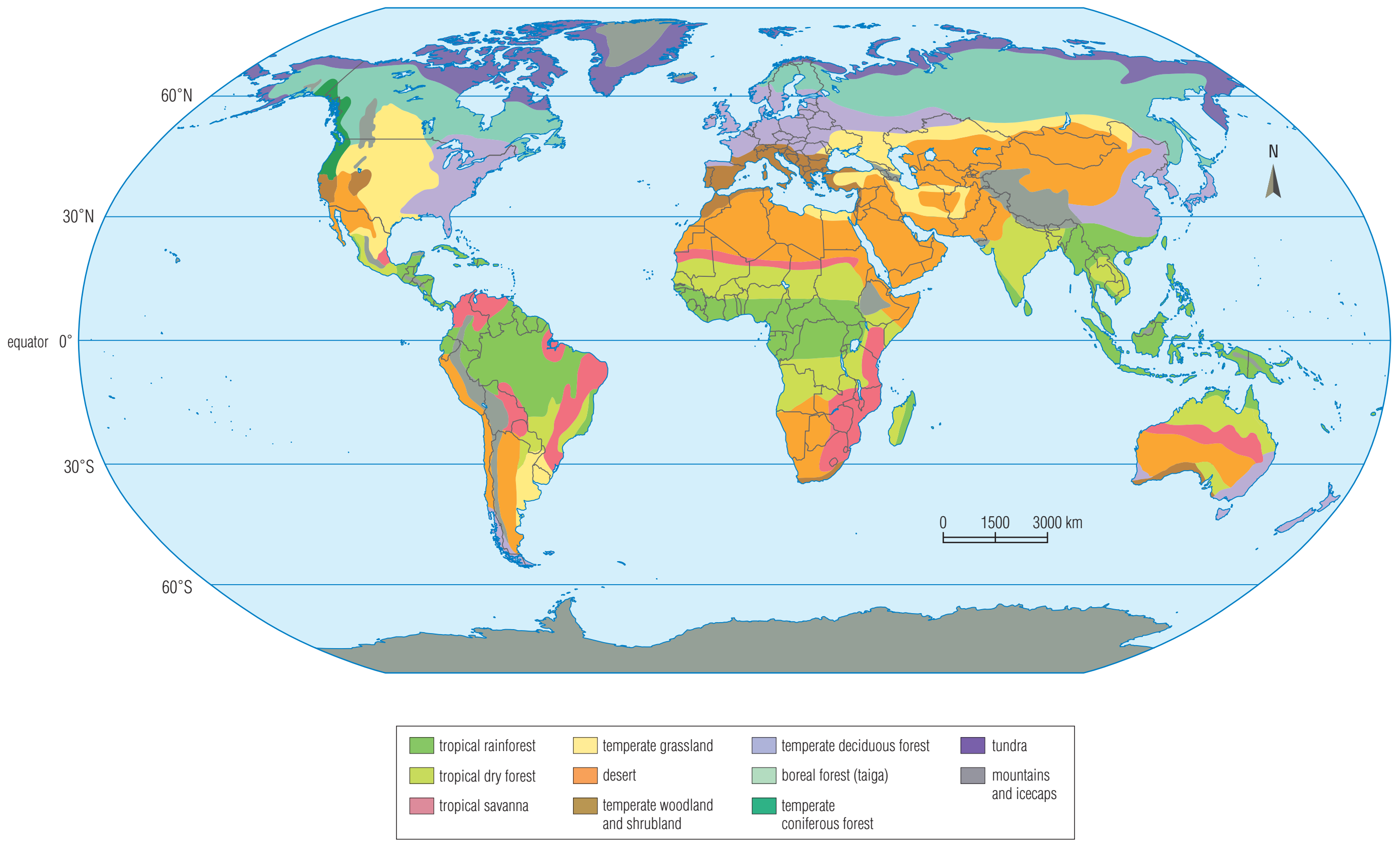


Figure 7.11 Earth's biomes reflect the climate (average temperature and amount of precipitation) in different regions.

Canadian Biomes and Climate

The six terrestrial biomes in Canada are tundra, boreal forest (also called taiga), temperate deciduous forest, temperate grassland, temperate coniferous forest, and mountain. Mountains show several different biomes as you climb, with tundra at the tops of the highest mountains. Table 7.4 shows the characteristics of each biome. Precipitation is measured in millimetres (mm) of liquid depth — the snow is melted before the measurement is taken. Note that Table 7.4 shows general trends only. Since climate conditions change gradually over the land, there is no distinct line between one biome and another. Many regions on Earth have characteristics of more than one biome.

Suggested Activity •
C5 Quick Lab on page 272

Table 7.4 Climatic Characteristics and Organisms of Canada's Terrestrial Biomes

	Climate				
Biome	**Average Annual Temperature (°C)**	**Precipitation (mm/y)**	**Description**	**Plants**	**Animals**
Tundra	–15 to 5	<200, mostly snow	short summer, 20–30 days	lichens, mosses, sedges, dwarf shrubs	arctic fox, caribou, musk oxen, polar bears, ptarmigan, mosquitoes
Boreal forest (taiga)	4 to 14	400–1000, much as snow	cool summers, cold winters	coniferous trees, lichens, grasses and sedges	woodpeckers, hawks, rodents, moose, bears, wolves, mosquitoes
Temperate deciduous forest	10 to 15	750–1500	well-defined summer and winter seasons	deciduous trees, shrubs, grasses, ferns, flowering plants	songbirds, hawks, rabbits, skunks, deer, black bears, timberwolves, raccoons, snakes, insects
Temperate grassland	4 to 10	250–600	well-defined summer and winter seasons	grasses, some flowering plants	hawks, snakes, rodents, buffalo, elk, coyotes, badgers
Temperate coniferous forest	10 to 20	800–1000	warm damp summers, mild wet winters	tall coniferous trees: Douglas fir, western red cedar	vultures, trumpeter swans, coyotes, black and grizzly bears, lynx
Mountains	depends on altitude	depends on altitude	depends on altitude	as you climb, small coniferous trees, then alpine flowering plants, mosses and lichens	boreal forest animals at lower altitudes; higher: ground squirrels, bighorn sheep, mountain goats, eagles

C3 *Just-in-Time Math*

Constructing a Climatograph

Climatographs show the average monthly temperatures and precipitation amounts on a single graph. The advantage of using a climatograph instead of a table of numerical data is that it is easier to interpret and compare the data (Figure 7.12).

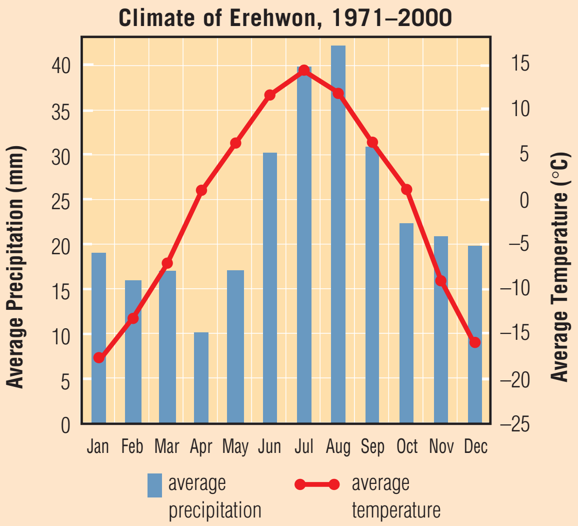


Figure 7.12 A sample climatograph

1. You can use graph paper or spreadsheet software to construct climatographs.
2. Study the information in Table 7.5.
3. Draw a graph outline with two vertical axes, one on each side of the graph. Label the horizontal axis with the months of the year.
4. Determine the range of the temperature data for the year. Label the vertical axis on the right side with this temperature range.
5. Plot the average monthly temperature data as a line graph.
6. Determine the range of the precipitation data for the year. Label the vertical axis on the left side with this precipitation range.
7. Plot the average monthly precipitation data as a bar graph.
8. Write a legend and a title for the climatograph. The title should include the location and the time the data was collected.

Table 7.5 Climate Data for Thunder Bay, ON, 1971–2000

	J	F	M	A	M	J	J	A	S	O	N	D
Average monthly temperature (°C)	–14.8	–12.0	–5.5	2.9	9.5	14.0	17.6	16.6	11.0	5.0	–3.0	–11.6
Average monthly precipitation (mm)	31.0	25.0	42.0	42.0	67.0	86.0	89.0	88.0	88.0	61.0	56.0	38.0

C4 *Inquiry Activity*

Skills Reference 2

SKILLS YOU WILL USE

- Interpreting data/information to identify patterns or relationships
- Communicating ideas, procedures, and results in a variety of forms

Toronto, Then and Now

Environment Canada provides climate data from its 2200 weather stations throughout the country. The global standard for climate data is 30 years, with the ending year as a decade year (e.g., 1971–2000). Because of this standard, you can easily compare climate data from cities around the world.

A weather station has been operating on Bloor Street in Toronto since 1840. *The Emigrants' Handbook*, published in 1864, included climate data from this site for 1840–1859. Nowadays, climate data for the same site can be obtained from Environment Canada. Constructing climatographs using the historical and recent climate data can help you compare people's living conditions now and 150 years ago.

C4 *Inquiry Activity (continued)*

Question

How has Toronto's climate changed in the last 150 years?

Materials & Equipment

- graph paper or spreadsheet software

Procedure

1. Predict your answer to the question.
2. Copy Tables 7.6 and 7.7 into your notebook.
3. Construct your two climatographs as described in "Constructing a Climatograph" on the previous page. Use two spreadsheet files, or construct your climatographs side by side on a sheet of graph paper.
4. When you determine the range of the average monthly temperature data over the year, select a range that accommodates both sets of data.
5. When you determine the range of the average monthly precipitation data, again select a range that will accommodate both sets of data.
6. Write a title for each climatograph.

Analyzing and Interpreting

7. Study each climatograph. Write a few sentences on each, describing the data, such as monthly data changes and if you think the temperature and precipitation are related.
8. Compare the two climatographs, and describe any differences you observe between them. Explain any differences.

Skill Practice

9. What are the advantages of using spreadsheet software over graphing by hand?

Forming Conclusions

10. What factors could have affected the climate between 1840 and now?
11. Would you feel confident making a statement about climate change in Toronto based on this information? If you answered "yes," why and what would the statement be? If you answered "no," why not?
12. Why would you construct climatographs for data averaged over a number of years instead of just an individual year?

Table 7.6 Climate Data for Toronto, ON, 1840–1859

	J	F	M	A	M	J	J	A	S	O	N	D
Average monthly temperature (°C)	–4.6	–5.9	–1.1	5	10.7	16.2	19.5	18.9	14.4	7.3	2.5	–3.3
Average monthly precipitation (mm)	36.0	26.0	39.0	63.0	84.0	81.0	89.0	74.0	104.0	57.0	79.0	41.0

Table 7.7 Climate Data for Toronto, ON, 1971–2000

	J	F	M	A	M	J	J	A	S	O	N	D
Average monthly temperature (°C)	–4.2	–3.2	1.3	7.6	14.2	19.2	22.2	21.3	17.0	10.6	4.8	–0.9
Average monthly precipitation (mm)	61.0	51.0	66.0	70.0	73.0	72.0	68.0	80.0	83.0	65.0	76.0	71.0

C5 *Quick Lab*

Your Biome and You

Purpose

To classify the climate of your local region and compare it with others in Ontario, Canada, and the world

Materials & Equipment

- books about biomes
- ***ScienceSource***

Procedure

1. Look at Figure 7.13, and determine where your community is on the map.
2. Determine the name of the biome where you live.
3. ***ScienceSource*** Use the Internet or books to locate some information that characterizes the biome you live in.
4. Organize the information you located into a fact sheet about the climate you live in.

Questions

5. Look at Figure 7.13, and describe the other biomes located in Ontario. How is your biome different from the others in the province?
6. Look at the world biome map (Figure 7.11), and describe any patterns you notice in the distribution of biomes around the world.
7. Write at least two ways your daily life is affected by the biome you live in.
8. Identify one biome you think is the most different from the one you live in. Explain your choice.
9. If you could pick the ideal biome to live in, what would it be and why?
10. Go to ***ScienceSource*** and find the Koppen climate map, the ecoregion map, and the horticulture zone map for Canada or Ontario. How does the information in these maps compare with the biome map? Can you think of uses for each map?

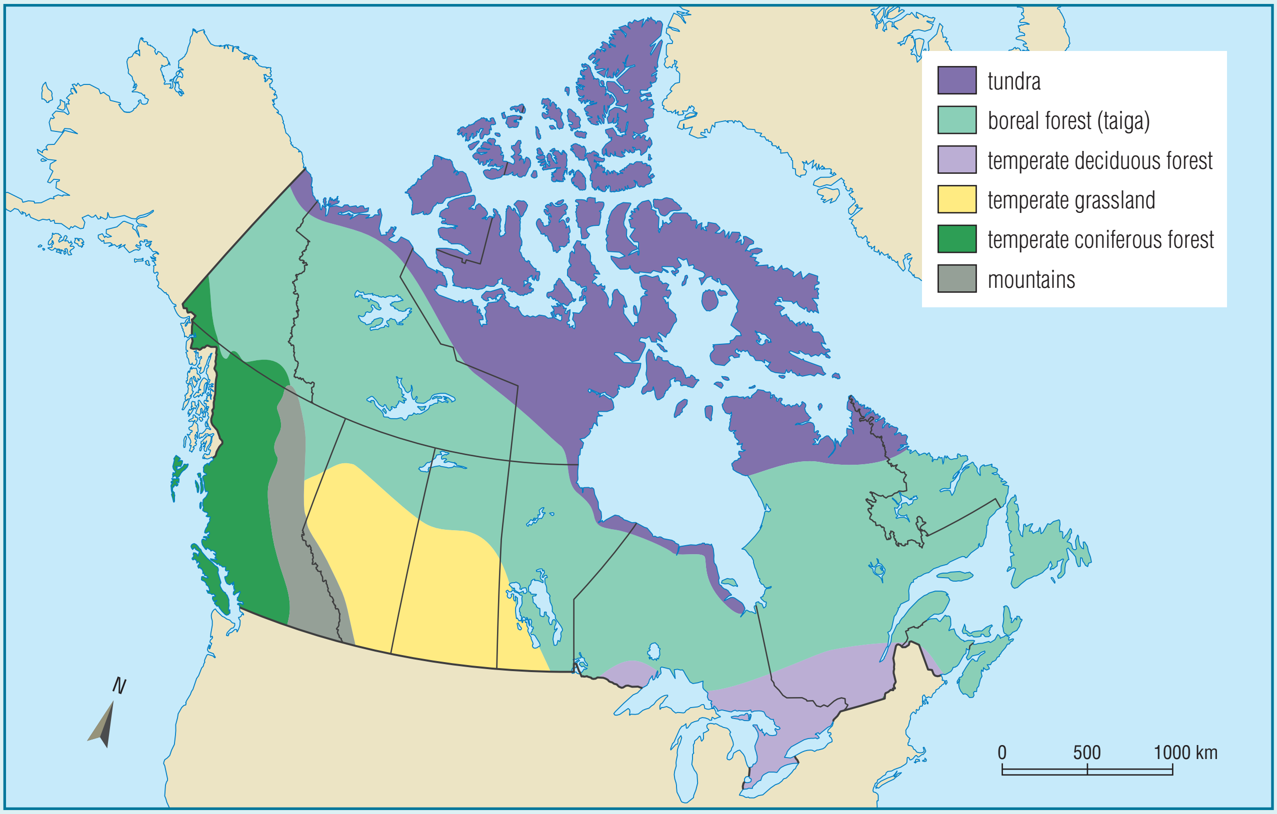


Figure 7.13 Canada can be divided into six biomes. Three of these biomes are found in Ontario.

7.1 CHECK and REFLECT

Key Concept Review

1. Define "weather" and "climate" in your own words.
2. Explain why the Sun is considered the source of almost all the energy on Earth.
3. List the interacting components of the biosphere, and briefly describe how they interact.
4. Look at the photographs, and list three words to describe the climate depicted in each.

Question 4

5. Describe one example of how climate affects people.
6. Make a list of the components you would find in Earth's atmosphere.
7. Describe two ways the lithosphere is warmed.
8. Create a pictorial representation of how the water in Earth's hydrosphere is classified.
9. State whether each of the following terms is related more to weather or to climate.
   (a) cloud cover
   (b) annual rainfall
   (c) chance of precipitation
   (d) average monthly temperature
10. Define the word "biome."
11. List two important facts about each part of the biosphere.
12. What is the difference between solar radiation and thermal energy?
13. List the six biomes in Canada. Briefly describe their climates and name one animal and one plant found in each.

Connect Your Understanding

14. Compare the similarities and differences between weather and climate, and explain how each affects your daily life.
15. Why is it important that Earth has a biosphere? Why is it important to study each component of the biosphere separately as well as consider them as a system?
16. Earth's biosphere, atmosphere, lithosphere, and hydrosphere are all interconnected. Identify one way these layers interact with each other.
17. Use the information in Table 7.4 on page 269 to make up three questions about biomes for a classmate to answer.
18. To be able to discuss a topic such as climate change, it is often important to learn some background information. Reflect upon this statement, and give your opinion about it. Support your opinion with evidence.

Reflection

19. What is one thing you learned in this section that you would like to find out more about?

For more questions, go to ***ScienceSource***.

7.2 Heat Transfer and the Natural Greenhouse Effect

Here is a summary of what you will learn in this section:

- The natural greenhouse effect is a natural process that occurs in Earth's atmosphere and is essential to life.
- Earth's net radiation budget is the difference between the amount of incoming radiation from the Sun and the outgoing energy from Earth.
- The amount of energy reflected from Earth is affected by the albedo of the area.
- Thermal energy is transferred by radiation, conduction, and convection.
- The transfer of thermal energy on Earth affects winds and ocean currents.

Figure 7.15 The glass or plastic walls and roof of a greenhouse trap heat from the Sun.

Figure 7.14 Even though it is winter outside, this school bus has been sitting in the sunshine all day and is much hotter inside than outside.

Trapping Heat

After a lovely sunny day at the outdoor education centre, you return to your school bus and climb in (Figure 7.14). You are hit by a wall of heat and can hardly breathe! Stumbling back out of the bus, you get a couple of friends to help you. You all run onto the bus, open all the windows, and then put your heads out to breathe the cool air. You have just experienced how a greenhouse works.

You can find greenhouses all across Ontario. Some are in public gardens, such as Allan Gardens in downtown Toronto, where tropical plants thrive year-round, and the Niagara Parks Botanical Gardens (Figure 7.15). Some greenhouses are at garden centres, where they protect young plants from cold weather outside. Some are tiny greenhouses made by private gardeners from hoops and plastic, to give their plants a head start on the growing season.

Tomatoes, lettuce, and cucumbers are grown in commercial greenhouses (sometimes called hothouses) so we can buy Ontario-grown produce early in the season. Some greenhouse operators plant flower and vegetable seeds in greenhouses in late winter and sell the young plants in the spring. Municipalities and many gardeners prefer to buy young plants instead of seeds because they get the flowers or vegetables earlier in the season. Delicate or fragile ornamental plants are grown in greenhouses because they survive better than if grown outdoors.

Greenhouse operators rely on the sun to keep their greenhouses warm. Sunlight passes through the glass in the windows of the greenhouse (Figure 7.16). Some of the solar radiation reflects off the tables, ground, and plants inside and escapes back through the windows. Some of the solar radiation heats those tables, the ground, and the plants. These heat the air in the greenhouse. However, this air cannot escape so the greenhouse becomes warmer and warmer. While the glass lets the sunlight in, it does not let the warm air out.

Greenhouse operators often use temperature-controlled devices to open the greenhouse windows when the inside air becomes too hot, and close them again when it has cooled. When the day is cloudy, the operators use back-up heaters.

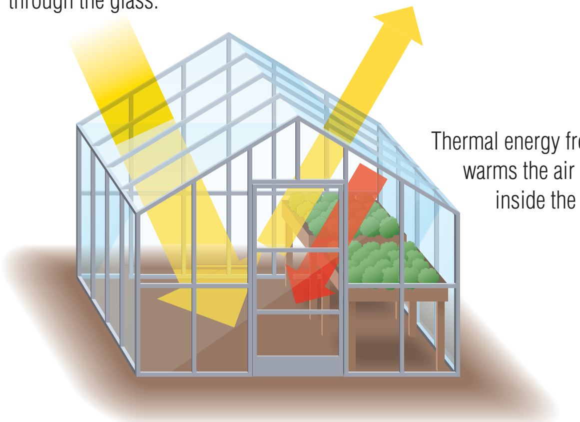


Figure 7.16 How a greenhouse works

C6 *Quick Lab*

Too Much Heat

You may have had experiences similar to those of the students getting on the school bus. Recall these situations, and look for patterns.

Materials & Equipment

- pencil and paper

Purpose

To discover why some places seem to be warmer than expected

Procedure

1. Form a group of four students.
2. In the middle of your sheet of paper, write “unexpectedly warm places” and circle the words.
3. Draw a line from the title to another place on the sheet and write “school bus parked in the sun.” Add a sketch to illustrate this.
4. Discuss other times this has happened to you or a member of your group. Add these to the sheet of paper.

Questions

5. What do you notice about these warm places? What do they have in common?
6. Discuss how you think this concept is related to the study of climate.
7. Write a summary of your group’s discussion in your science notebook.

Insolation and the Natural Greenhouse Effect

Although virtually all the energy on Earth comes from the Sun, different regions receive different amounts of solar radiation. **Insolation** is the amount of solar radiation received by a region of Earth's surface (see Figure 7.6). Insolation depends on latitude, which is the distance of any place on Earth from the equator, shown on a globe by a series of lines drawn around it parallel to the equator. The equator is at 0° latitude, and the North Pole is at 90° latitude. Toronto is at latitude 43°40' ("minutes") N (north of the equator). Insolation also depends on specific characteristics of the lithosphere, atmosphere, and hydrosphere in that region. Some of these characteristics can change from day to day.

As the insolation reaches Earth, some of it is scattered by collisions with water vapour, gas molecules, and dust in the atmosphere. Some of the scattered insolation returns to space, some is absorbed by the atmosphere, and some makes it to Earth's surface.

The Natural Greenhouse Effect

Suggested Activity •
C9 Inquiry Activity on page 287

Some of the solar radiation that is absorbed by Earth's surface is re-emitted into the atmosphere as infrared radiation (Figure 7.17). Most of this radiation is absorbed as thermal energy in the atmosphere by clouds and gases such as water vapour, carbon dioxide (CO_2), and methane (CH_4). Without the atmosphere, this thermal energy would escape into space, and Earth would be significantly cooler. The absorption of thermal energy by the atmosphere is known as the **natural greenhouse effect**. The natural greenhouse effect helps keep the temperature of our planet in the range that supports life. The average temperature at Earth's surface in 2007 was 14.7°C. Without the natural greenhouse effect, the average temperature on Earth would be about –20°C.

Water vapour, carbon dioxide, nitrous oxide, and methane are called **greenhouse gases**, gases that contribute to the natural greenhouse effect. Since so much water vapour is present in the atmosphere, it is the main contributor to the natural greenhouse effect. However, carbon dioxide, methane, and nitrous oxide also absorb significant amounts of thermal energy.

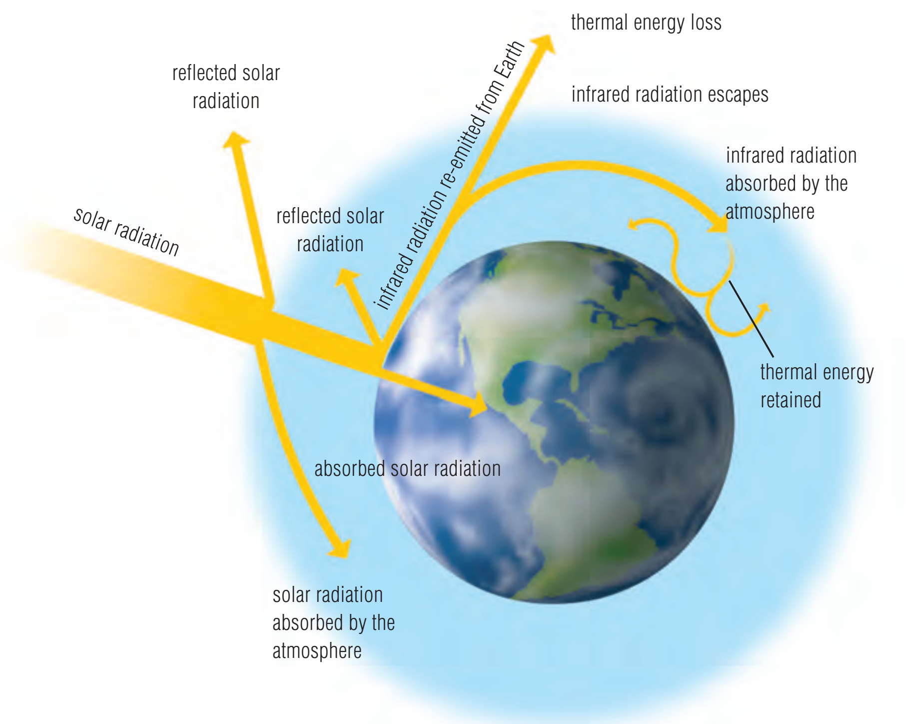


Figure 7.17 The natural greenhouse effect keeps Earth warm enough to support life by absorbing some of the infrared radiation re-emitted from Earth's surface.

The natural greenhouse effect has helped maintain Earth's climate for millions of years. While the climate has varied considerably over that time, its temperatures and precipitation amounts have always been in a range to support life on Earth.

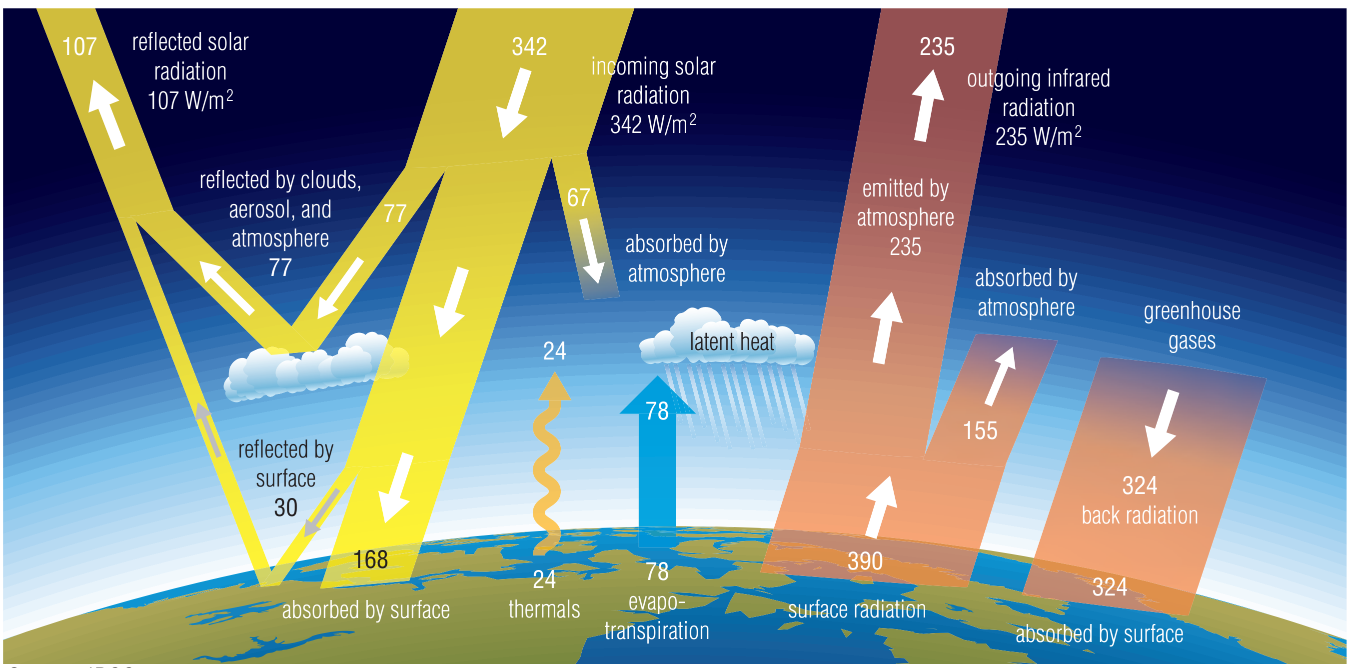
The Net Radiation Budget

Earth is a warm, habitable planet because Earth's surface and the atmosphere absorb incoming insolation. However, not all the incoming solar radiation is absorbed. Some is reflected out to space, and some is re-emitted as thermal energy by Earth's surface and atmosphere.

Figure 7.18 shows the relative contribution of different aspects of Earth's average **net radiation budget**, which is the difference between the amount of incoming radiation and the amount of outgoing radiation. Each square metre of the outer surface of Earth's atmosphere receives an annual average of 342 W of solar radiation. The W stands for watts, which are energy units per second. Of the 342 W/m^2, 31 percent is immediately reflected back into space by clouds, the atmosphere, and Earth's land surface. About 30 percent of the remaining solar radiation is absorbed by the atmosphere. The rest warms Earth's surface, which returns that heat to the atmosphere as infrared radiation, thermal energy, and water vapour. The atmosphere, in turn, emits radiation both up and down. The radiation lost to space comes from cloud tops and atmospheric regions much colder than the surface.

Almost all the energy absorbed by Earth's atmosphere, lithosphere, and hydrosphere is eventually radiated back into space as infrared radiation (Figure 7.18). Less than one percent of the incoming solar radiation is transformed by photosynthesis into chemical energy.

Figure 7.18 Earth's annual global net radiation budget. Incoming solar radiation is shown on the left side, and how the atmosphere emits the outgoing infrared radiation is shown on the right side. All numbers are in watts per square metre.



Source: IPCC

Balancing the Radiation Budget

On average, the amount of incoming radiation is equal to the outgoing radiation for all of planet Earth. In a word equation:

$$\begin{aligned}\text{net radiation budget} &= \text{incoming radiation} - \text{outgoing radiation}\\ &= \text{zero}\end{aligned}$$

If this balance were to change, then the average global temperature would either increase or decrease until the net radiation budget was balanced again. For example, if the amount of radiation re-emitted back into space decreased and the amount of incoming radiation remained the same, Earth's average global temperature would increase.

Although the net radiation budget is balanced for Earth as a whole, some regions on Earth have an unbalanced net radiation budget. Latitude is an important factor in predicting whether the net radiation budget of a region is out of balance. For example, polar regions tend to have less incoming radiation than outgoing radiation, and the tropics have more incoming radiation than outgoing.

Albedo

The amount of solar radiation that is reflected from Earth's surface depends on the characteristics of that surface. The **albedo** of a surface is the percent of the incoming solar radiation that it reflects. The albedo of our entire planet is about 30 percent. Light-coloured, shiny surfaces such as snow, ice, and sand reflect much more solar radiation — about 90 percent — than do darker, duller surfaces such as open water (about 10 percent), forests, and soils (Figure 7.19). Think about how bright it seems when you walk out of school after a fresh snowfall when every surface is covered with snow.

Suggested Activity •
C10 Inquiry Activity on page 288

Albedo varies with the seasons. Ontario usually has a higher albedo in winter than in the summer because of snowfall, frost, or dried grass. Albedo can affect a region's radiation budget because it can affect the temperature and rate of evaporation in that region.

During Reading Thinking Literacy

Make a Text-to-World Connection

What concerns are there in North America and around the world about climate change and the greenhouse effect? How has this issue reached the public? How can we check to see which information is true?

Learning Checkpoint

1. Explain what happens to the solar radiation that reaches Earth.
2. What would the average temperature on Earth be without the natural greenhouse effect?
3. State whether the following surfaces would have a high or a low albedo.
   (a) a mirror
   (b) a lawn
   (c) a sidewalk
   (d) an asphalt driveway

Thermal Energy Transfer

Thermal energy transfer is the movement of thermal energy from an area of high temperature to an area of low temperature. Suppose you took a bicycle outdoors on a cold day. The temperature of the bicycle would fall to the same temperature as the air outside. If you then brought the bicycle back inside, the temperature of the bicycle would increase to the indoor temperature. In this example, thermal energy was transferred first from the bicycle to the outdoor air and then from the indoor air to the bicycle. Thermal energy transfer can occur by radiation, conduction, or convection.

(a)

(b)

Figure 7.19 (a) The Amazon jungle and (b) the Sahara Desert each receive about the same amount of solar radiation. However, the dark jungle has a low albedo and absorbs most of the solar radiation that hits it. The desert with its high albedo reflects most of the solar radiation into the atmosphere.

Radiation

Radiation is the emission of energy as waves. When radiant energy encounters particles of matter, it may be reflected or absorbed. Absorbed energy can increase the movement of the particles (their kinetic energy). An increase in kinetic energy increases the temperature of the matter.

Any substance at a higher temperature than its surroundings will emit radiant energy, usually as infrared radiation (Figure 7.20). For example, the Sun radiates energy in the form of electromagnetic waves (solar radiation). When this radiant energy reaches Earth, some of it is absorbed by matter such as land, water, or air. The absorbed radiant energy increases the kinetic energy of the molecules in the matter, and the temperature of the matter increases. The warmed matter then transfers some of its thermal energy to substances at lower temperatures or re-emits it as infrared radiation.

Conduction

Conduction is the transfer of thermal energy through direct contact between the particles of a substance, without moving the particles to a new location. Thermal energy transfer by conduction usually takes place in solids. Recall that particles in a solid all have a certain average kinetic energy. During conduction, particles with more kinetic energy transfer some of their energy to neighbouring particles with lower kinetic energy (Figure 7.20). This increases the kinetic energy of the neighbouring particles, which may, in turn, transfer energy to other neighbouring particles, increasing their kinetic energy. For example, in Figure 7.20, the barbecue is radiating energy to the solid metal pan. The particles of metal closest to the burner absorb some of this radiated energy and increase in kinetic energy. These particles can then transfer energy by conduction to neighbouring particles, causing an increase in temperature.

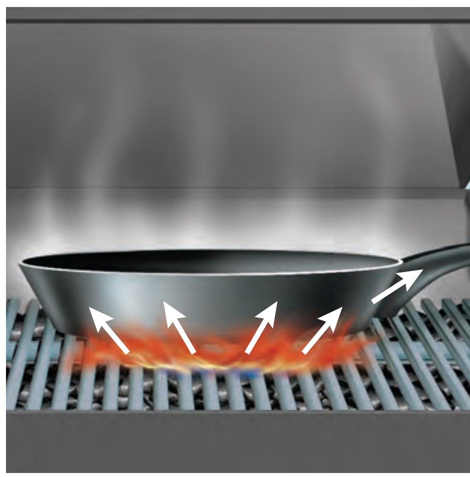


Figure 7.20 In this illustration, energy is radiated from the heat source and is absorbed by the lower surface of the pan. Thermal energy is then transferred to other parts of the pan (e.g., the handle) by conduction. Conduction transfers thermal energy from one particle to another through direct contact.

Convection

Figure 7.21 Convection transfers thermal energy through the movement of particles from one location to another.

Convection is the transfer of thermal energy through the movement of particles from one location to another. Thermal energy transfer by convection usually occurs in fluids, which are substances with no definite shape, such as gases and liquids. During convection, the movement of the particles forms a current, which is a flow, from one place to another in one direction. For example, when the water in the pot in Figure 7.21 absorbs energy from the barbecue, the water molecules increase in kinetic energy. The water molecules then begin to move apart from one another, causing the water to expand in volume. This expansion lowers the density, or mass per volume, of the water. The warmer, less dense water rises to the top, forming an upward convection current. When it contacts the cooler air at the surface, the water cools and contracts, which increases its density and forms a downward convection current.

Both water and air are fluids, but water has a higher heat capacity than air has. This means that it takes a lot of energy to increase the temperature of a mass of water. Also, when the mass of water cools down, large amounts of energy are released from the water. Water heats up and cools down slowly compared to other substances. Think about how, in summer, the sidewalk can feel much hotter than a puddle on the sidewalk does. Since Earth's surface is over 70 percent water, water has a large effect on Earth's climate. Therefore, regions closer to large bodies of water tend to experience more moderate weather conditions than regions farther from them. This feature is attractive to many people and is one reason why coastal cities tend to attract large populations.

Thermal Energy Transfer in the Atmosphere

Earth as a whole receives insolation from the Sun, but different parts of Earth receive different amounts. Since Earth's climate system is one interrelated whole, thermal energy is transferred throughout the atmosphere and hydrosphere.

The temperature of the atmosphere tends to increase in areas close to or at the equator. As the heated atmospheric gases gain energy and expand, the air becomes less dense and rises. In areas close to or at the poles, the temperature of the atmosphere tends to decrease. Here, the cooling atmospheric gases lose energy and contract and the air becomes denser and falls. If Earth were not spinning, there would be a continuous convection current between the polar and the equatorial regions (Figure 7.22).

Atmospheric pressure is the pressure exerted by the mass of air above any point on Earth's surface. Since warm air is less dense than cold air, warmer regions of the atmosphere generally exert less

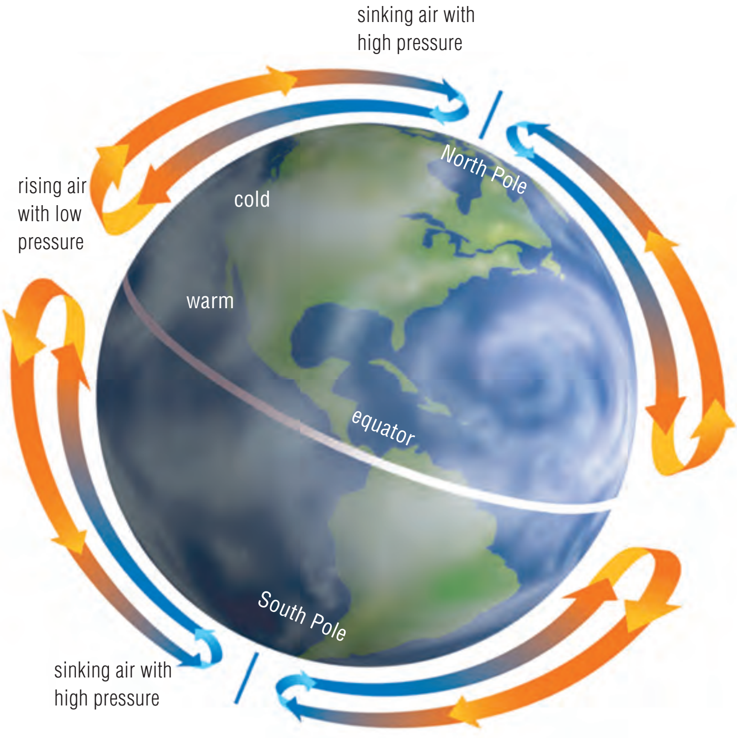


Figure 7.22 If Earth did not rotate, differences in thermal energy in the atmosphere would cause these convection currents.

atmospheric pressure than cooler regions. **Wind** is the movement of air from areas of high pressure to areas of low pressure. The rising and sinking masses of air in convection currents cause changes in atmospheric pressure, which cause wind.

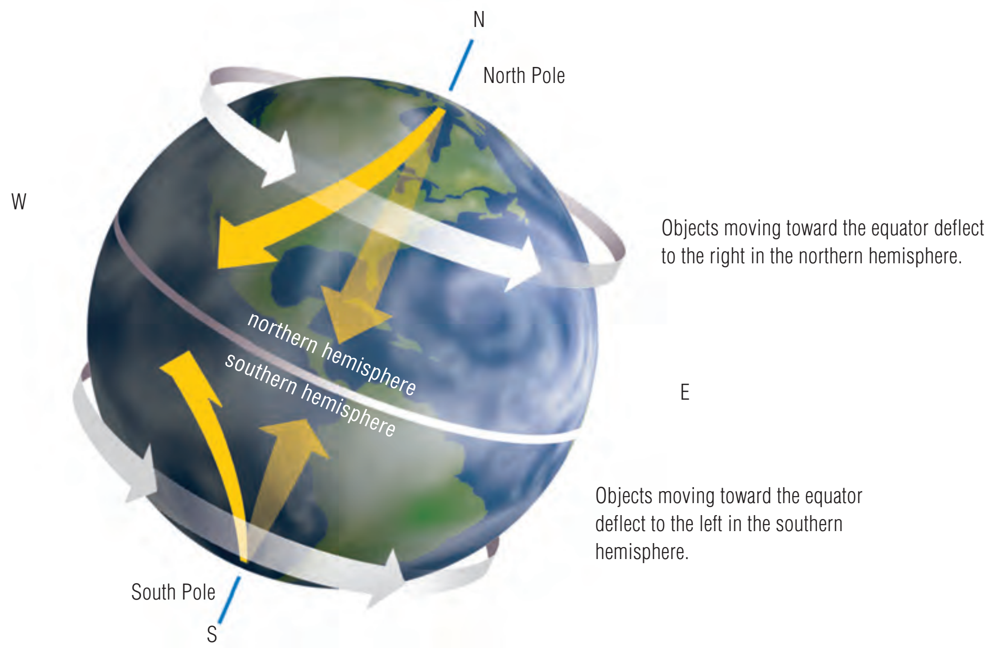
The Coriolis Effect

The difference between the net radiation budget at the poles and at the equator tends to cause air to move directly north and south. However, since Earth is rotating on its axis, the winds are deflected either toward the right or toward the left. The **Coriolis effect** is the deflection of any object from a straight-line path by the rotation of Earth. The Coriolis effect causes moving air or wind to turn right in the northern hemisphere and left in the southern hemisphere.

Suggested Activity •
C8 Quick Lab on page 286

To better visualize the Coriolis effect, imagine you are standing at the North Pole and you launch a rocket southward. Relative to space, your rocket travels south in a straight line from where you launched it. However, as the rocket travels, Earth rotates beneath it. Relative to the North Pole, the rocket is deflected westward, to the right. Similarly, if you launched a rocket from the South Pole toward the equator, Earth's rotation would again deflect the path of the rocket westward, which from the South Pole is to the left (Figure 7.23 on the next page).

Figure 7.23 The white arrows show Earth's rotation. Because of the Coriolis effect, winds are deflected to the right in the northern hemisphere (pretend you are looking southward from the North Pole) and to the left in the southern hemisphere (looking northward from the South Pole). The winds in temperate regions of the northern hemisphere tend to circulate clockwise, while those in the temperate regions of the southern hemisphere tend to circulate counterclockwise.

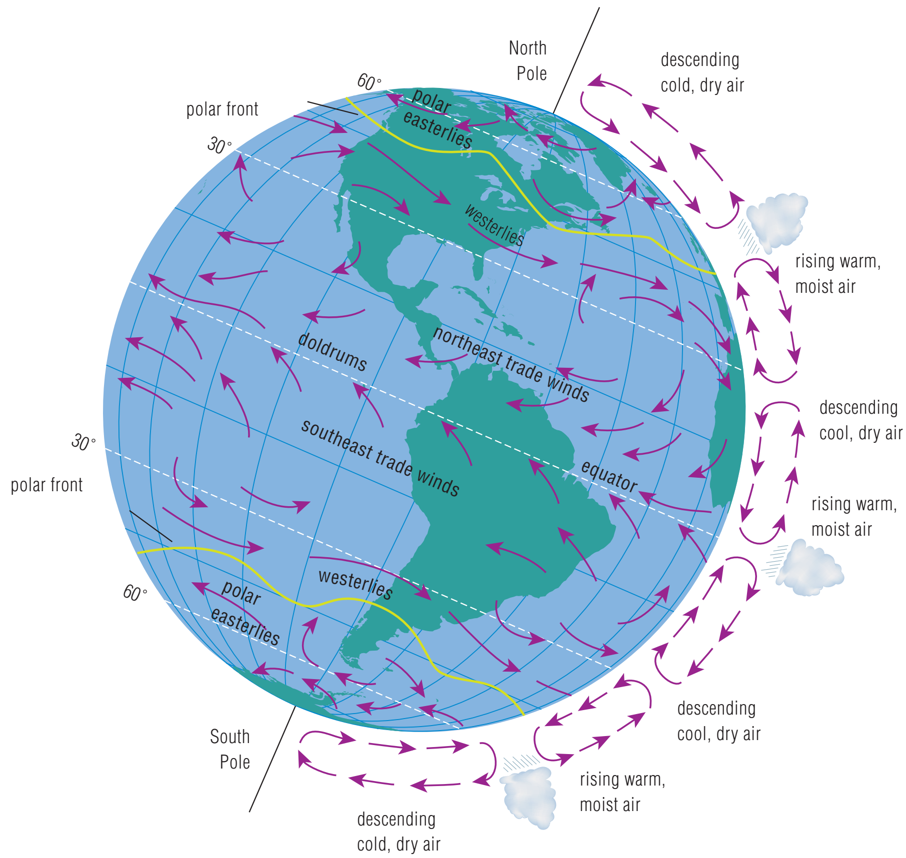


Global Wind Patterns

The convection currents in the atmosphere and the Coriolis effect result in the global wind patterns (Figure 7.24). Global winds transfer thermal energy from areas of net radiation budget surplus to areas of net radiation budget deficit. If this did not occur, areas at or near the equator would grow very hot while the rest of Earth would become much colder.

Figure 7.24 Global wind patterns are caused by the unequal heating of Earth's atmosphere and the deflection of winds by the Coriolis effect. The trade winds and polar easterlies tend to blow to the west. The doldrums are a region of very low winds in a band about the equator.

Ontario is subjected to the prevailing westerlies, which blow from west to east. They also occur at the same latitude in the southern hemisphere.



In regions near the equator, warm, rising air currents cause higher altitude winds that flow toward the poles. To replace the rising air, cooler surface air moves toward the equator from higher latitudes. This air movement is called the trade winds. The Coriolis effect makes the trade winds curve to the west, whether they are travelling to the equator from the south or north.

At latitudes of about 30°N and 30°S, some of the warm air from the equator is cooled enough to sink and move westward toward the equator. The rest of the warm air moves toward the poles and is pushed west by the Coriolis effect, which causes cold air to rush in, in a eastward direction. This gives rise to the westerly winds that prevail at latitudes between 30° and 60° in both directions from the equator. At the poles, sinking cold air is pushed westward, forming easterly winds.

Jet Streams

Local conditions such as the presence of continents or large bodies of water also affect wind patterns. Earth's surface and the density of the troposphere produce friction, which slows global winds. A jet stream is a band of fast-moving air in the stratosphere. Because of their high altitude, these winds are not subject to much friction and so are much faster than winds closer to Earth's surface.

Earth has several jet streams, which circle Earth at various latitudes (Figure 7.25). There are usually two or three jet streams in the northern and southern hemispheres. Like the surface winds, the convection currents in Earth's atmosphere also form the jet streams. Their speed and location vary with the amount of thermal energy in the atmosphere. During the cooler months, the jet streams tend to be closer to the equator and move more quickly.

Changes in the jet streams affect the formation of severe weather events such as squalls, storms, and cyclones. The movements of the jet streams, particularly those in polar regions, can also affect the movement of the air at lower levels of the atmosphere. Changes in the jet streams are therefore very important in predicting weather changes, so you are likely to hear them mentioned during weather forecasts.

During Reading

Thinking Literacy

Make Connections Among Ideas

Draw a mind map to connect the terms and ideas on these pages. Use lines and labels to show the relationships among the Coriolis effect, wind patterns, the jet stream, and heat transfer.

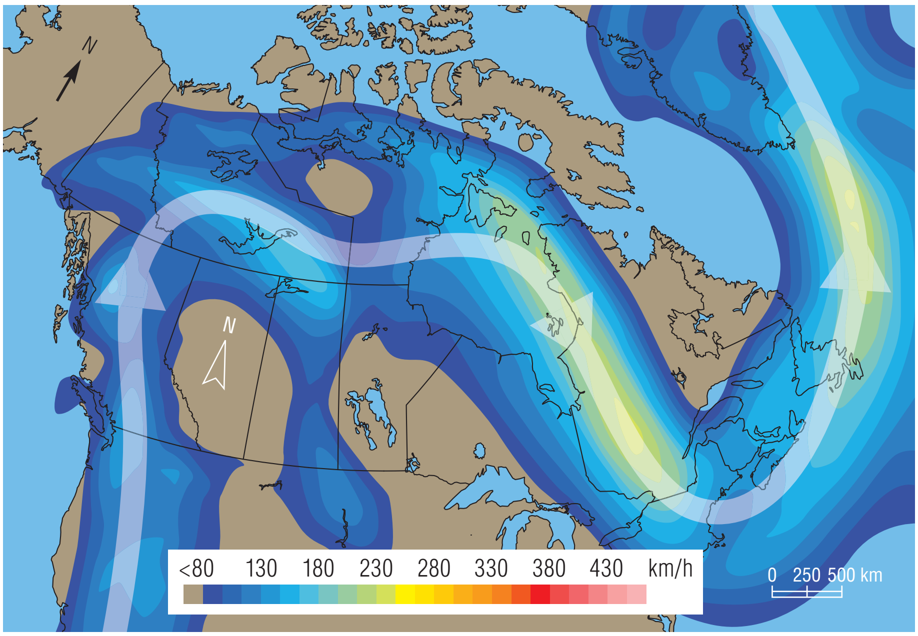


Figure 7.25 The jet stream across Canada on November 2, 2008

Thermal Energy Transfer in the Hydrosphere

The effect of water on the transfer of heat in the hydrosphere is very significant. Since water covers about 70 percent of Earth's surface and different forms of water can be found throughout Earth's biosphere, Earth's climate is influenced greatly by phase changes during the hydrologic cycle.

Recall what you know about the hydrologic cycle, also called the water cycle (Figure 7.26). At various stages in the hydrologic cycle, water molecules undergo changes in phase, from solid to liquid to vapour and back again. Whenever water changes phase, thermal energy is either released or absorbed. During a phase change, the temperature of the water remains the same even though the quantity of thermal energy increases or decreases. Thermal energy is released when water goes from liquid to solid. When liquid water changes to water vapour, thermal energy is absorbed. Through such changes of state, the hydrologic cycle transfers thermal energy through the biosphere.

Since water molecules undergo many phase changes during the hydrologic cycle, energy can be transferred in the biosphere without any changes in temperature of the water. This helps to keep the average temperature of Earth relatively stable.

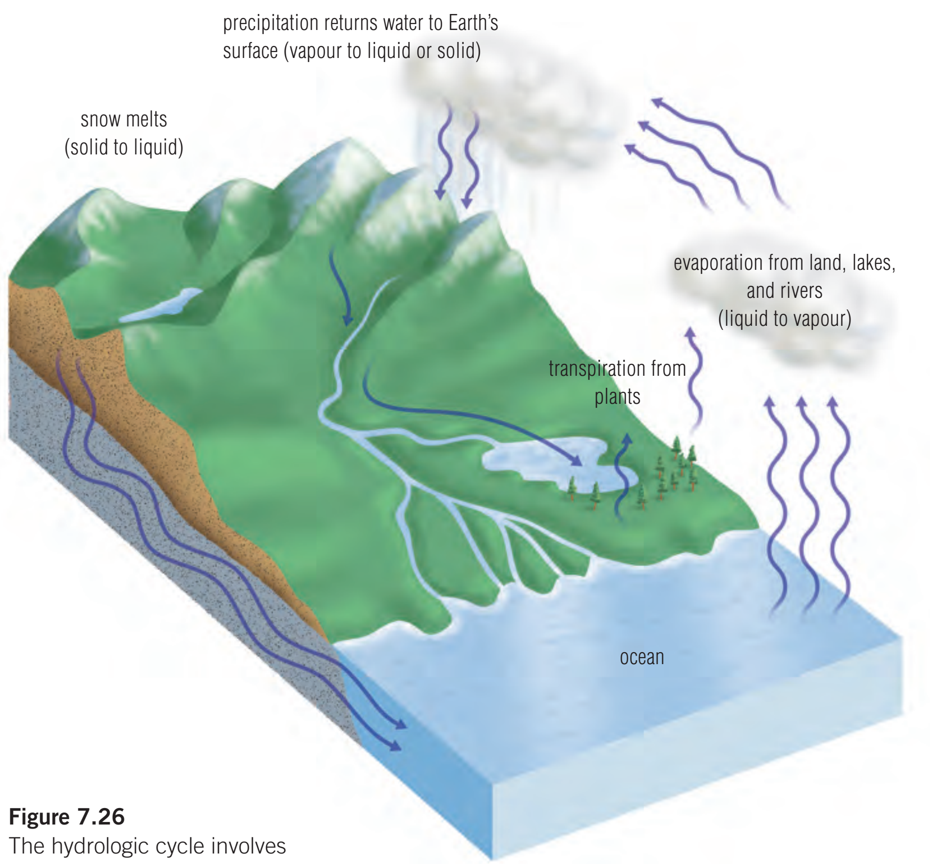


Figure 7.26
The hydrologic cycle involves many phase changes.

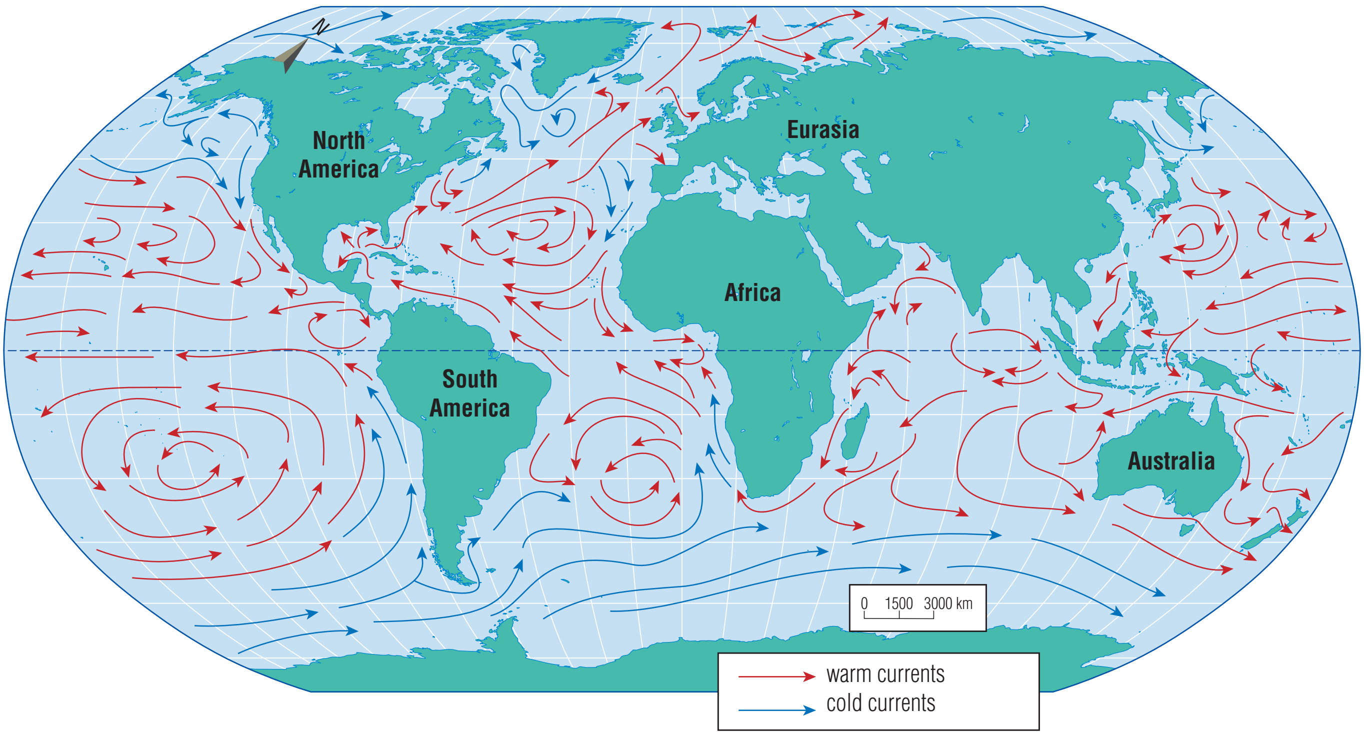


Figure 7.27 The surface ocean currents extend from the surface of the oceans to a depth of about 100 m and reflect the pattern of Earth's global winds.

Thermal Energy Transfer in the Oceans

Ocean currents are the main pathways for the transfer of thermal energy from the warmer latitudes near the equator to cooler areas near the poles. As the global winds blow on the ocean surface, they push on the water, driving the surface currents in the oceans. Figure 7.27 shows the major patterns of these currents. The warmer waters near the equator are driven by the trade winds between the equator and latitudes 30°N and 30°S. The winds change direction from westerly in the middle latitudes to easterly in the polar latitudes. They drive ocean currents that move warm water toward the poles in the mid-latitudes and cold water southward in higher latitudes.

As with global winds, the pattern of surface ocean currents is modified by the Coriolis effect. Currents in the northern hemisphere veer to the right. Currents in the southern hemisphere veer to the left. Earth's continents also affect the general pattern of the ocean's currents, however. The currents have to change direction when they encounter a large land mass. Some coastal regions, such as the east coast of the United States, experience a continuous current of warm water, whereas other regions, such as the east coast of Labrador, experience a continuous current of cold water.

Thermal energy is also transferred vertically through the oceans and other bodies of water, through convection currents. Just like the density of air, the density of water decreases when its temperature increases, so warm water tends to rise. Cooler water is denser, so it tends to sink. Deep ocean currents also carry water around the globe.

Take It Further

Jet streams influence air travel as well as weather. Find out how jet streams affect air travel, and write a short summary paragraph of your research. Compare your summary with that of a partner. If hearing a partner's summary gives you ideas for improving your summary, make the improvements now. Begin your research at ***ScienceSource***.

C7 STSE Science, Technology, Society, and the Environment

Who Owns the Arctic Ocean?

Canadians have always assumed that the Arctic Ocean between Canada and the North Pole was part of Canada. However, this view is not held by all countries. In the past, this issue has not seemed important, but climate change has brought the question of "who owns the Arctic Ocean" to the forefront.

Figure 7.28 Canadian Rangers are part-time military personnel who patrol the Arctic region and assist military, scientific, and search and rescue operations. Most of the 4500 Rangers are Inuit or First Nations people.

Geologists think that large amounts of Earth's undiscovered fossil fuels lie beneath the Arctic Ocean. Also, the loss of Arctic Ocean ice has led to ice-free summers in the Northwest Passage, now used by cargo and cruise ships.

In order to determine whether the "Canadian" part of the Arctic Ocean is geographically part of Canada, geologists such as Ruth Jackson of the Geological Survey of Canada are mapping the ocean floor to see how far the continental shelf extends outward from the land.

1. What do you think would be the consequences if scientists could not prove that the "Canadian" part of the Arctic Ocean is part of Canada? Do you think Canada should retain sovereignty over this area? Discuss this issue with a classmate.
2. Currently, the Canadian Rangers monitor the large land area of the Canadian Arctic. Go to ***ScienceSource*** to find out about the Canadian Rangers (Figure 7.28).

C8 Quick Lab

The Coriolis Effect

Purpose

To model the Coriolis effect

Materials & Equipment

- piece of cardboard at least 30 cm wide
- nail or large pin
- pen or marker

Procedure

1. Cut a circle at least 30 cm in diameter from a piece of cardboard. Put the nail or pin into the exact centre of the circle so that it spins freely.
2. Label the centre of the circle as the North Pole and the outer edge as the equator.
3. Draw a counterclockwise arrow on the circle at the edge, to indicate the direction of Earth's rotation.
4. To demonstrate the Coriolis effect, have a partner slowly rotate the circle as you draw a straight line from the North Pole to the equator.

Questions

5. Look at the line drawn on the cardboard circle. In which direction does the line twist?
6. What does the twisting line represent?
7. How does this activity model the Coriolis effect?
8. If you repeated this activity on the underside of the circle, in which direction would the lines twist?

DI Key Activity

C9 *Inquiry Activity*

Skills Reference 2

SKILLS YOU WILL USE
- Conducting inquiries safely
- Processing and synthesizing data

Modelling a Greenhouse

Question

How does a model greenhouse show how greenhouses warm up and stay warm?

Materials & Equipment

- 2 thermometers or temperature probes
- one-hole stopper to fit bottle
- 2-L clear plastic bottle
- masking tape
- retort stand
- clamp
- reflector (heat) lamp with 200-W bulb
- timer or stopwatch
- graph paper, spreadsheet software, or graphing calculator

CAUTION: The lamp will be hot and bright. To avoid burn injury, do not touch the lamp. Do not look directly into the light.

Procedure

1. Carefully insert one thermometer or temperature probe into the one-hole stopper. Fit the stopper assembly snugly into the top of the empty 2-L bottle. The bulb of the thermometer should be as far down into the bottle as possible.
2. Secure the stopper in place with tape. Tape the bottle to the table to prevent it from falling over.
3. Attach the second thermometer to the retort stand with the clamp. Make sure that the bulb of the thermometer is at about the same height as the one inside the bottle. Position the stand and thermometer near the bottle.
4. Position the heat lamp so it is at an equal distance from both thermometers. Your model should look like Figure 7.29. Do not turn on the lamp yet.
5. Create a data table to record the temperature inside and outside the bottle every minute for at least 15 min.
6. Record the starting temperatures, then turn on the lamp. Record the temperatures every minute.
7. When the temperatures stop rising, continue to monitor and record them for another 3–5 min.
8. Clean up your work area. Make sure to follow your teacher's directions for safe disposal of materials. Wash your hands thoroughly.

Analyzing and Interpreting

9. Graph your results. Choose a method to distinguish the temperatures inside the bottle from those outside. Explain your method in the legend.
10. Compare the temperature changes inside and outside the bottle. Explain any observed differences.

Skill Practice

11. Why was it important to have both thermometers the same distance from the lamp?

Forming Conclusions

12. Explain why the temperature eventually stopped rising inside the bottle, even with the lamp still on.
13. Was the bottle a good model of the natural greenhouse effect in the atmosphere? How did it help you understand the natural greenhouse effect better? What are the limits of this model?
14. How useful is this model in showing you how a greenhouse works?

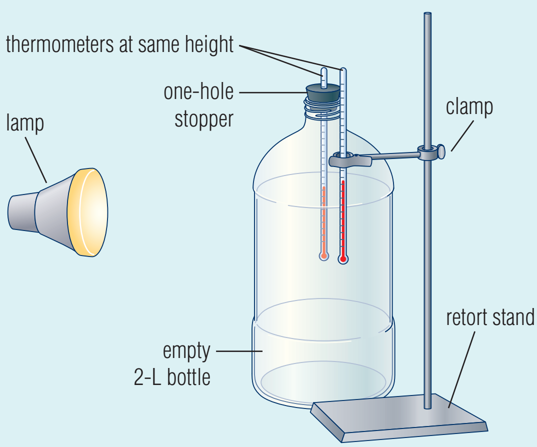


Figure 7.29 The completed model

C10 *Inquiry Activity*

Skills Reference 2

SKILLS YOU WILL USE

- Observing and recording observations
- Evaluating whether data supports or refutes hypothesis

Modelling Albedo in the Biosphere

Question

When two samples with different albedos are exposed to equal amounts of radiation, how will that affect the temperatures above and below the sample surfaces?

Materials & Equipment

- 3 paper baking cups
- white sugar
- green-dyed sugar
- graph paper, spreadsheet software or graphing calculator
- 5 thermometers or temperature probes
- retort stand
- 5 clamps
- reflector lamp with a 200-W bulb
- timer or stopwatch

CAUTION:
To avoid burn injury, do not touch the light bulb.
Do not look directly into the light.
Never eat anything in a science lab.

Hypothesis

Create a hypothesis that relates the albedo of white sugar and green sugar to the change in temperature above and below the surface of the sugar samples.

Procedure

1. Fill one baking cup with white sugar and another with green sugar. Fill both cups close to the top, and flatten off the surface of the sugar. Leave the third baking cup empty as a control.
2. You will measure the temperatures of the sugar samples and of the air just above the sugar samples every 2 min for 10 min. You will also measure the temperature inside the control cup at the same times. Using graph paper or spreadsheet software, create a data table to record these data. If you are using a graphing calculator, open the appropriate application to collect or enter temperature data.
3. Place the bulb of one thermometer or temperature probe just under the surface of each sugar sample. Place two more thermometers or probes with their bulbs just above the surface of each sugar sample. Place the last thermometer or probe inside the empty baking cup so that it is not touching any surface. Secure all the thermometers to the retort stand with clamps. Record the initial temperature of each thermometer.
4. Place the lamp about 30 cm above the containers. Set the timer to zero.
5. Turn on the lamp, and start the timer. Record the thermometer readings every 2 min for 10 min with the light on. After 10 min, carefully turn off the lamp.
6. Clean up your work area. Make sure to follow your teacher's directions for safe disposal of materials. Wash your hands thoroughly.

Analyzing and Interpreting

7. Using your data, draw graph(s) of the temperature versus time. Your graph(s) should include temperatures above and below each sugar sample and in the control for each time point.
8. Describe the temperature changes above and below the surfaces of the white sugar and green sugar and in the control. Outline any differences among the samples and the control.
9. According to your graph(s), over which sugar sample did the air temperature change more when the light was on? Relate this to the albedos of the two sugar samples.

Skill Practice

10. Why did you need to determine the temperature of the air in the empty baking cup?

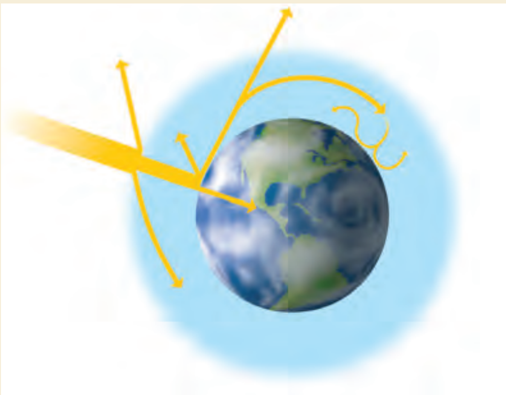
Forming Conclusions

11. How effectively do the different sugar samples represent surfaces with different albedos?
12. How do the temperature readings you recorded answer the initial question?
13. Do the data you collected support or refute your hypothesis? Explain.
14. What are the implications of the results of this experiment with respect to the loss of ice shelves in the Arctic?

7.2 CHECK and REFLECT

Key Concept Review

1. Explain what is meant by the term "the natural greenhouse effect."
2. Study the word "insolation," and explain why it stands for incoming solar radiation.
3. Why is it important that some of the insolation hitting Earth returns to space?
4. Draw the following diagram in your notebook, give it a title, and label it.



Question 4

5. What is thermal energy? What is another name for the absorption of thermal energy by the atmosphere?
6. Define "conduction," "convection," and "radiation," and draw a sketch of each to illustrate their mechanisms of heat transfer.
7. Explain how the Coriolis effect influences the direction of wind in the northern hemisphere.
8. Describe how thermal energy is transferred in the hydrosphere.

Connect Your Understanding

9. Why is the natural greenhouse effect necessary to life on Earth?
10. Explain what would happen to Earth without the natural greenhouse effect.
11. Discuss the scenarios that could occur if Earth's net radiation budget became unbalanced.
12. State whether each of the following is an example of conduction, convection, and/or radiation. Explain if you think there is more than one possibility.
    (a) You are cooking, and the handle of the spoon you are using to stir the soup starts to feel hot.
    (b) A pail of hot water is added to a child's inflatable pool. After a while, the pool is warm.
    (c) You go to the park, and when you sit on a metal bench, it is hot.
    (d) You are standing near a barbecue, and you feel the heat on your face.
13. Why are coastal cities attractive to many people seeking a moderate climate?

Reflection

14. Think back to the story on page 274 about how greenhouses trap heat. Did learning about how a greenhouse works enhance your understanding of the natural greenhouse effect? Explain your answer.
15. What is one thing you learned about the natural greenhouse effect that you would like to learn more about?
16. Describe the most interesting thing you found about Earth's net radiation budget.
17. Recall an earlier time you learned about conduction, convection, and radiation. How have you added to this knowledge in this section?

For more questions, go to ***ScienceSource***.

Investigating CAREERS in Science

Great CANADIANS in Science Sheila Watt-Cloutier

Over thousands of years, the Inuit peoples of the Arctic have developed skills and knowledge that allow them to live in the Arctic climate (Figure 7.30). However, climate change may mean the end of a way of life for these communities. Sheila Watt-Cloutier is doing everything she can to make sure this doesn't happen (Figure 7.31).

Watt-Cloutier has been politically active since 1995. In her role as chair of the Inuit Circumpolar Council from 1995 to 2001, she represented 155 000 Inuit in Russia, Alaska, Greenland, and Canada.

In 2005, Watt-Cloutier joined with Inuit hunters and elders from communities across Canada and Alaska to file a complaint to the Inter-American Commission on Human Rights based on the results of the Arctic Climate Impact Assessment. The complaint stated that loss of sea ice may make the Inuit hunting culture impossible to maintain and alleged that the cause of this loss was greenhouse gas emissions from the United States.

In a 2006 *Globe and Mail* article, Watt-Cloutier said, "Until now, there has been no human connection with climate change—just bureaucracies. Few grasp it until they hear the stories. Climate change affects every facet of Inuit life. We have a right to life, health, security, land use, subsistence, and culture. These issues are the real politics of climate change."

Figure 7.31 Sheila Watt-Cloutier

Figure 7.30 Many Inuit fish from kayaks in the summer. Warmer water in the Arctic Ocean may drive away the fish that prefer colder water.

Watt-Cloutier was born in Kuujjuaq, Nunavik (northern Quebec). She lived a traditional life for her first 10 years until she was sent away to school in Nova Scotia and Manitoba. She studied counselling, education, and human development at McGill University. Since then, she has worked tirelessly to improve education and life for the Inuit communities.

Throughout her career, Watt-Cloutier's work has been recognized as outstanding. Among the many awards she has received are a National Aboriginal Achievement Award, Officer of the Order of Canada, and the Rachel Carson Prize. She has also received honorary doctorates from various universities across Canada.

For Watt-Cloutier, the issues of climate change are real, immediate, and threatening to her community's way of life. She has made it her life's work to bring these issues to the public's attention.

Questions

1. How does learning about the threat to Inuit culture affect your thinking about climate change?
2. Go to ***ScienceSource*** and find out what Sheila Watt-Cloutier is doing now. What would you like to ask her about her work?

Science in My FUTURE Environmental Educators

In order for environmental issues such as climate change to be well understood by the public, people need to be educated about them. Many people who are concerned about these issues become environmental educators.

Provincial and national parks and outdoor education centres are often mandated to include environmental stewardship and conservation in their programs. At these parks and centres, people learn about these issues while enjoying the natural surroundings. They also learn that some natural surroundings could be threatened by inaction, both governmental and personal, regarding environmental issues (Figure 7.32).

Some environmental educators are authors and journalists who write newspaper and magazine articles or books on the environment. Reading these articles and books helps the general public keep up to date on the issue. Other environmental educators make documentary films and TV shows.

As people learn more about the environment, they use their knowledge in making personal decisions about household management, transportation, and even whom to vote for in elections.

Other environmental educators enjoy working specifically with students. Maggie Ballantyne has found a way to do this as an EcoSchools student leadership facilitator (Figure 7.33).

Figure 7.32 When people are exposed to the beauty of nature, they are more likely to want to protect it.

Figure 7.33 As a facilitator, Maggie Ballantyne helps students achieve environmental goals.

EcoSchools is a K–12 Environmental Education program that stresses waste reduction, energy conservation, schoolground greening, and ecological literacy. Ballantyne works with secondary school students, teaching them how to bring about change in their own schools using the EcoSchools model.

Students interested in bringing the EcoSchools program to their own schools have an ally in Maggie Ballantyne. She sets up “EcoTeams” to begin the process, conducts audits of the schools, and works with the teams on projects to help remediate climate change and other environmental problems.

If you want to become an environmental educator, a diploma or a degree in environmental science will help. As well, practise your communication skills! Students often work at provincial parks during their summer breaks, learning environmental education on the job.

Questions

1. Why might it be necessary for the public to be educated about environmental issues?
2. Why might it be an advantage to find a job that supports your interests? Go to ***ScienceSource*** to explore job possibilities.

7 CHAPTER REVIEW

ACHIEVEMENT CHART CATEGORIES

k Knowledge and understanding t Thinking and investigation
c Communication a Application

Key Concept Review

1. What is the biosphere? k
2. (a) How does climate differ from weather? k
   (b) Use an analogy to illustrate the difference between climate and weather. c
3. Describe the climate of each region shown below. Describe how life in one region would differ from life in the other. k

Question 3 (a) Moosonee, Ontario; (b) Guelph, Ontario

4. Describe what happens to the insolation received by Earth. k
5. How does cloud cover influence the amount of insolation that reaches Earth's surface? k
6. (a) Why does the temperature of the thermosphere vary from −100 °C to + 1000 °C each day? k
   (b) What terrestrial biome shows a similar type of temperature fluctuation? k
7. How does the net radiation of a region change with its latitude? k
8. In a brief descriptive paragraph, distinguish between the hydrosphere, lithosphere, and atmosphere. c
9. Explain the relationship between the troposphere and the survival of humans. k
10. What is atmospheric dust, and where is it found? k
11. What three gases in Earth's atmosphere are most important in supporting life? k
12. What two sources of energy warm the lithosphere? Identify which one is more significant. k
13. What states of water are found in the biosphere, and where are they located? k
14. List six terrestrial biomes found in Canada. Describe each in your own words. k
15. Why are there no clear boundaries between biomes? k
16. Explain why the albedo of an area can change with the seasons. k
17. Explain how thermal energy is transferred when you take your backpack from inside your home to the outdoors during a cold winter day. a
18. Use this figure to explain the Coriolis effect. t


Question 18

19. What are the trade winds, and where do they occur? k
20. What are jet streams? k

21. Define the term “natural greenhouse effect” in your own words. k

22. Write a one-sentence, catchy slogan to describe the natural greenhouse effect. c

23. Explain the idea of a net radiation budget. c

24. What happens to the solar radiation that reaches Earth’s surface but is not reflected back into space? k

25. How does latitude affect the net radiation budget of a region? k

Connect Your Understanding

26. Draw a cartoon to depict one aspect of heat transfer presented in this chapter. c

27. It is difficult to include water vapour in a chart or table of the composition of Earth’s atmosphere. Why is this? t

28. A large island, surrounded by ocean, has two cities at the same latitude. One city is situated on the west coast, and the other on the east coast. Cold ocean currents travel along the west coast of the island, and warm ocean currents travel along the east coast. Predict which city would have the warmer average annual temperature. Explain your answer. t

29. Create a model of a biome that is within a 50-km radius of your school. Include the lithosphere, hydrosphere, atmosphere, and the organisms that live there. a

30. Draw a word web to illustrate your understanding of the natural greenhouse effect. c

31. What do you think would happen if conditions on Earth suddenly changed so that much less heat was reflected back into space than is the case now? t

32. Why is it important for the net radiation budget of Earth to be in balance? k

33. Organize the information about incoming and outgoing solar radiation in a graphic organizer that makes sense to you. t

34. How do you think classifying biomes adds to information about climate? c

Reflection

35. If the climate of your region became warmer, how would that affect your way of life? Share this with a group of classmates. c

36. Describe the climate of the region you live in. If you could change one thing about that climate, what would it be and why? List potential impacts of that change. c

37. Think about when you have encountered the term “greenhouse effect.” What is your reaction to the term? Why do you think this is? a

38. Describe how your lifestyle reflects the climate in which you live. a

39. If you had to move to a region with a different climate than yours, what types of changes do you think would be the easiest and hardest for you to make? c

After Reading

Thinking Literacy

Reflect and Evaluate

List the various types of connections that you made as you read this chapter. How did making connections help you to understand and learn the terms and ideas from this chapter?

Write a brief paragraph explaining which “making connections” strategy helped you the most. Exchange paragraphs with a partner to find out whether you chose the same or a different strategy.

Unit Task Link

As you do research for your unit task, consider any severe weather events in the last 12 to 18 months. Have any of these events brought new concerns to the forefront? Have they affected locations that have not been affected before? Are the effects different from those in the past? Clip newspaper articles, bookmark Web pages, or make notes to add to your portfolio for the Unit Task.