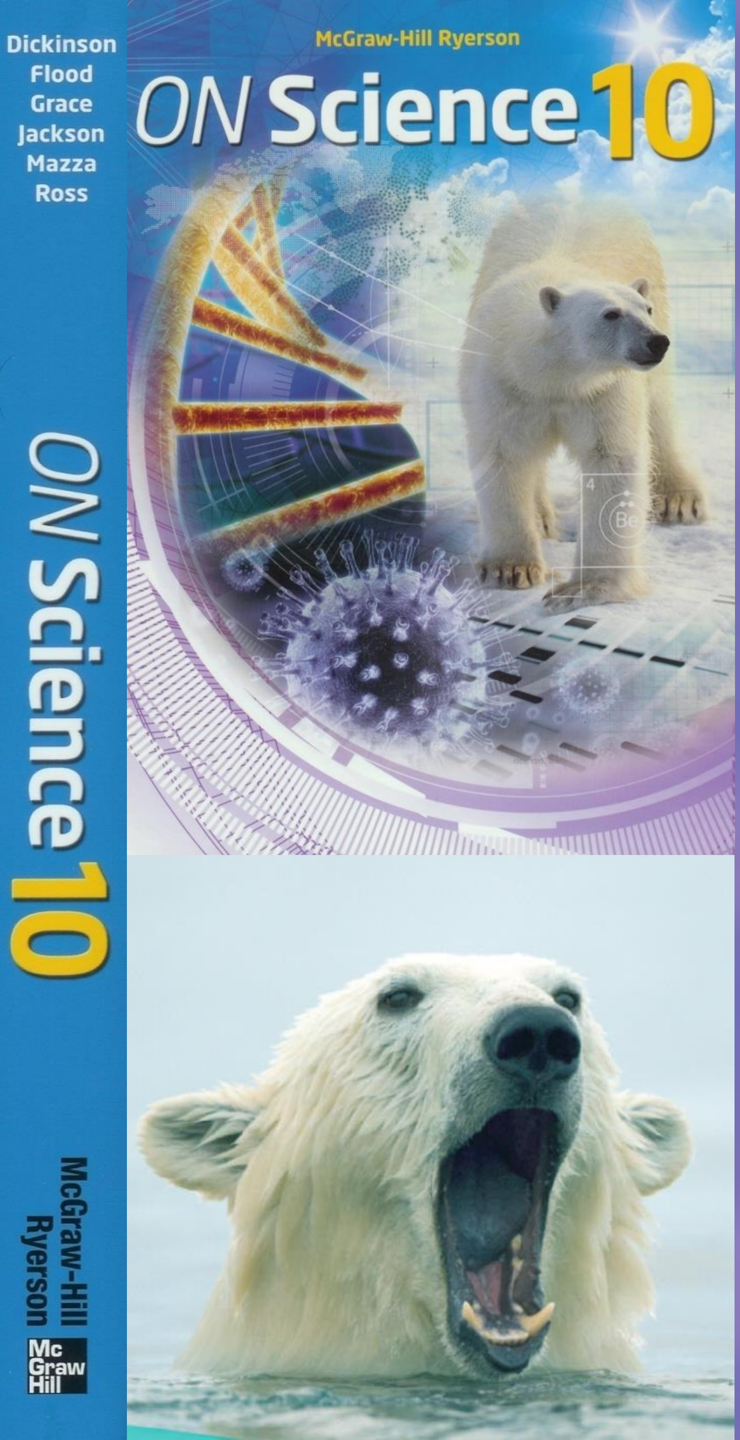


UNIT 3

Climate Change

Chapter 7: *Earth's Climate System*

Chapter 8:*Dynamics of Climate Change*

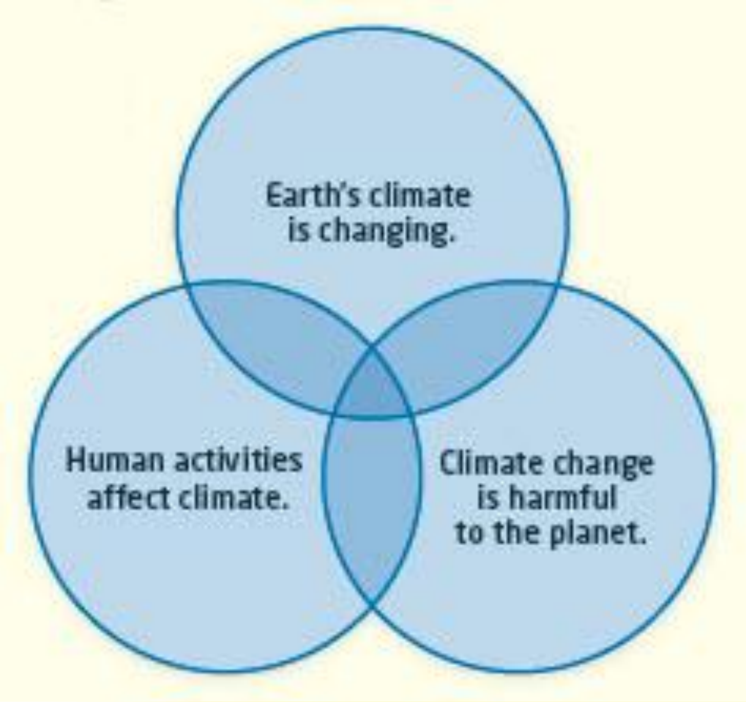
Chapter 9:*Addressing Climate Change*

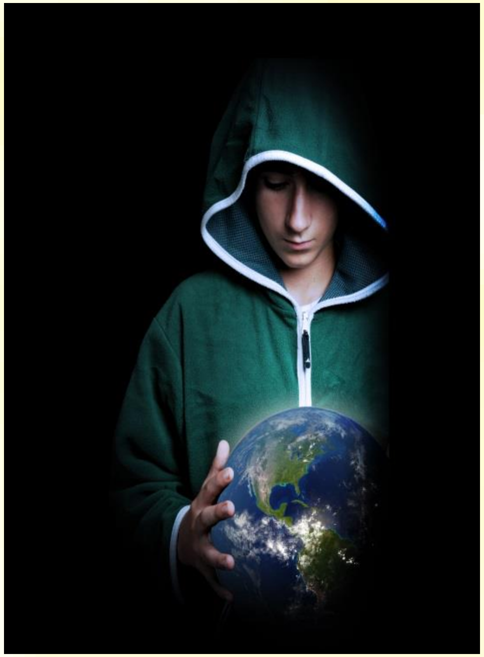
In this chapter, you will:

- ***identify*** *the principal components of Earth's climate system*
- ***describe*** *various tools and systems for classifying climates*
- ***analyze*** *effects of climate change on human activities and natural systems*
- ***investigate*** *natural and human factors that affect climate change*
- ***assess*** *and* ***evaluate*** *tools and systems for studying climates*
- ***analyze*** *some of the effects of climate change around the world*

Views on Climate Change

A variety of views are held on the issue of climate change, the seriousness of the problem, the human contribution to the problem, and the actions that must be taken.



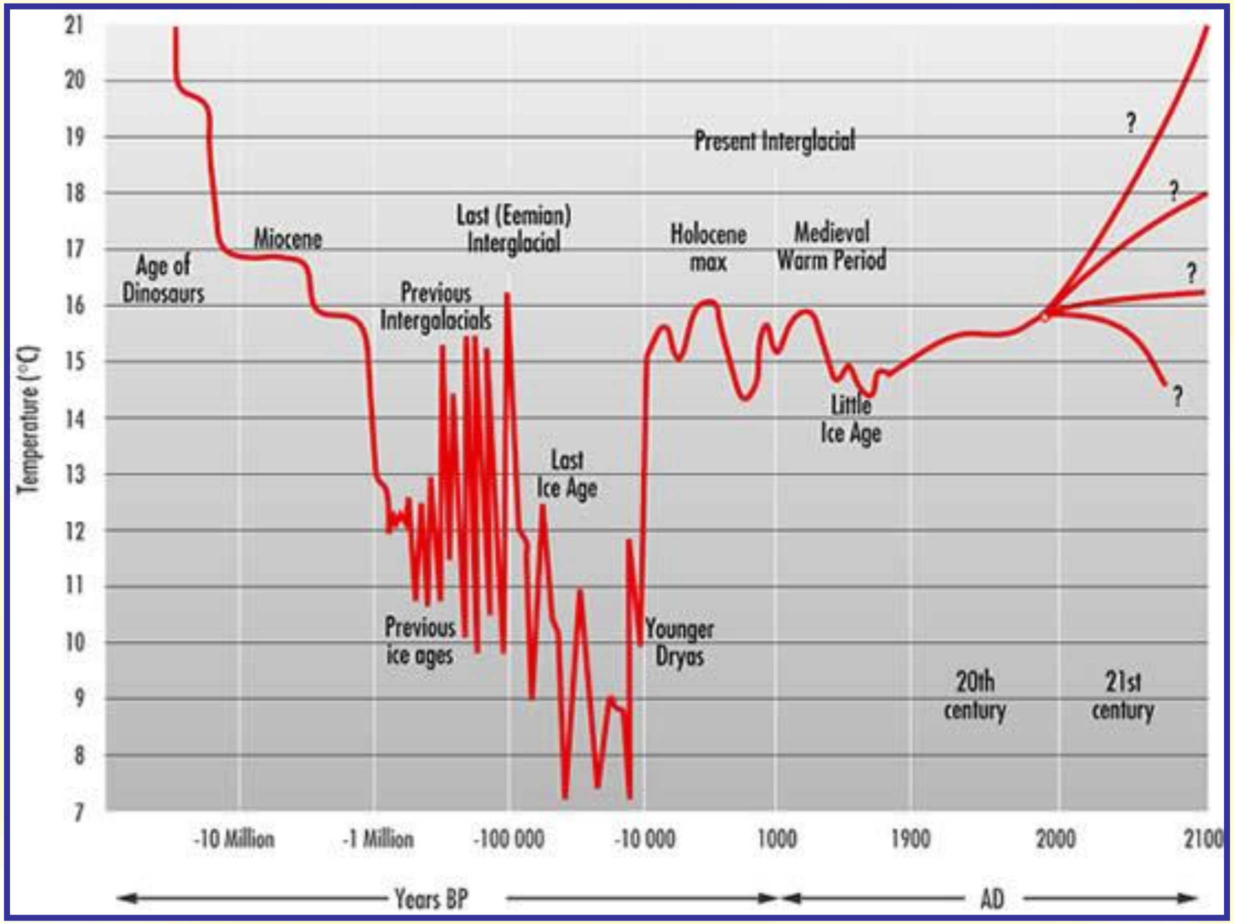


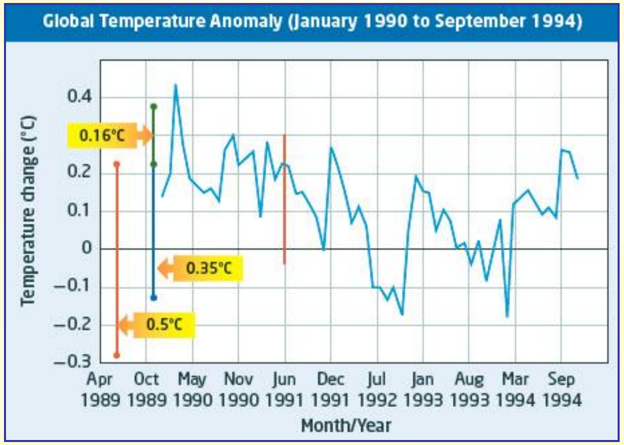
http://www.climatechange.gc.ca

What are your views on this issue?

Historic Climate Change

In the past, Earth has experienced many climatic changes.





http://www.bom.gov.au/info/climate/change/gallery/51.shtml

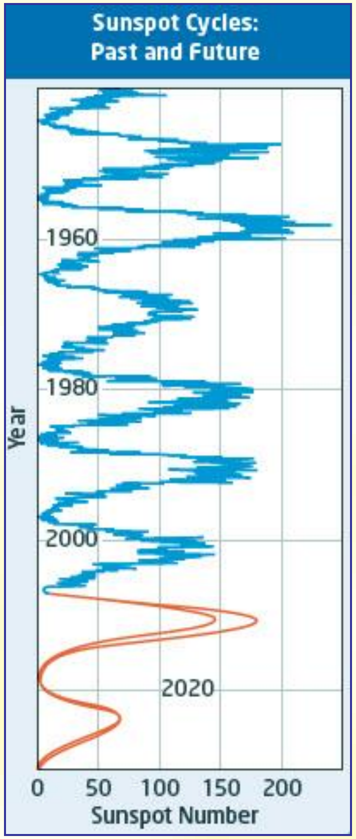
7.1 Factors That Affect Climate Change (Page 269)

The **atmosphere** is a layer of gases surrounding Earth.

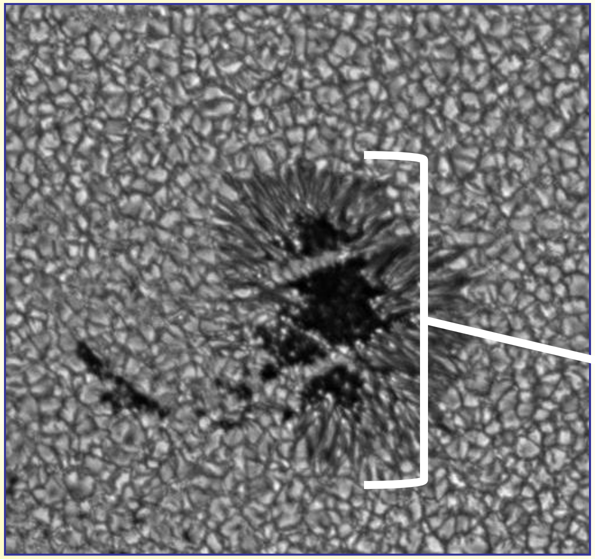
A region's **climate** describes the characteristic pattern of weather conditions within a region, including temperature, wind velocity, precipitation, and other features, averaged over a long period of time.

Earth and the Sun

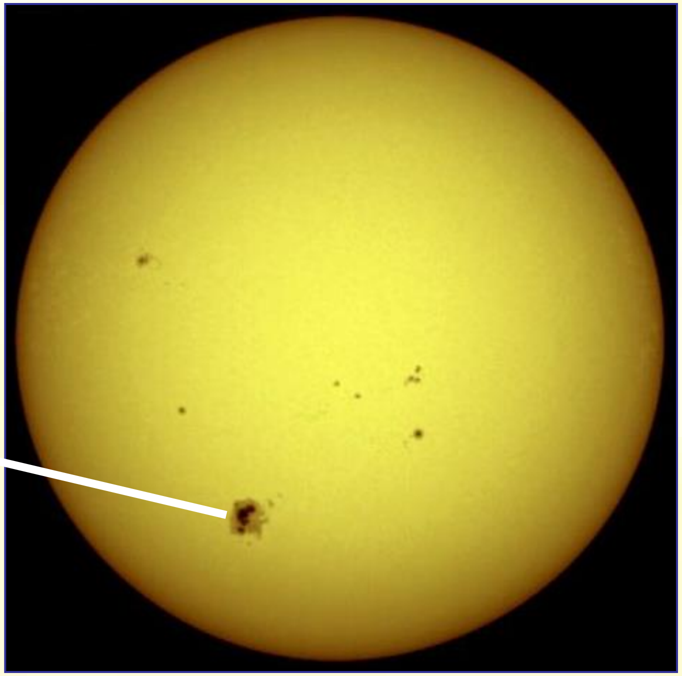
Energy from the Sun is the single most important factor that affects climate on Earth.



Sunspot Activity



http://solarscience.msfc.nasa.gov/images/sunspot1.jpg



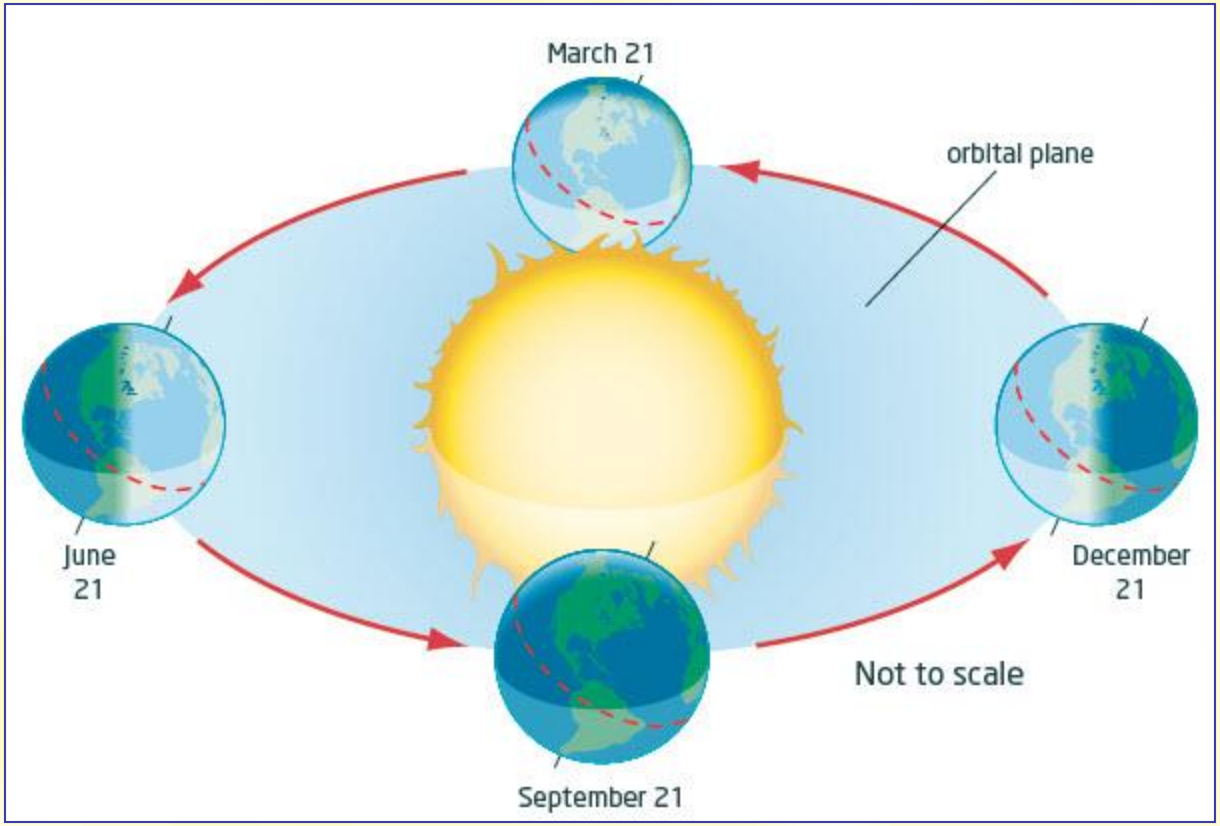
http://solarscience.msfc.nasa.gov/images/w920607.jpg

When the number of **sunspots** is high, the **Sun** emits higher amounts of solar radiation.

Movements of Earth in Space

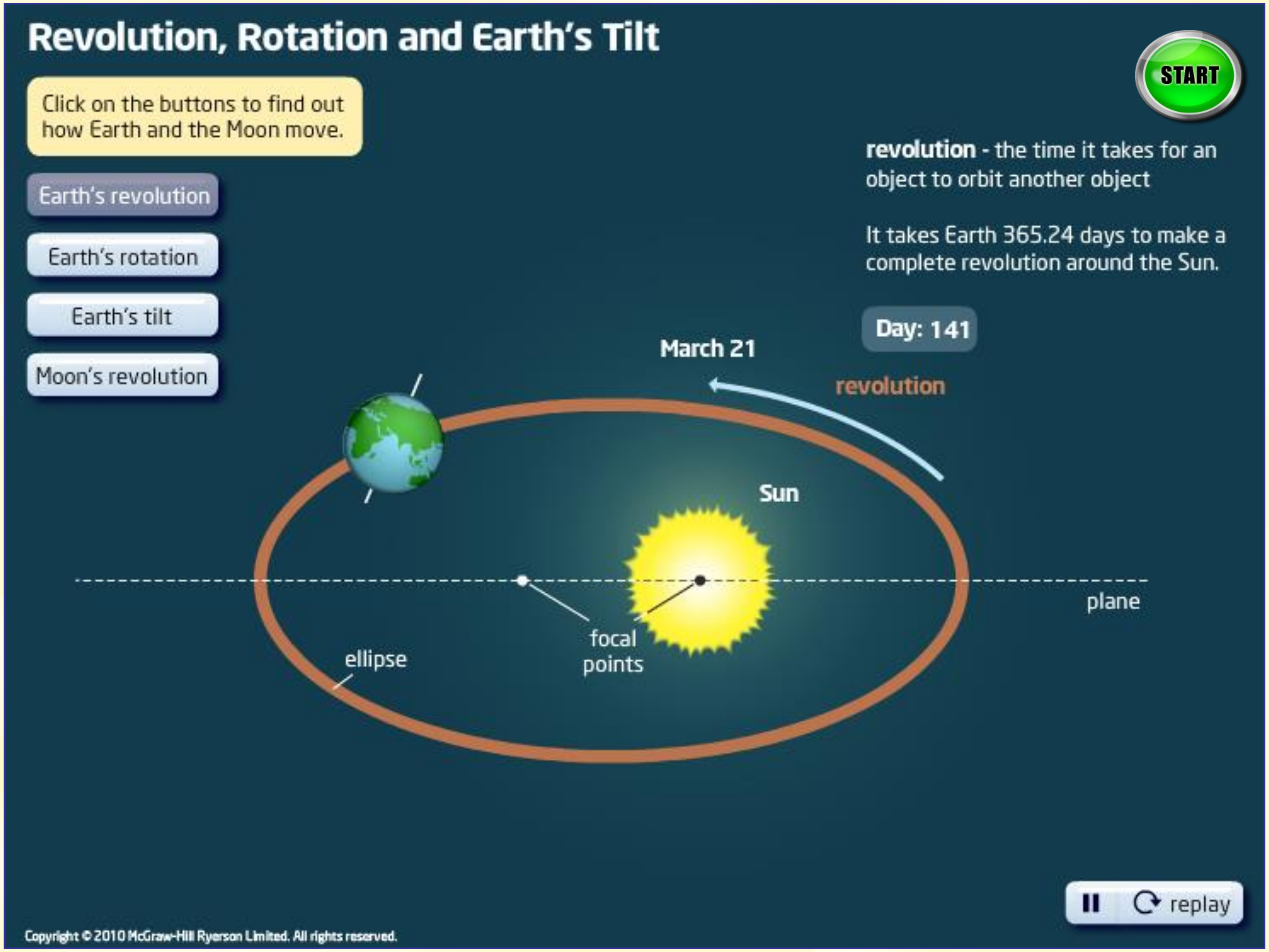
(Page 270)

The climatic **seasons** that we experience on Earth are caused by a combination of Earth's **annual orbit around the sun** and its **tilted axis of rotation**.



Revolution, Rotation, and Tilt

Click the “Start” button to review your understanding of the revolution, rotation, and tilt of Earth as it travels around the Sun.

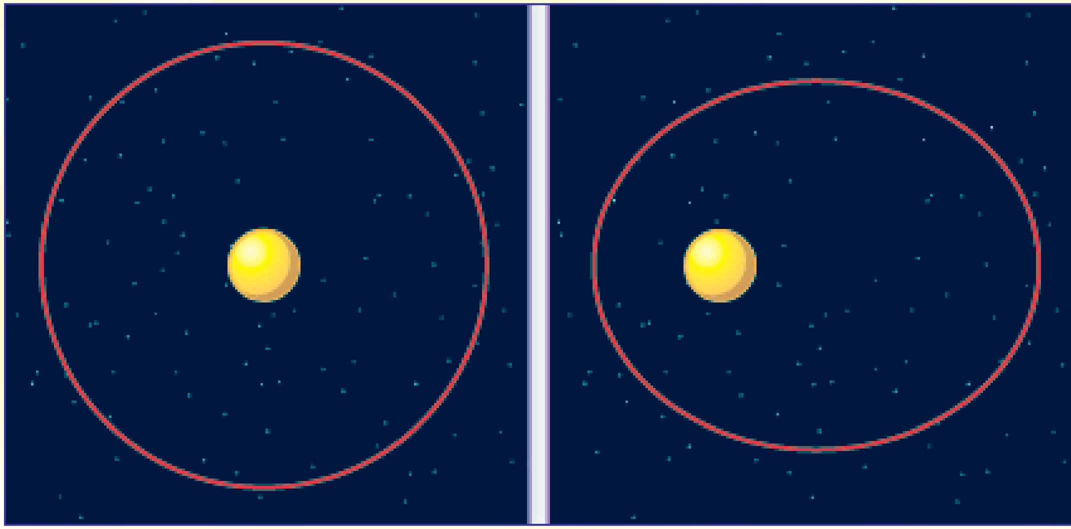


Revolution, Rotation, Tilt, and the Seasons (Page 271)

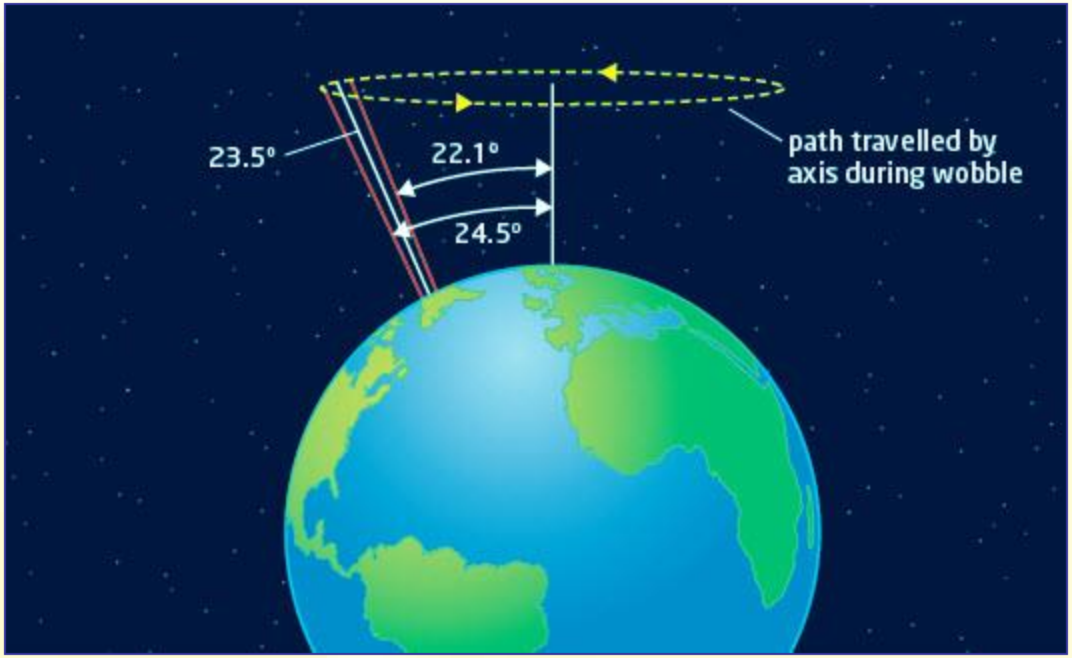
Click the "Start" button to review your understanding of how revolution, rotation, and tilt affect the seasons experienced on Earth.

Changes in Revolution, Rotation, and Tilt (Page 271)

Over a period of about 100,000 years, the orbital path of Earth changes from nearly **circular** to **elliptical** and back again. Length and intensities of seasons are affected by these changes.

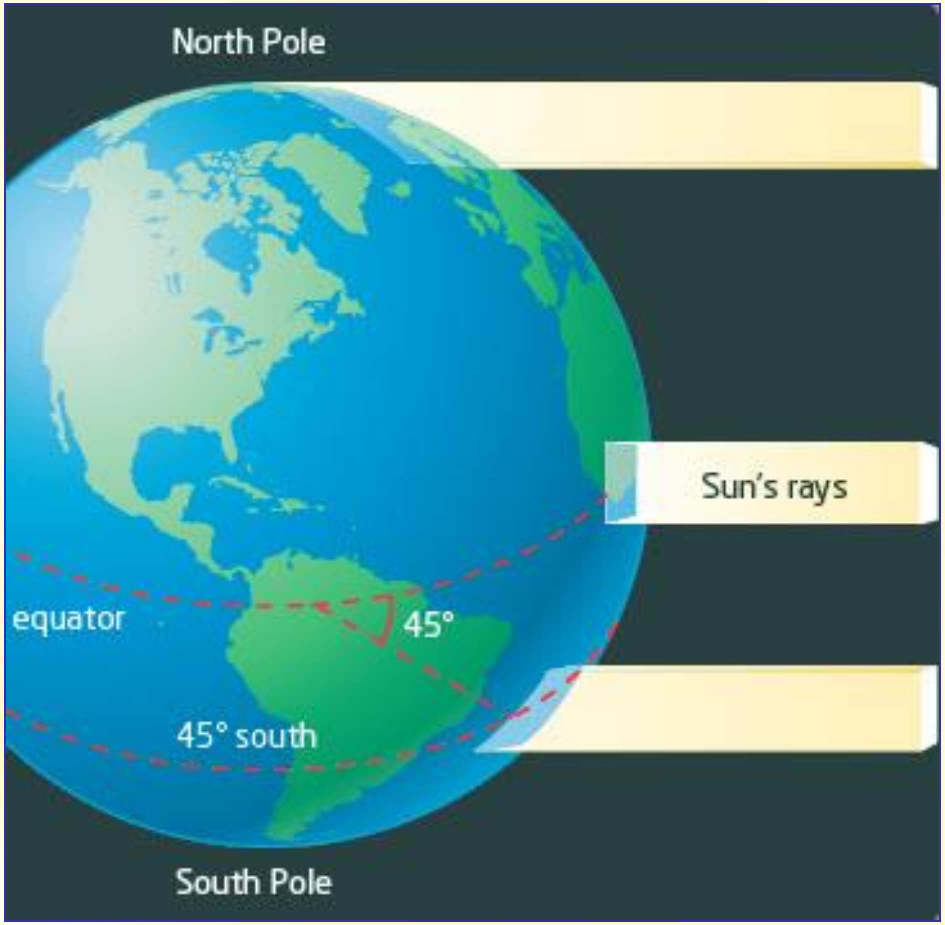


Earth's **angle of tilt** changes by **~2.4^0** over a period of 41,000 years. The greater the tilt, the greater the temperature differences between summer and winter.



The Effect of Latitude on Climate and Seasons

(Page 272)



The **curved shape of Earth affects** the area of the surface covered by the same amount of sunlight. Rays of sunlight hitting Earth more directly will have a higher intensity than those hitting Earth at an angle.

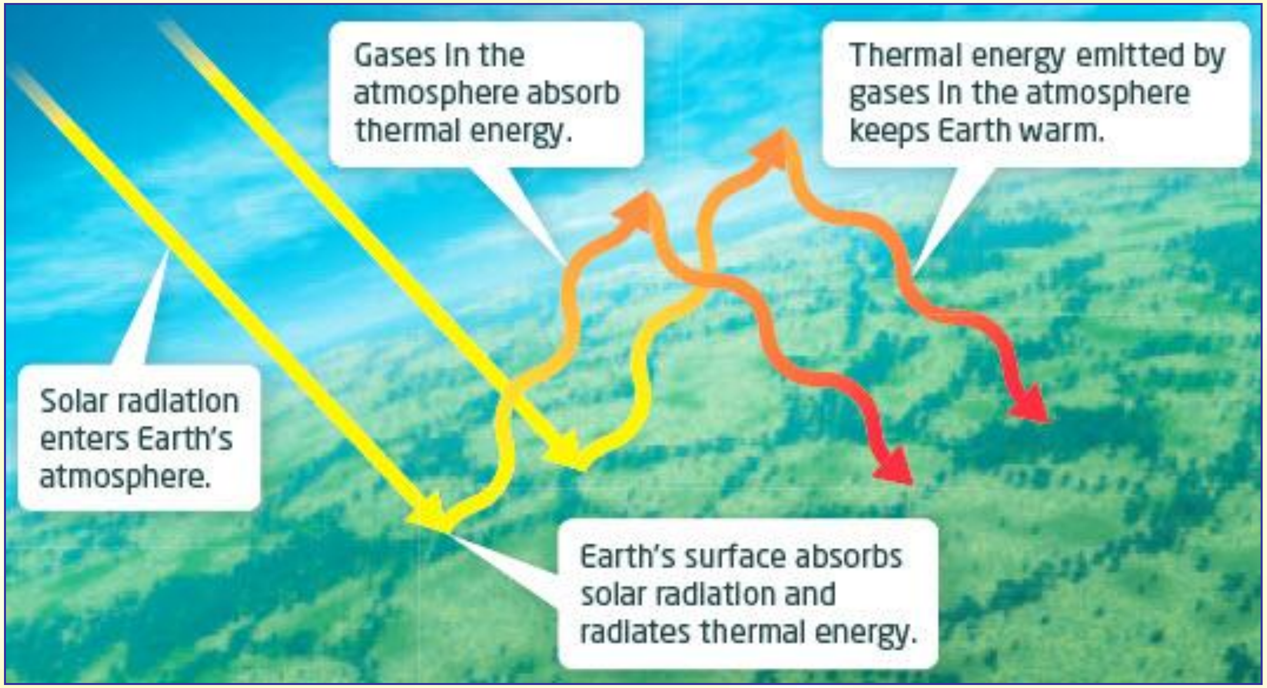
equator = highest intensity

45^0 = moderate intensity

poles = lowest intensity

How the Atmosphere Affects Climate
(Page 273)

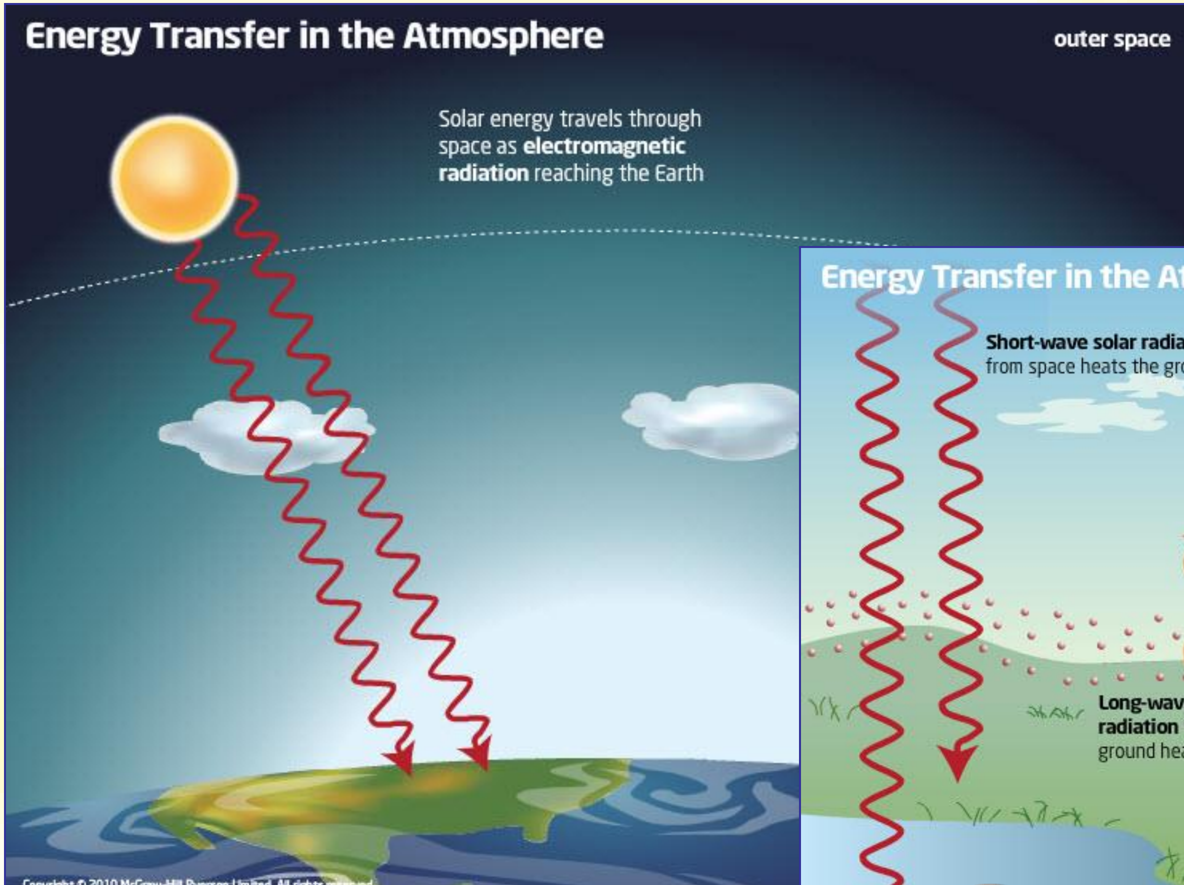
Earth's atmosphere can absorb and reflect radiation emitted from the Sun and from Earth's surface. It can also prevent radiation from escaping into space.

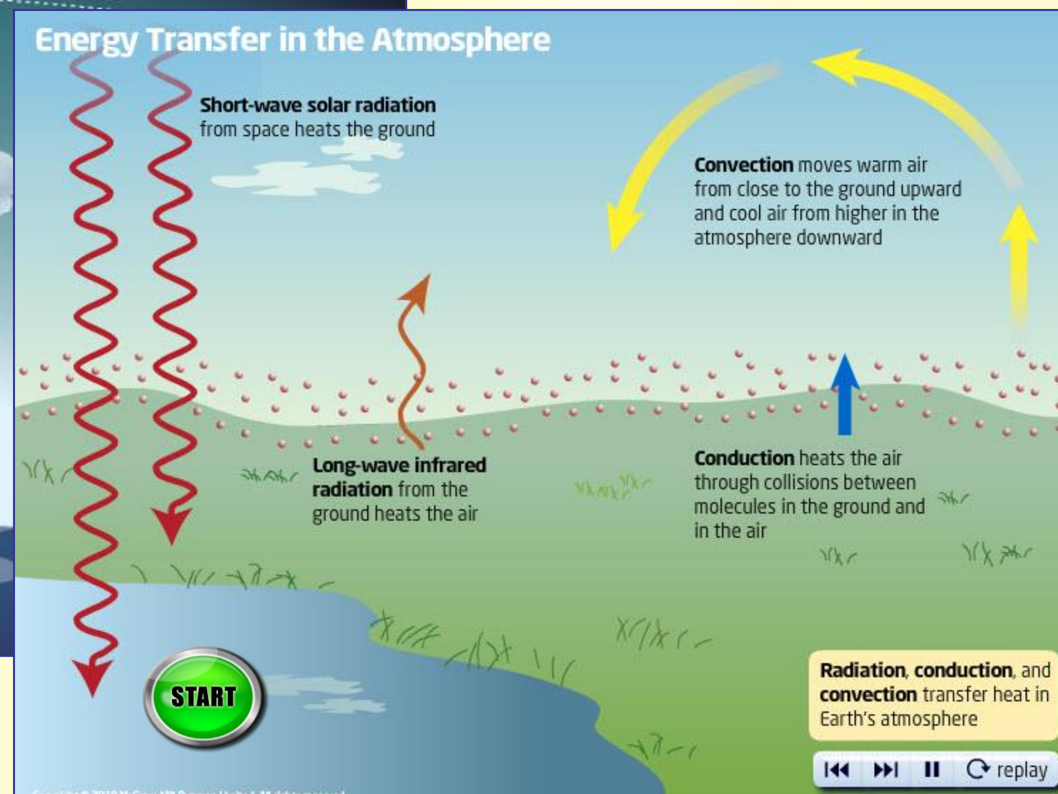


The **greenhouse effect** is the natural warming of Earth, caused when gases in Earth's atmosphere absorb thermal energy that is radiated by the Sun and Earth.

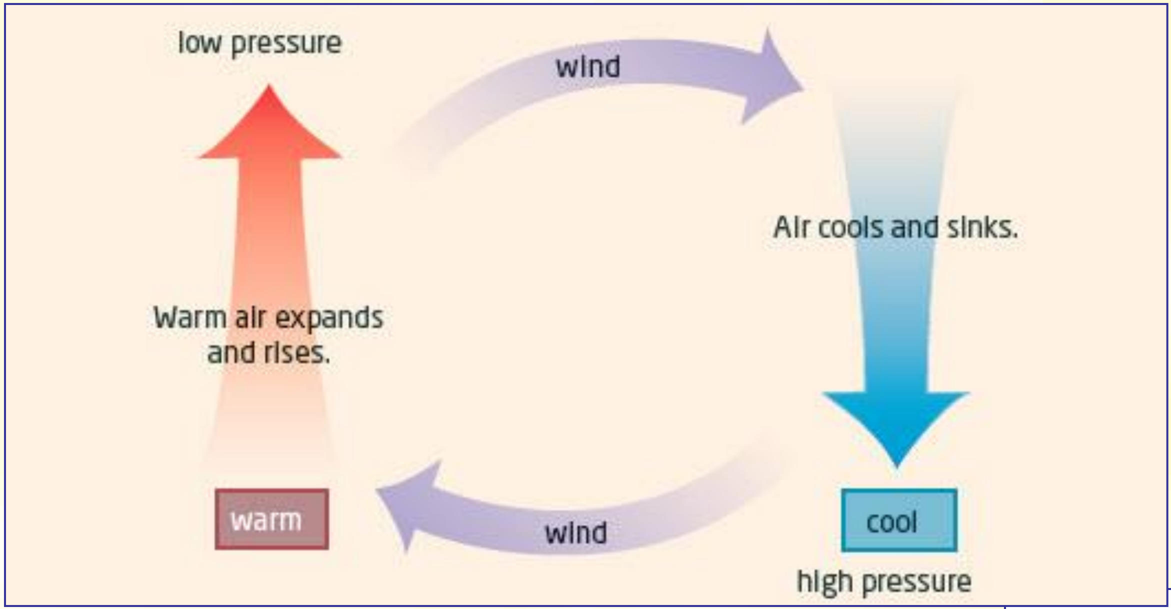
Energy Transfer in The Atmosphere (Page 273)

Click the “Start” buttons to review your understanding of energy transfer in the atmosphere.





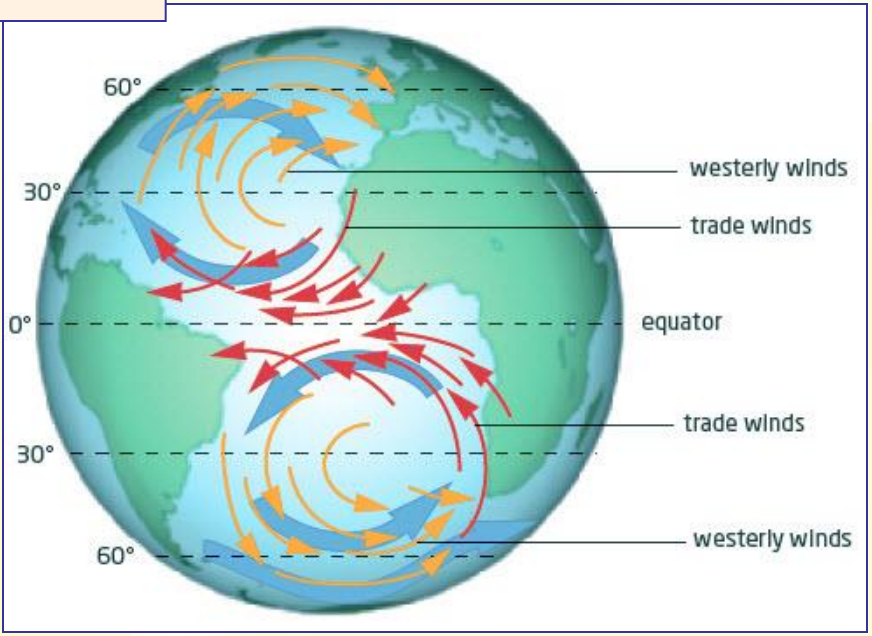
Winds Disperse Energy through the Atmosphere (Page 273)



Wind is caused by the **uneven heating** of Earth’s surface. The rising of warmer air and the sinking of cooler air results in areas of high and low pressure.

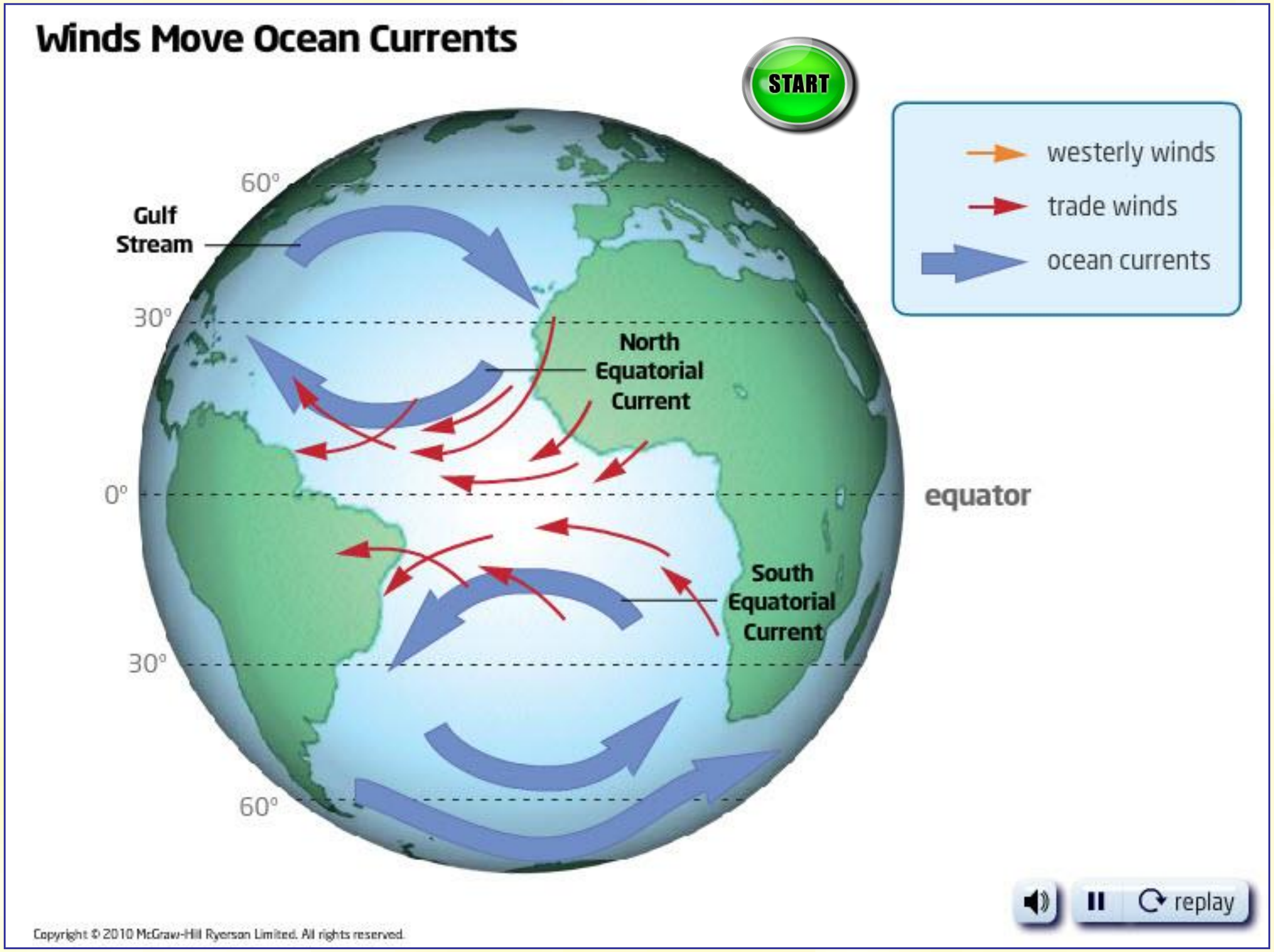
Wind is the movement of air from areas of high pressure to areas of lower pressure.

This movement of air affects global **ocean currents** and **precipitation** patterns.



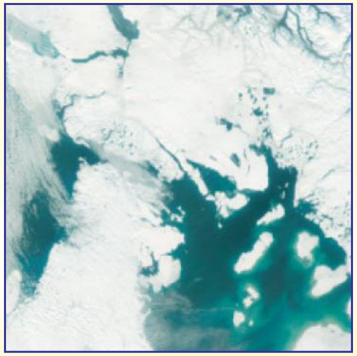
Winds and Ocean Currents

Click the "Start" button to review your understanding of how winds affect ocean currents.



How the Hydrosphere Affects Climate (Page 274)

The **hydrosphere** is the collective mass of water found on, under, and over the surface of Earth in the form of liquid water, ice, and water vapour.



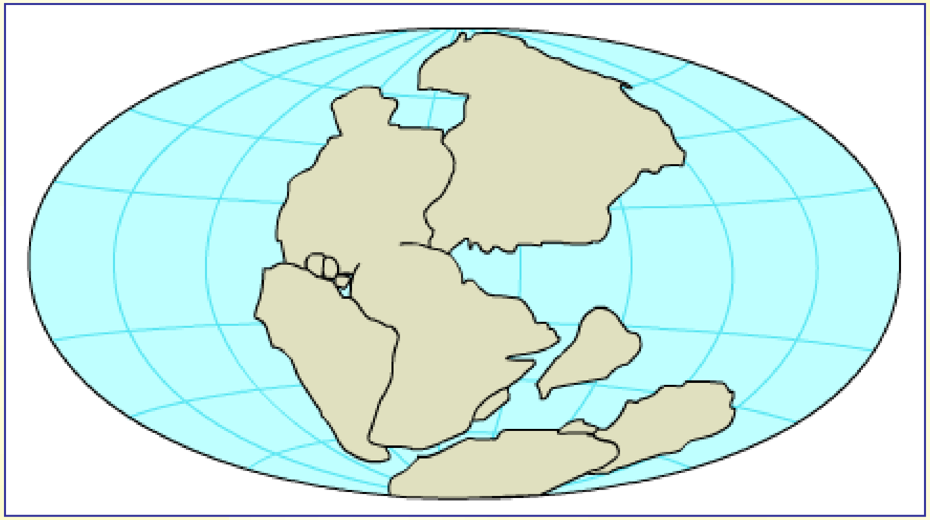
Oceans and **lakes** act as **heat reservoirs,** holding much more heat than the atmosphere can.

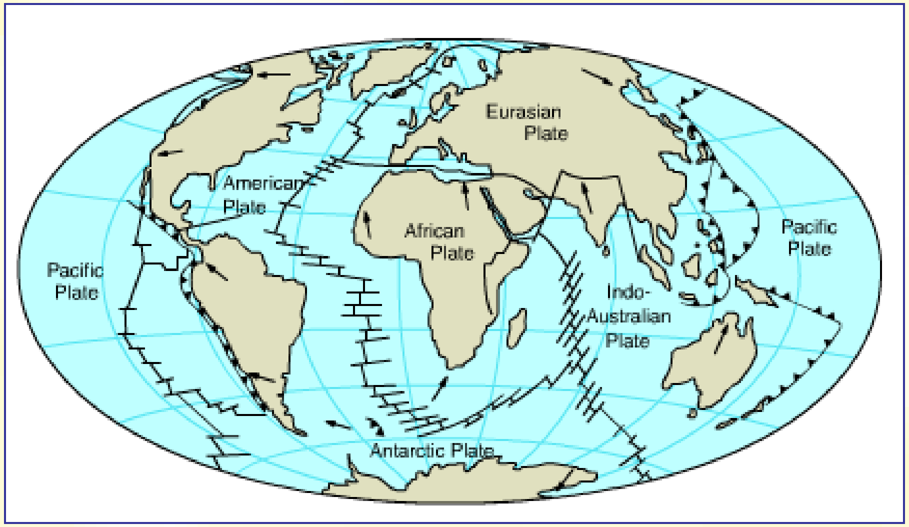
Snow and **ice** can reflect heat from the Sun back into the atmosphere. The fraction of the light that is reflected by a surface is known as **albedo**.

The distribution of water, ice, snow, and land on Earth's surface greatly affects the average global temperature.

How Moving Continents Affect Climate (Page 275)

Tectonic plates are pieces of Earth's outer shell (the lithosphere) that move around on the slowly flowing underlying rock layer (the asthenosphere).





The movement of the plates can result in the formation of new continental land masses, oceans, and mountain ranges and changes in their latitudes on Earth. These changes can greatly affect heat transfer, wind patterns, precipitation, and ocean currents.

Volcanic Eruptions

Volcanic eruptions spew ash and other particles into the atmosphere. These particles, called **aerosols,** can reflect solar radiation, resulting in a net cooling of Earth.

Volcanic eruptions also add large amounts of **greenhouse gases** (such as CO_2) to the atmosphere, which might cause an increase in global temperatures.

How Human Activity Affects Climate

(Page 277)

Human activities, such as the burning of fossil fuels, may be partially contributing to climate change. Such activities lead to the emission of massive amounts of greenhouse gases into the atmosphere.

Anthropogenic: relating to or resulting from the influence of humans

Section 7.1 Review

(Page 278)

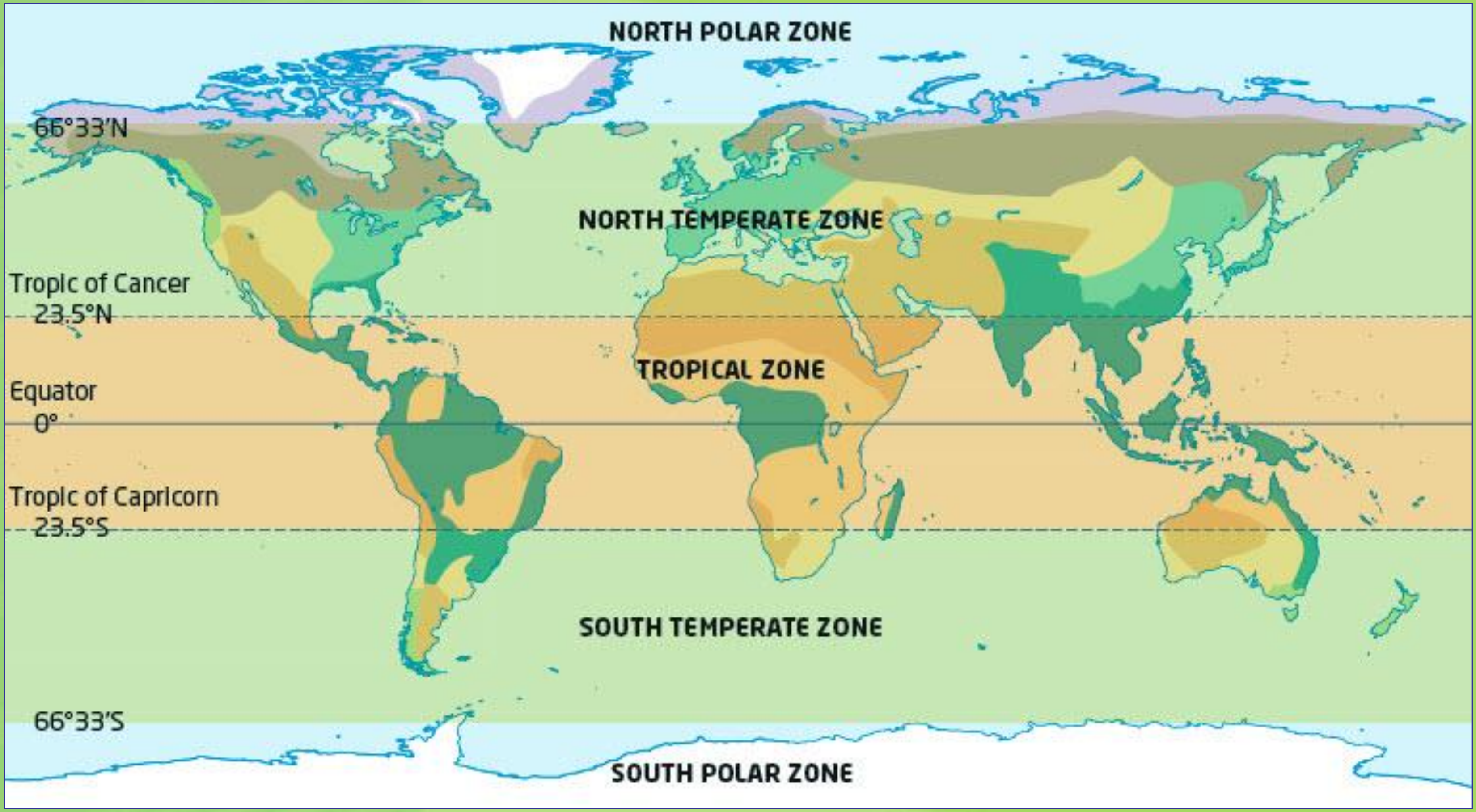
Concepts to be reviewed:

- *an understanding of all the aspects that make up the* ***climate*** *of a region*
- *the factors that affect the amount of solar energy a particular area receives from the Sun*
- *how factors such as winds, ocean currents, and the shape and size of continents affect climate*
- *an understanding of how* ***albedo*** *can affect global temperatures*
- *an understanding of the effects of* ***volcanic eruptions*** *on global climate*
- *an understanding of the effects of* ***human activities*** *on global climate*

7.2 Describing Climates

(Page 279)

Distance from the equator affects both average temperature and average precipitation, creating three types of broad climatic zones (**polar**, **temperate**, and **tropical** zones).



Climatographs

(Page 280)

A **climatograph** is a graph of climate data for a specific region. The data is usually obtained over 30 years, using observations made at local weather stations.

Climatographs include data for both **monthly precipitation** and **average daily temperatures**.

The Köppen Climate Classification System (Page 282)

The **Köppen climate classification system** is a method of identifying and describing climates based on observable features such as temperature ranges and rates of precipitation.

The world is divided into **five major climate zones** based on the following **three** factors:

- **average monthly temperature**
- **average monthly precipitation**
- **average annual precipitation**

The Köppen Climate Classification System

(Page 282)

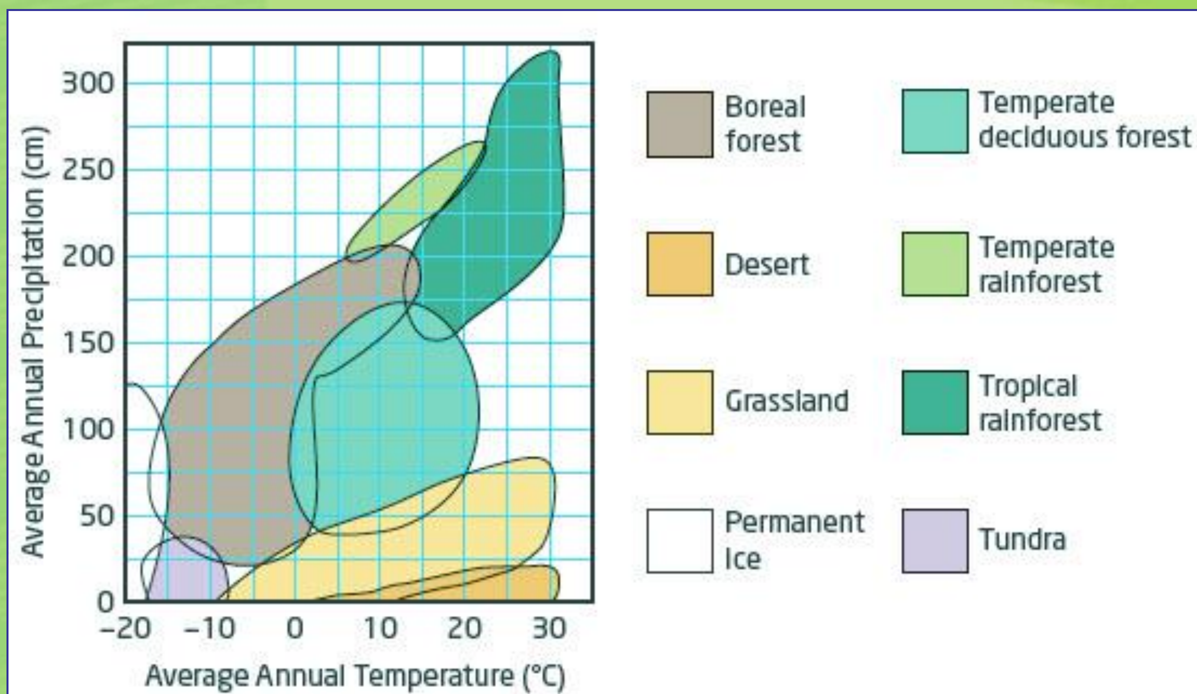
Köppen's Category	Description
A. tropical moist climate	All months average above 18°C. Annual precipitation is greater than 1500 mm. There may be no dry season or a short dry season.
B. dry climate	Temperatures range from up to 40°C in summer to −40°C in winter. Precipitation is low during most of the year and is exceeded by potential evaporation and transpiration.
C. moist mid-latitude climate with mild winters	Warm to hot summers. The average temperature of the coldest month is above −3°C.
D. moist mid-latitude climate with cold winters	Warm to cool summers. The average temperature of the coldest month is below −3°C.
E. polar climate	Cool summers and extremely cold winters. The average temperature of the warmest month is below 10°C.

Biomes

(Page 283)

A **biome** is the largest division of the biosphere. **Biomes** represent large regions that have similar **biotic** components (such as plants and animals) and similar **abiotic** components (such as temperature and amount of rainfall).

There are **eight** major **biomes** in the world. The average annual temperatures and precipitation levels are shown in the diagram below.

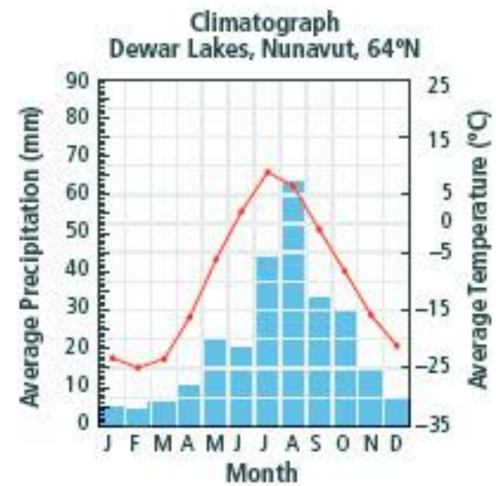


Climate Zones and Biomes in Canada

Of the **eight** major **biomes** found in the world, **seven** are found in Canada. Only the tropical rainforest biome is not found in Canada. The seven Canadian biomes are described on the following slides.

Permanent Ice

The polar icecaps of Canada's far north are permanently frozen zones with annual precipitation of less than 50 cm. Lichens and mosses can tolerate the cold and drought.

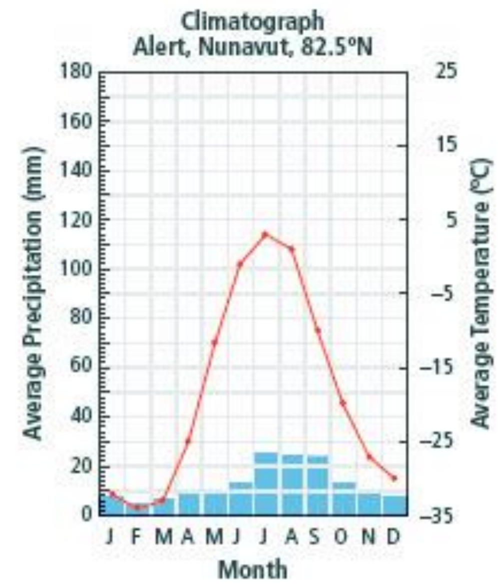


Climate Zones and Biomes in Canada

(Page 284)

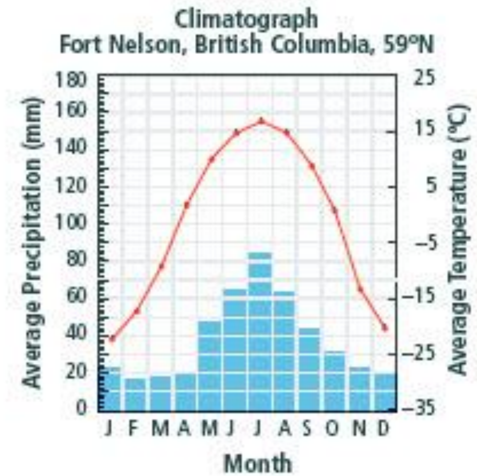
Tundra

The tundra has a layer of permanently frozen soil called permafrost. Few trees can survive the thin soils and lack of moisture. Plants grow close to the ground.



Boreal Forest

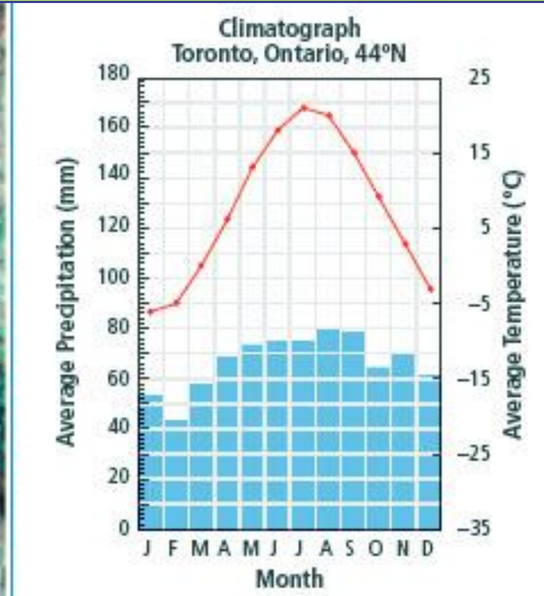
A broad band of northern Canada between latitudes 45° and 65° north is covered by a forest of coniferous trees such as black spruce and white spruce. Annual precipitation is between 30 cm and 85 cm, much of it falling as snow. Temperatures are below freezing for six months per year.



Climate Zones and Biomes in Canada
(Page 285)

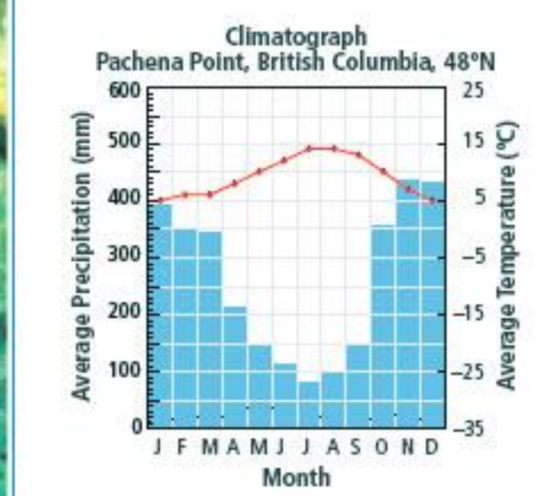
Temperate Deciduous Forest

Found mainly in eastern Canada, this zone has annual precipitation of 75 cm to 180 cm, distributed evenly throughout the year. Temperatures range from -30°C in winter to 30°C in summer. Maple, oak, and birch are typical trees in these forests.



Temperate Rainforest

Coastal British Columbia is home to Canada's temperate rainforest, receiving more than 200 cm of precipitation per year. Average temperatures are mild, ranging from 5°C to 25°C. This climate produces very tall trees, such as Sitka spruce and Douglas fir.

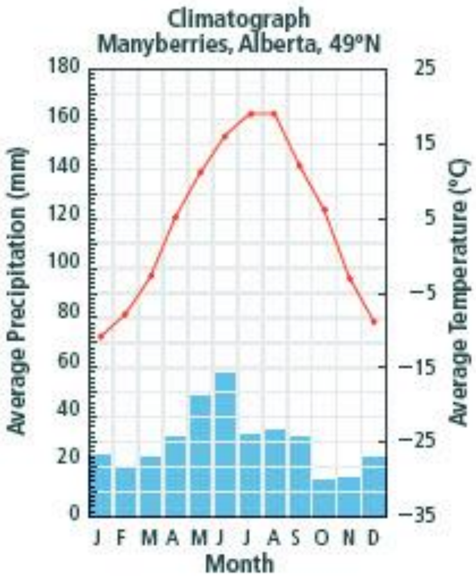


Climate Zones and Biomes in Canada

(Page 285)

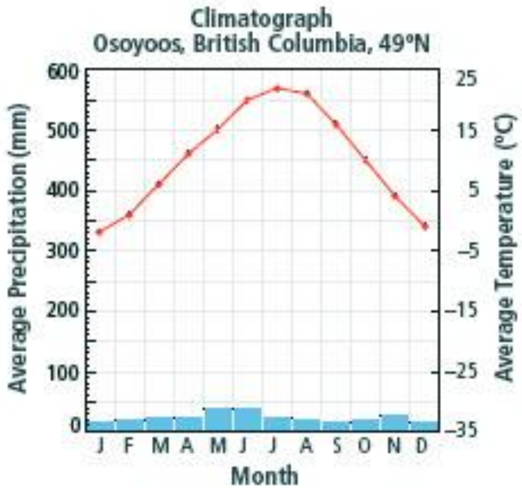
Grassland

The Canadian prairies have annual precipitation of 25 cm to 100 cm, with hot summers and cold winters. Limited rainfall restricts the growth of trees, and the typical vegetation is grasses with deep roots adapted for drought.



Desert

Canada's only desert zone is in southern British Columbia. It forms the northern end of the Great Basin Desert of the western United States. Rainfall is less than 25 cm annually. Plants have spiny leaves to conserve water and grow deep roots.



Bioclimate Profiles, Ecozones, and Ecoregions
(Page 286)

Bioclimate profiles are graphs of climatic conditions and related factors. They include elements such as:

- minimum, maximum, and mean temperatures
- probability of frost
- monthly total precipitation
- number of days with rain and days with snow
- water surplus and deficit

An **ecozone** is a division of Earth's surface that has developed over a long period of time and is separated by a geological feature such as an ocean, desert, or mountain range.

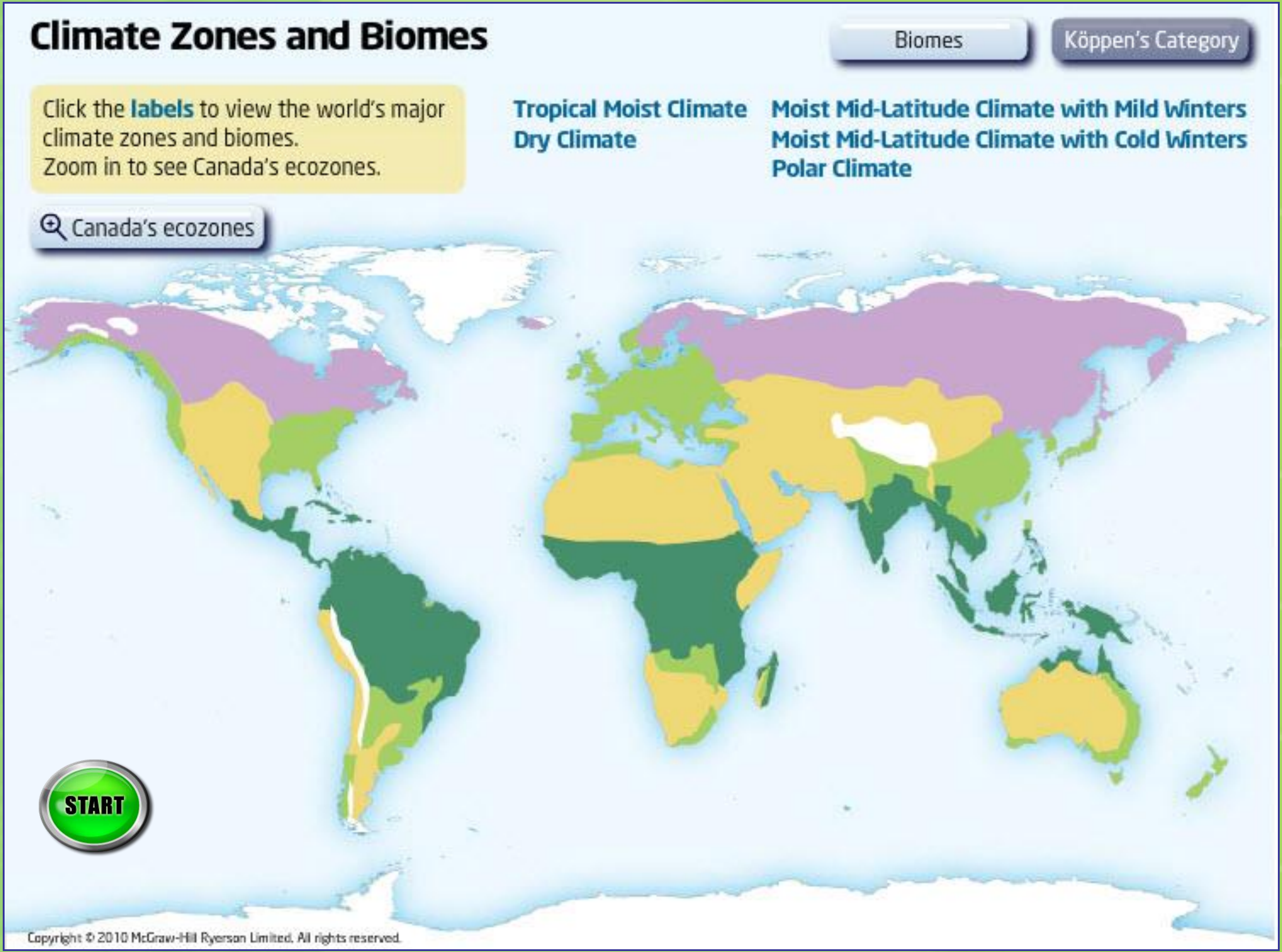
An **ecoregion** is a subdivision of an ecozone that is characterized by local landforms such as plains, lakes, mountains, and rivers.

Canada's Ecozones and Ecoregions

(Page 287)

Climate Zones and Biomes

Click the "Start" button to review the climate zones and biomes found around the world and in Canada.



Changing Climate, Changing Landscapes

(Page 288)

Climate classification systems help scientists understand current climatic patterns and predict the effect of climate changes on regions.

Section 7.2 Review

(Page 289)

Concepts to be reviewed:

- *the factors used to classify climate zones*
- *the purpose of and the interpretation of climatographs*
- *the use of climate classification systems to categorize and compare different parts of the world*
- *an understanding of global and Canadian biomes*
- *the nature and purpose of ecozone and ecoregion subdivisions*
- *the impact of climate change on human lifestyles*

7.3 Indicators and Effects of Climate Change

(Page 290)

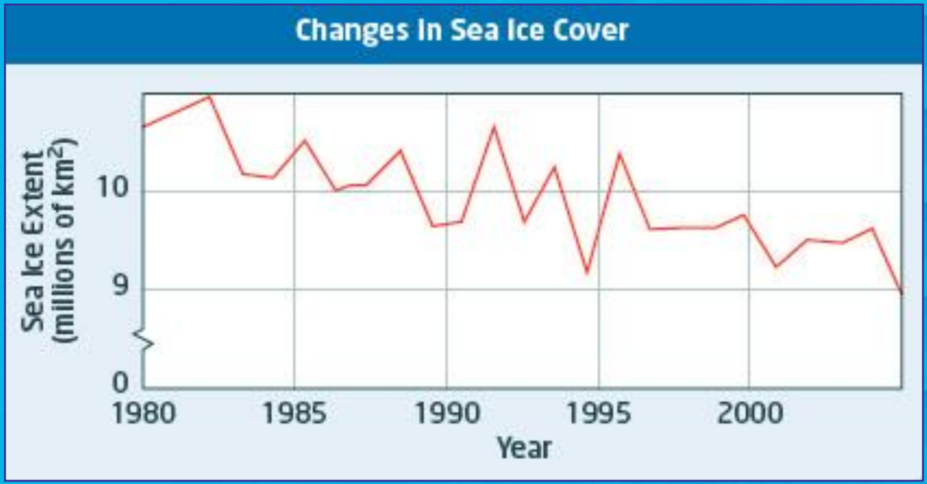
Global warming is described as an increase in global average temperature. This increase in the average temperature of the atmosphere and oceans is the largest single indicator of climate change.

The reduction in the area covered by Arctic ice is one of the indicators that scientists study.

Changes in Polar and Glacial Ice

(Page 291)

An overall reduction in Earth's ice cover will result in higher sea levels and will also impact the habitats of animals such as seals and polar bears.



With less ice, polar bears must swim longer distances to reach food and safety.

Rising Sea Level and Ocean Acidity

(Pages 292-293)

Indicator	Cause	Effects
Rising sea level	About half of this increase is due to the observed melting of glaciers and icecaps. The other half is a result of the thermal expansion of seawater due to increased temperature.	As sea level rises, more land will be covered by water. Many of the world's largest cities are located in coastal regions, so large populations of people will be displaced by rising seas.
Rising ocean acidity	Scientists estimate that the oceans have absorbed about half of all carbon dioxide produced from fossil fuel emissions over the past 200 years. Some of the dissolved gas forms carbonic acid, which lowers the pH of the water. Lower pH means that the water is more acidic.	Rising acidity threatens the ability of corals and other organisms to build shells and hard skeletons and the ability of fish and plankton to reproduce. The success of commercial fishers who supply food to humans may also be affected, and low-lying islands and coastal areas would be more vulnerable to storms.

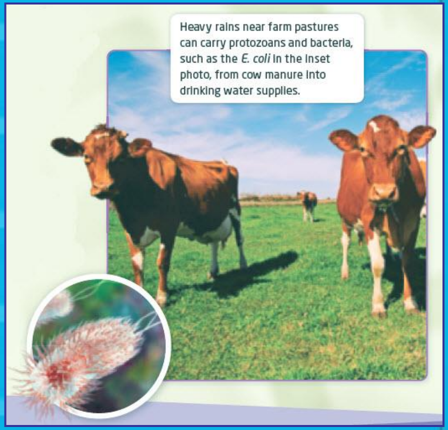
Changes in sea water pH could negatively affect coral reef ecosystems.

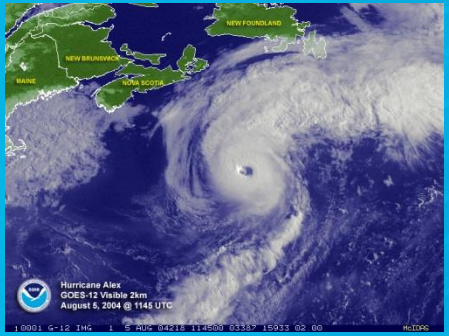
Ocean levels could rise by 20 to 40 cm within the next 100 years.

Climate and Health

Risks of disease and infection and the chances of accidental death due to extreme weather (heat waves, floods, tornadoes, lightning strikes, hurricanes, and snowstorms) are closely connected to climate change.

Outbreaks of disease spread by animals usually increase during periods of higher temperatures.





Source: NOAA

Source: iStock

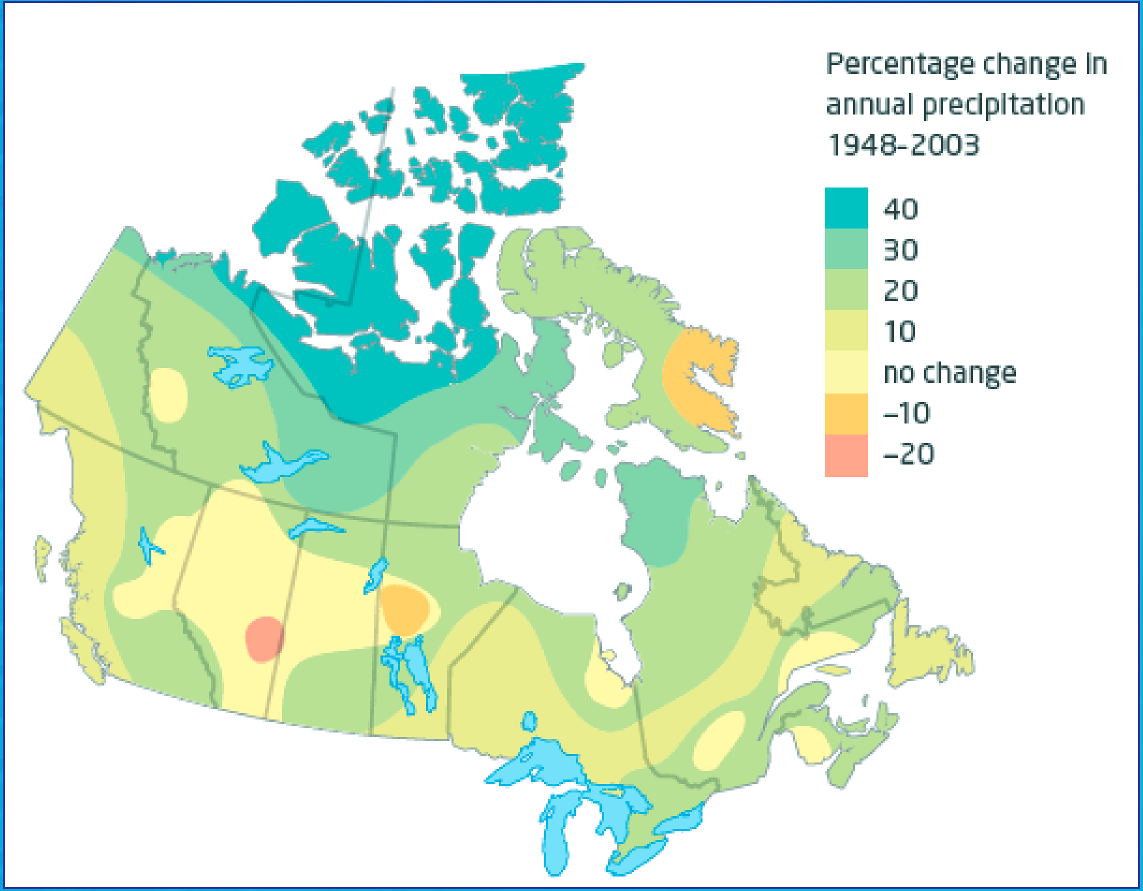
Source: The Canadian Press

Severe weather can pose year-round risks to Canadians.

Changing Wind and Precipitation Patterns (Page 295)

Changes in heat distribution over Earth's surface have led to changes in **wind patterns**. The speed, frequency, and direction of winds have been fluctuating unpredictably.

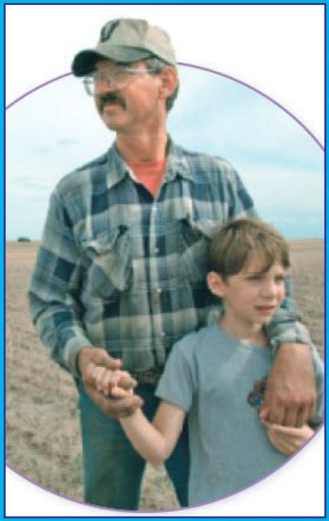
As average temperatures have increased, **precipitation patterns** have changed throughout Canada. As shown on the right, precipitation levels have increased or decreased depending on the region. Overall, precipitation in Canada has increased.



Desertification and Droughts

(Page 296)

Desertification is the process by which land slowly dries out until little or no vegetation can survive and the land becomes a desert.



Reduced levels of precipitation can lead to droughts that can dramatically reduce Canadian grain production.

Source: Ivy Images

Source: iStock

The cost of drought can be extremely high.

Mostly Costly Natural Disasters in Canada

Province	Event	Cost ($ billion)
British Columbia, Prairie provinces, Ontario, Quebec, Nova Scotia	drought (2001-2)	$5.8*
Ontario, Quebec, Atlantic Canada	ice storm (1998)	$5.4
Prairie provinces	drought (1979-80)	$2.5
Prairie provinces	drought (1988)	$1.8
Saguenay, QC	flood (1996)	$1.7
Prairie provinces	drought (1984)	$1.0

* est GDP drop
Data Sources: Natural Resources Canada, Environment Canada

Source: Government of Canada

Storm Intensity and Frequency

(Page 296)

Recent data seems to support the scientific hypothesis that higher average temperatures result in an increase in the intensity and frequency of storms.

Flooding, heavy rains, and strong winds can cause extensive damage to buildings, bridges, and roads. Storms also disrupt electrical service and put people in physical danger.

Changing Biomes

(Page 297)

As climate conditions change, the plants and animals that are adapted to a particular biome may no longer be able to survive there.

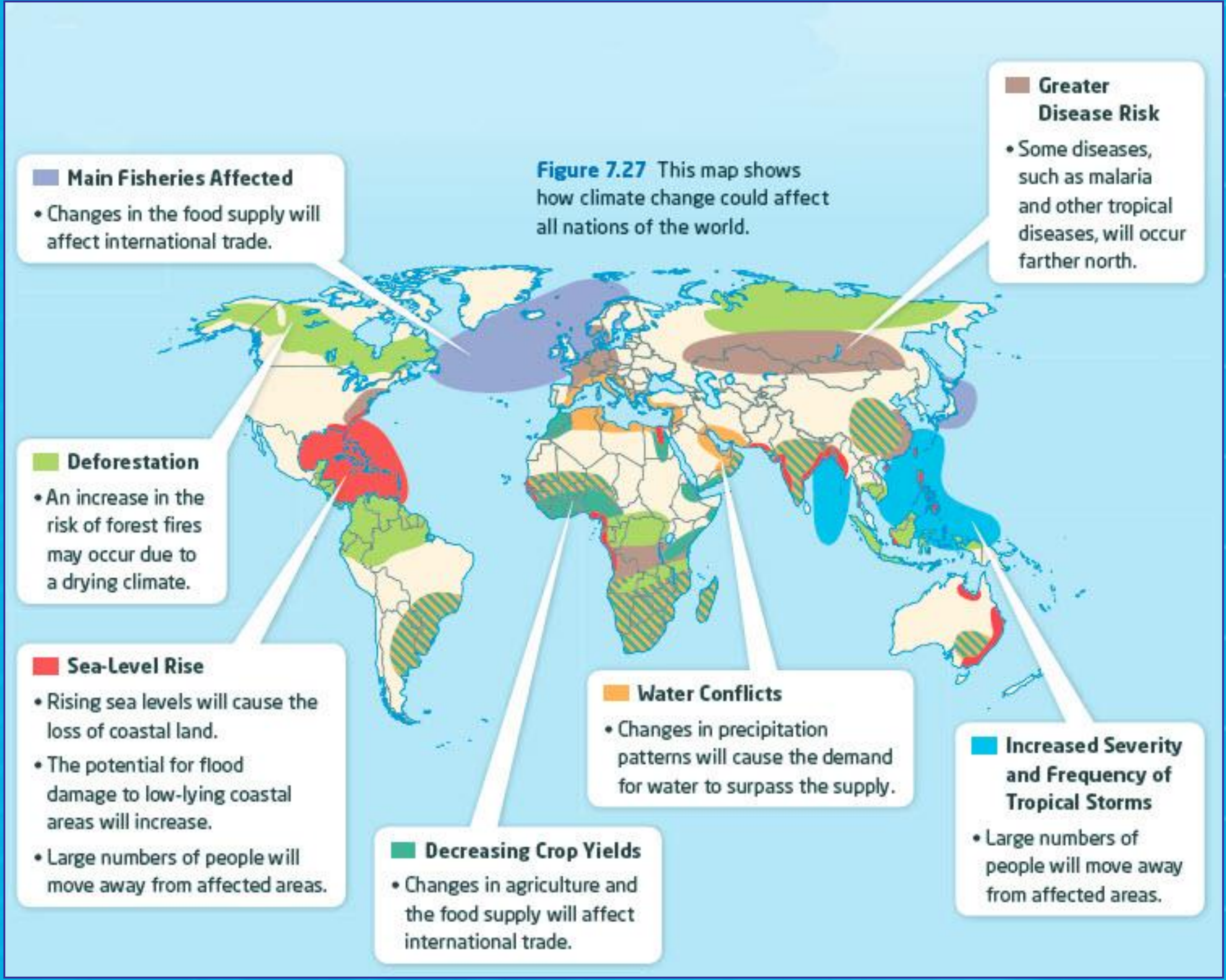


Figure 7.27 This map shows how climate change could affect all nations of the world.

Deforestation and Shrinking Wetlands

(Page 298)

Deforestation is the destruction of the world's forests through direct human activity such as logging or slash-and-burn clearing for agriculture and grazing and through indirect effects of climate change, pollution, and acid rain

Wetlands store and filter water, remove CO_2 from the air, and provide a habitat for a variety of animals. Lower lake levels shrink wetlands.

Section 7.3 Review

Concepts to be reviewed:

- *the concept of global warming*
- *the consequences associated with a reduction in polar ice*
- *the effect of rising sea levels on human population*
- *the effect of increased sea water acidity*
- *the consequences of changes in wind and precipitation patterns*
- *how climate change relates to human health*
- *the impact of deforestation and desertification*

CHAPTER 8 *Dynamics of Climate Change*

In this chapter, you will:

- ***describe*** *and* ***explain*** *heat transfer in Earth's climate system*
- ***describe*** *the natural greenhouse effect and* ***distinguish*** *it from the anthropogenic greenhouse effect*
- ***describe*** *the principal sources and sinks of greenhouse gases*
- ***investigate*** *the effects of heat transfer within Earth's oceans and atmosphere*

Modelling Balance in Systems

(Page 309)

In a **balanced system,** the amount of matter and energy that enters a system usually equals the amount that exits the system.

How would changing the composition of the atmosphere affect the balance of the climate system?

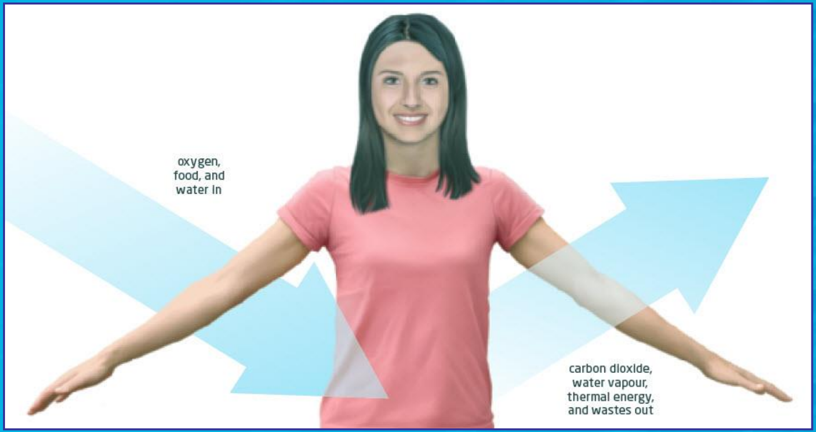
How might an unbalanced system be returned to balance?

8.1 Energy Transfer in Climate Systems (Page 311)

A **system** is a group of independent parts that work together to form a single, functioning whole.

Open systems are systems in which energy and matter cross the system's boundaries.

Closed systems are systems that allow energy but not matter to cross the system's boundaries.



All **organisms,** including humans, are examples of **open systems**.

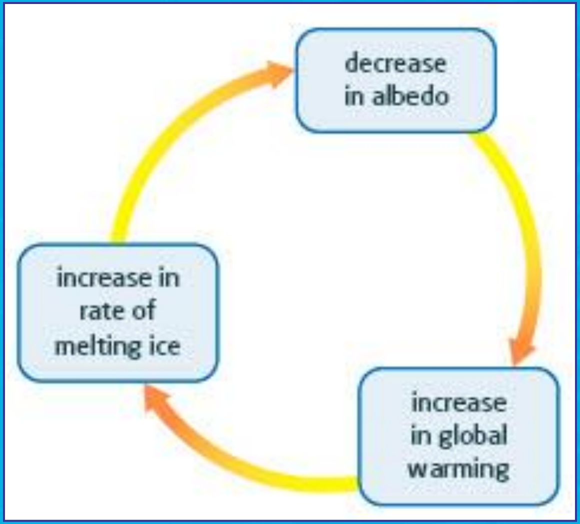
Earth generally behaves as a **closed system.**

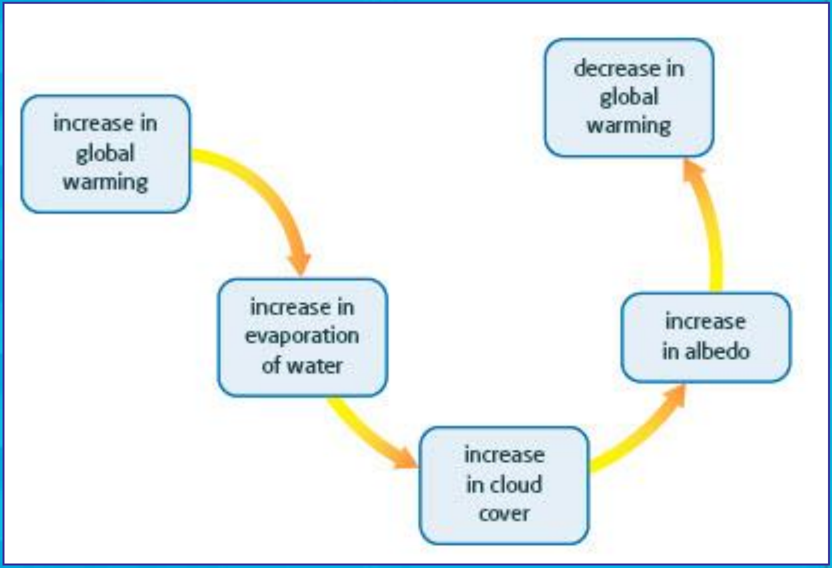
Effects of Feedback Loops on the Earth System

(Pages 312-313)

A **feedback loop** is a process in which part of a system's output is returned, or fed back, to the input.

A **positive feedback loop** acts to increase the effects of the interacting parts. Small changes can lead to large changes before the system achieves balance.

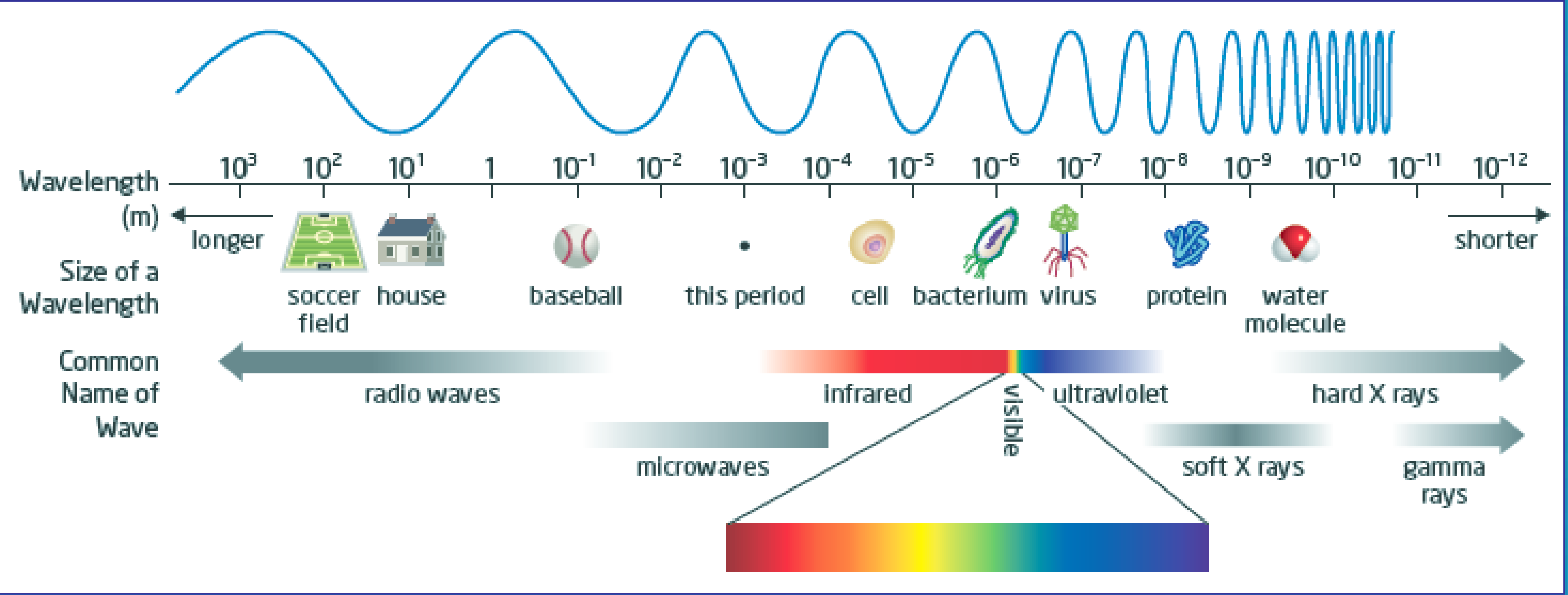




A **negative feedback loop** decreases the effects of the interacting parts and helps maintain a system's equilibrium.

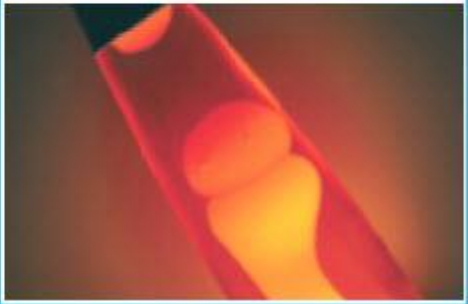
Heating the Planet

Electromagnetic radiation is energy that travels as waves that move outward in all directions from a source. This energy includes infrared radiation, ultraviolet radiation, radio waves, X rays, gamma rays, and visible light.



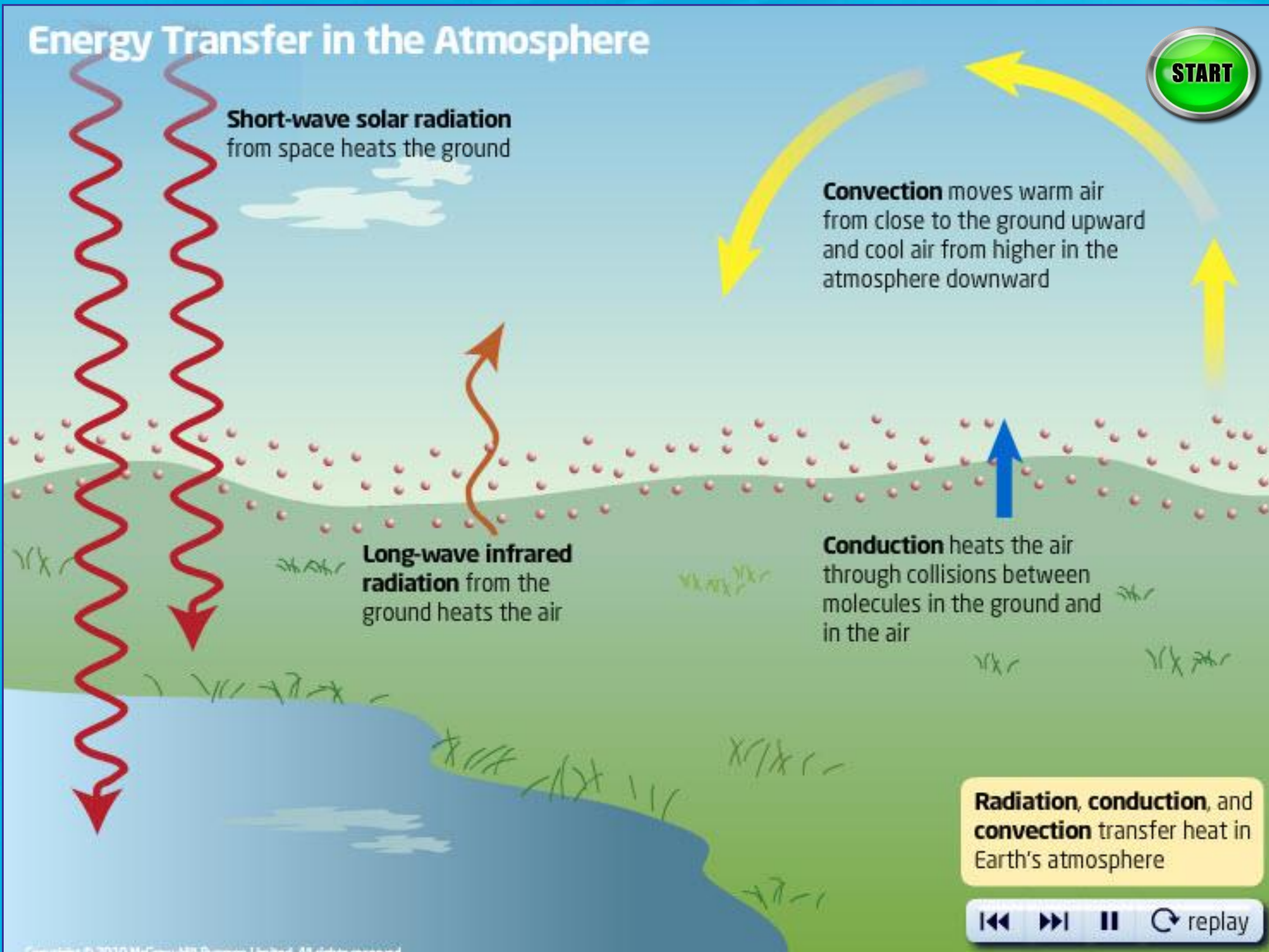
Heating the Planet

Thermal energy (heat) is transferred throughout Earth's climate system in the following three ways.

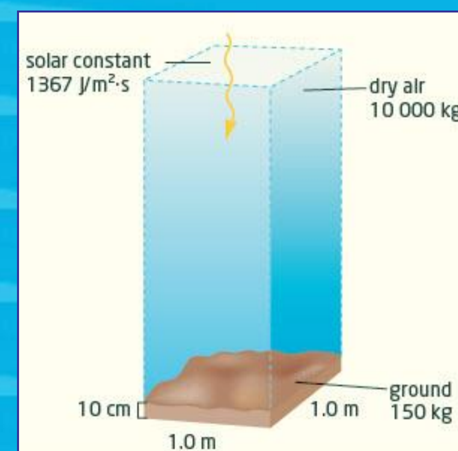
Type	Description	Example
Radiation	Radiation is the transfer of energy, including thermal energy, as electromagnetic radiation. Energy travels from the Sun to Earth as radiation, and heat travels from a fire to your body as radiation. All matter radiates some thermal energy—not only the Sun, but pebbles, bicycles, you, and even ice cubes. Because no matter is necessary to conduct radiation, this form of energy can travel through the vacuum of space. When radiation encounters matter, such as the atmosphere or your hand, it interacts with the matter. The matter may absorb the radiation, reflect it, or refract it.	
Conduction	Conduction is the transfer of thermal energy between two objects or substances that are in direct physical contact. The thermal energy always moves from a region of higher temperature to a region of lower temperature. For example, a hotplate conducts thermal energy to a skillet placed on it. In turn, the skillet conducts thermal energy to an egg.	
Convection	Convection is the transfer of thermal energy by highly energized molecules moving from one place to another. This movement can occur in liquids and gases, but not in solids. For example, when you turn on a lava lamp like the one shown to the right, a waxy substance at the bottom of the lamp is warmed by conduction. The wax expands and rises, carrying thermal energy by convection to the top of the lamp. The rising and sinking of wax bubbles create a pattern of circulation called a convection current.	

Energy Transfer in the Atmosphere

Conduction, **convection**, and **radiation** transfer heat in Earth's atmosphere as shown below.



Click the "Start" button to review energy transfer in the atmosphere.

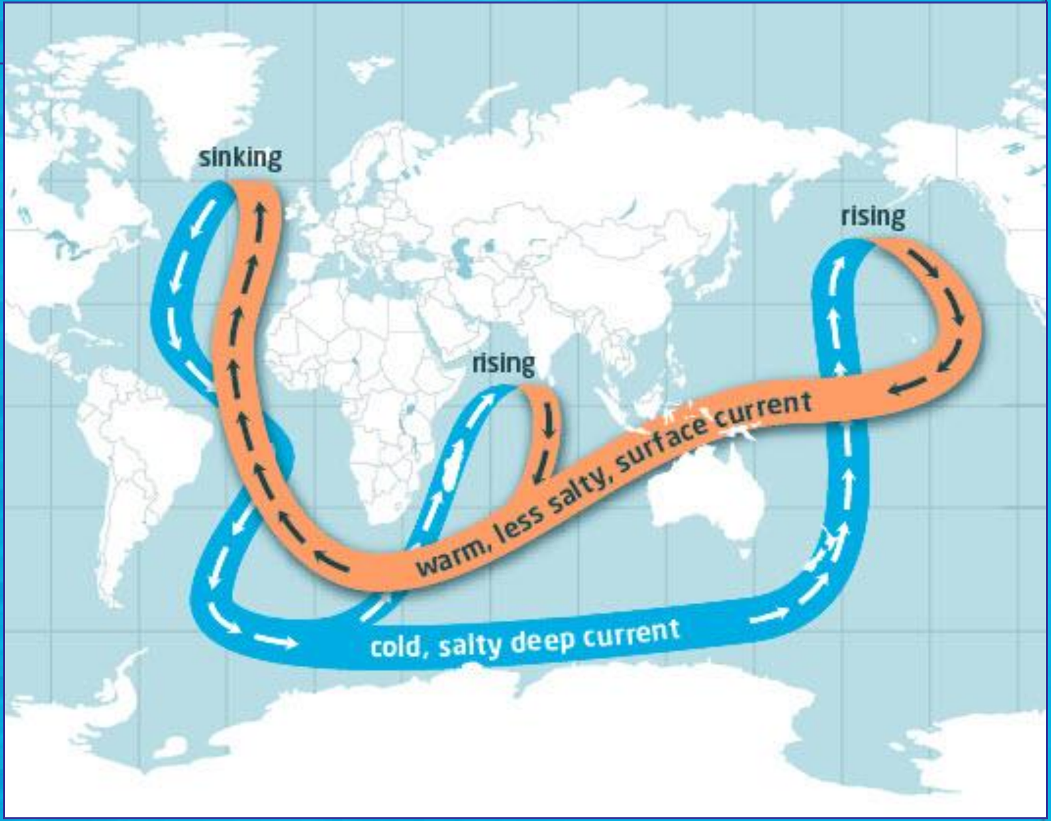


Energy Transfer in the Oceans

(Page 316)

The exchange of thermal energy between ocean currents and the atmosphere has a major influence on climates around the world and on climate change.

Thermohaline circulation is a three-dimensional pattern of ocean circulation driven by wind, heat, and salinity. It is an important component of the ocean-atmosphere climate system.



Water moves in a continuous loop from the surface of the ocean to the ocean floor and all around the planet, carrying thermal energy.

Global Warming and Thermohaline Circulation

(Page 317)

Global warming may disrupt the current pattern of thermohaline circulation by altering ocean salinity.

The sinking polar water is the driving force of the **thermohaline circulation system**. If polar water becomes less dense due to dilution from melting ice, it will be less likely to sink.

If higher temperatures increase evaporation of water in tropical regions, salinity levels will rise, making the water more dense.

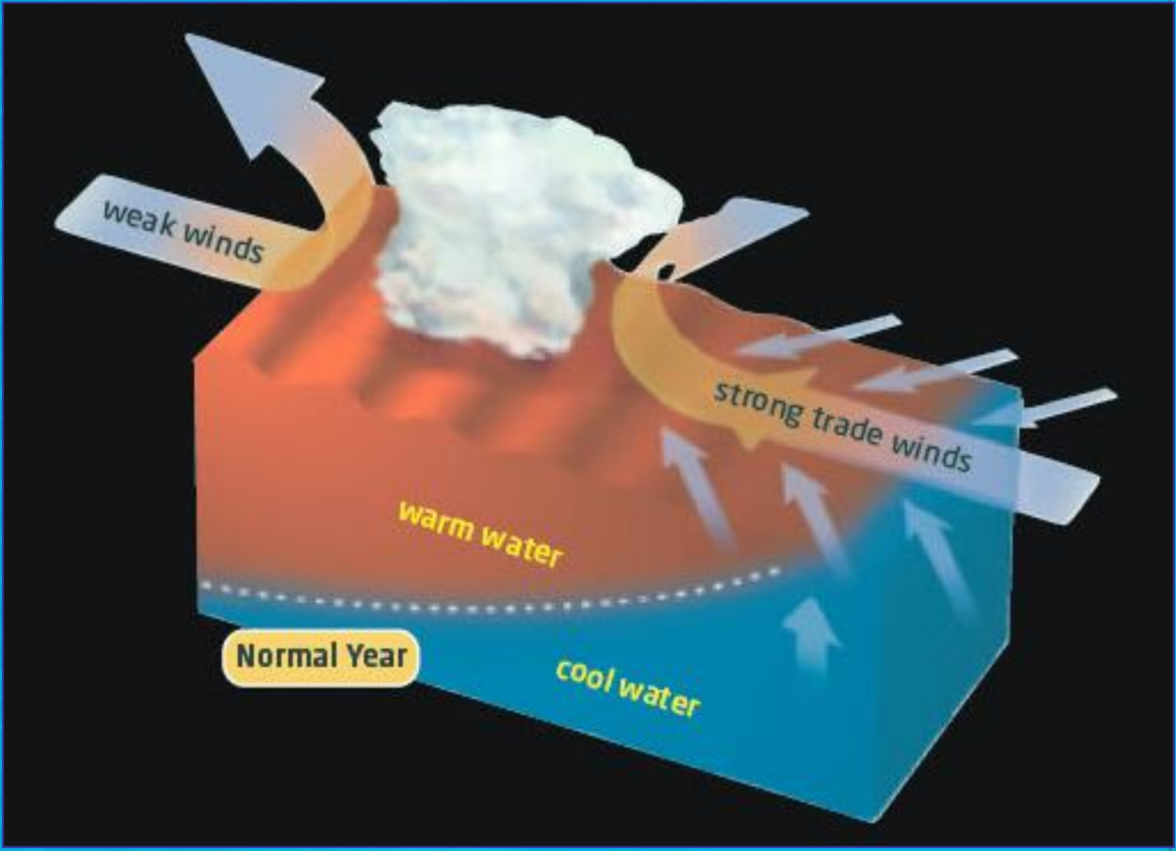
Changes in ocean circulation could have negative effects on living things by affecting upwelling patterns—the rising of ocean currents—that bring nutrients essential for marine life up from the depths.

Energy Transfer, El Niño, and La Niña

(Pages 318-319)

El Niño and **La Niña** are "sea-surface temperature anomalies" (changes in the temperature of the ocean) that occur in the southern Pacific Ocean. These changes have dramatic effects on the transfer of thermal energy and, therefore, on climate change.

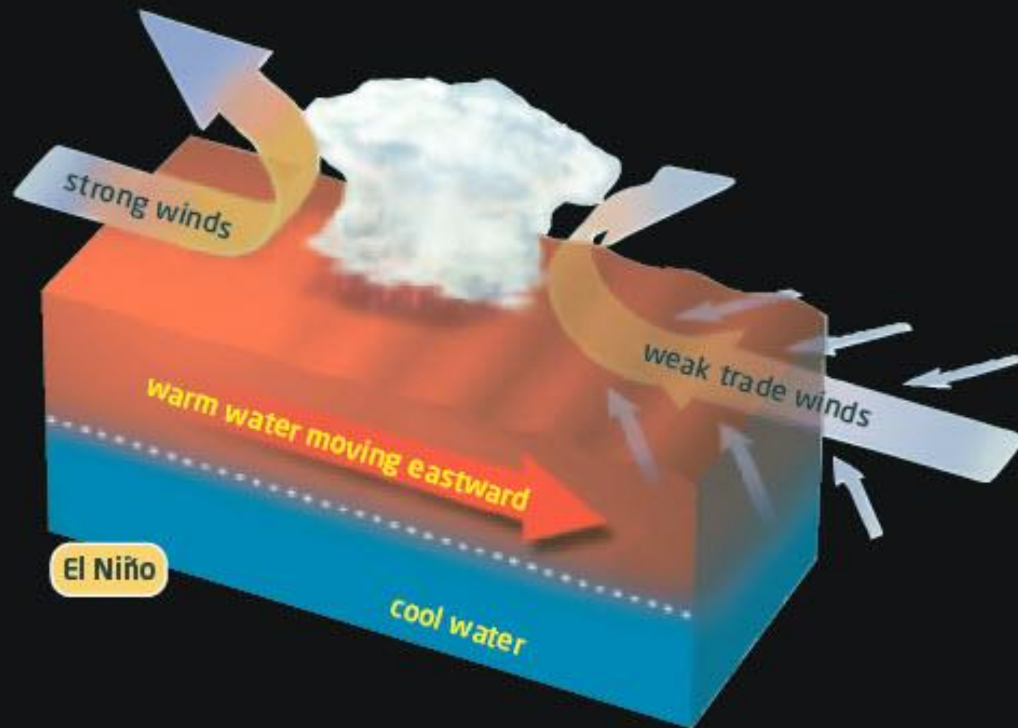
In a **normal year**, strong winds keep warm surface waters contained in the western Pacific Ocean while cooler water wells up to the surface in the eastern Pacific.



El Niño

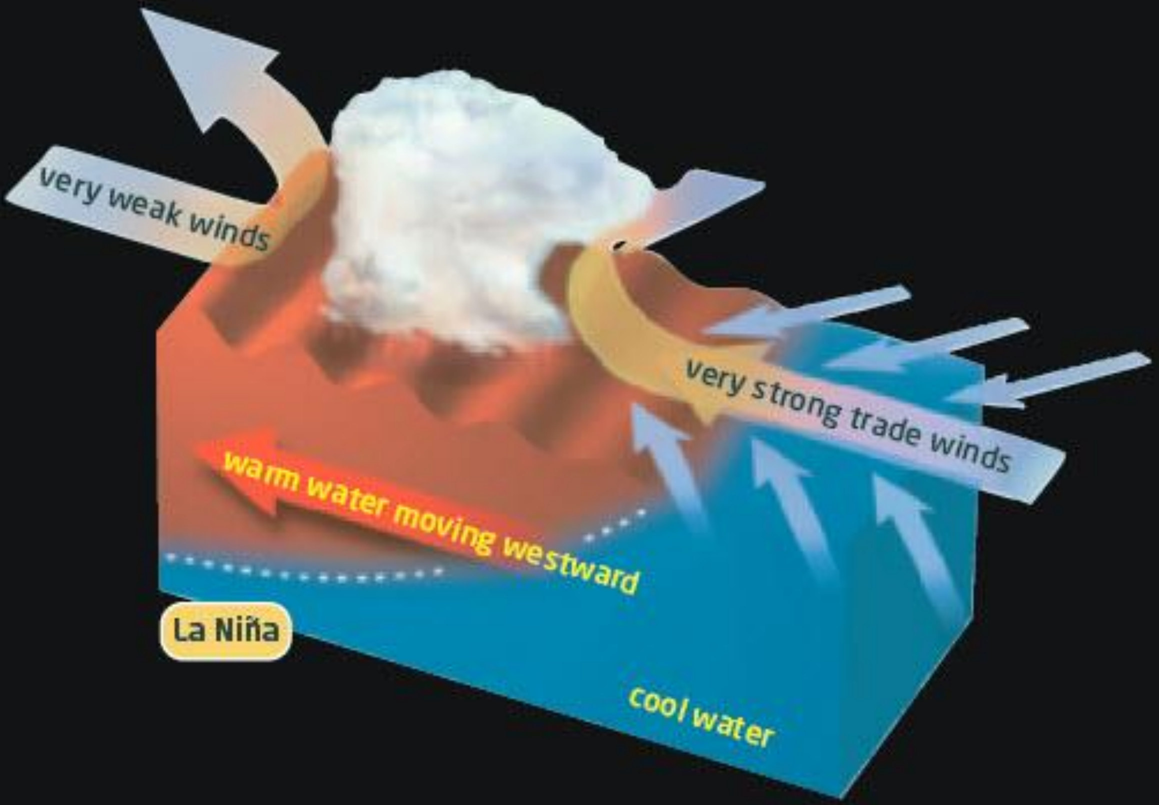
(Page 318)

EL NIÑO During El Niño years, winds blowing west weaken and may even reverse. When this happens, warm waters in the western Pacific move eastward, preventing cold water from upwelling. This change can alter global weather patterns and trigger changes in precipitation and temperature across much of North America.



Water in the eastern Pacific Ocean (closest to Canada) stays warmer.

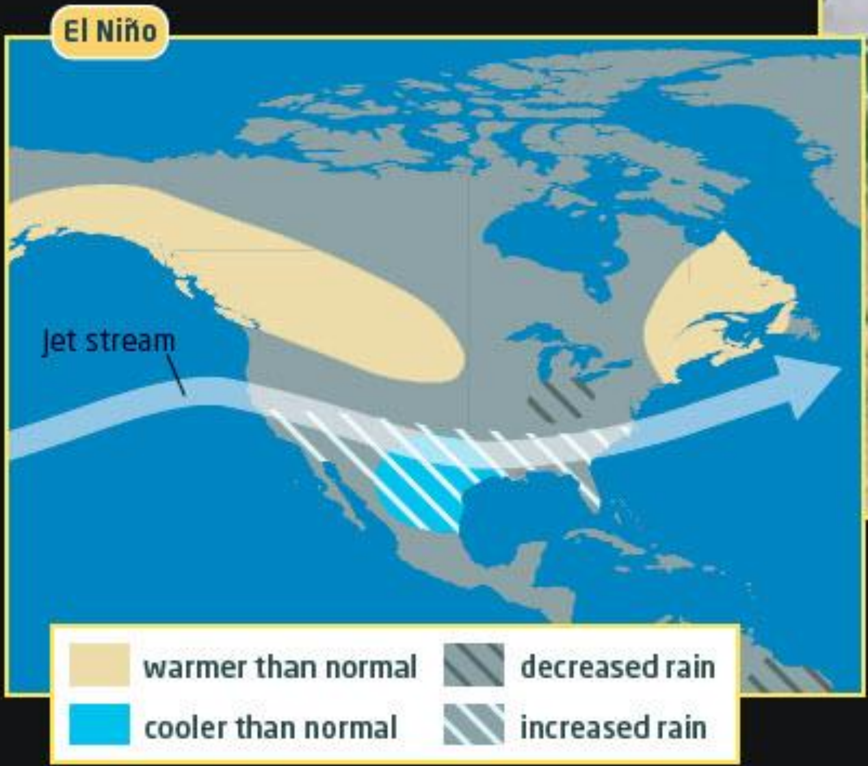
La Niña



LA NIÑA During La Niña years, stronger-than-normal winds push warm Pacific waters farther west, toward Asia. Cold, deep-sea waters then well up strongly in the eastern Pacific, bringing cooler temperatures to northwestern North America.

Water in the eastern Pacific Ocean (closest to Canada) stays cooler.

Consequences of El Niño

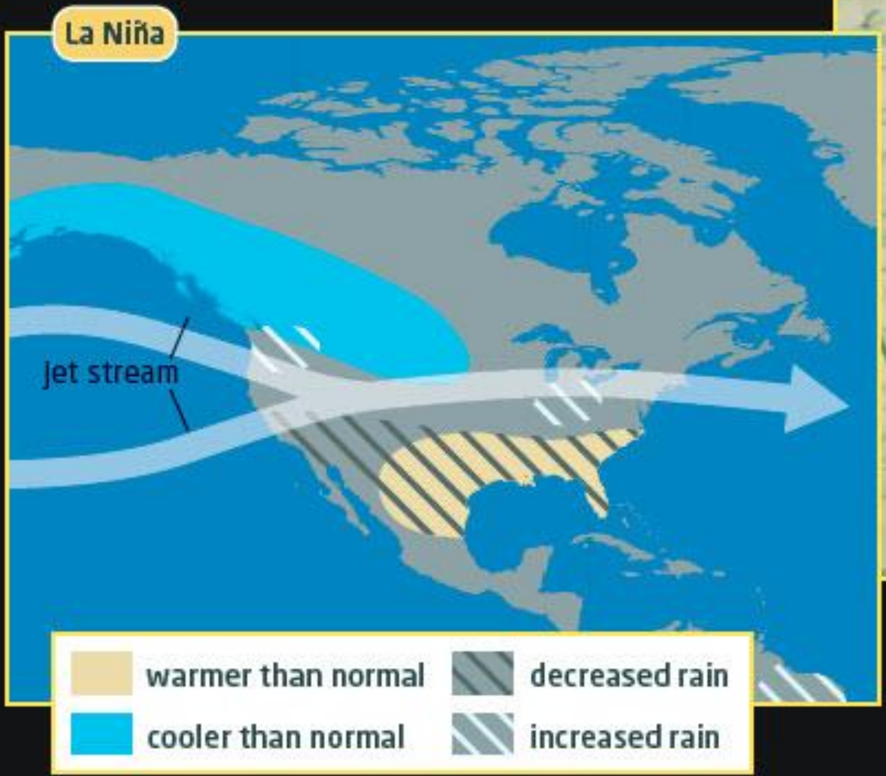


Sun-warmed surface water spans the Pacific Ocean during El Niño years. Clouds form above the warm ocean, carrying moisture aloft. The jet stream, shown by the white arrow above, helps to bring some of this warm, moist air to the southern parts of North America.

▲ **LANDSLIDE** Heavy rains in California resulting from El Niño can lead to landslides. This upended house in Laguna Niguel, California, took a ride downhill during the El Niño storms of 1998.

Consequences of La Niña

(Page 319)



During a typical La Niña year, warm ocean waters, clouds, and moisture are pushed away from North America. A weaker jet stream often brings cooler weather to the northern parts of the continent and hot, dry weather to southern areas.

▲ **PARCHED LAND** Some areas may experience drought conditions, like those that struck these cornfields during a La Niña summer.

Earth's Energy Budget

(Pages 320-321)

Earth's energy budget is a description of the total energy exchange within a system. It is a summary of how energy from the Sun enters, moves through, and leaves the Earth system.

Energy from the Sun is either **reflected** or **absorbed** by Earth's atmosphere.

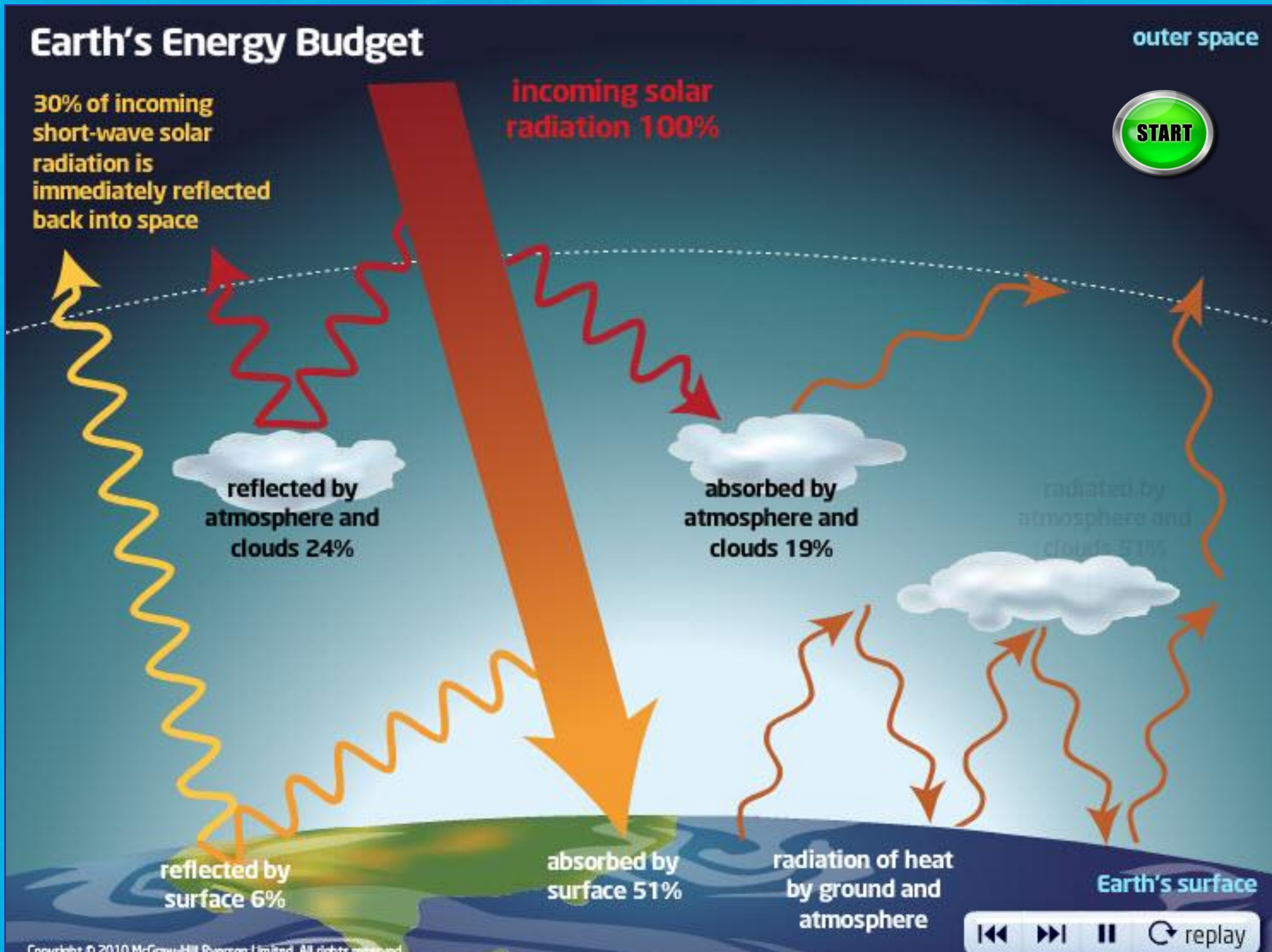
Reflection of Solar Radiation		Absorption of Solar Radiation	
• Aerosols in atmosphere	6%	• Gases in atmosphere	16%
• Clouds	20%	• Clouds	3%
• Surface	4%	• Surface	51%
Total reflected	30%	Total absorbed	70%

Radiation that has been absorbed by the atmosphere, clouds, and Earth's surface is **re-emitted** at a **longer wavelength** than radiation that is reflected. These waves raise the atmospheric temperature.

Earth's Energy Budget

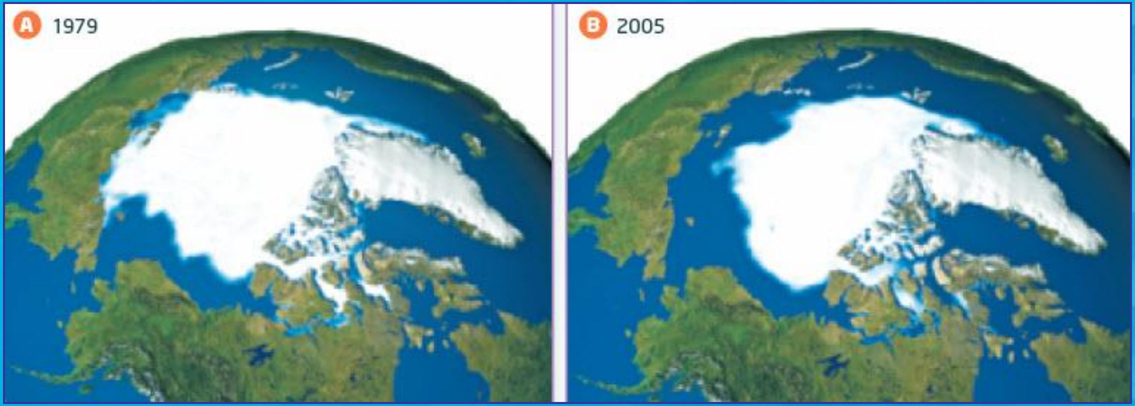
(Page 320)

Click the "Start" button to review Earth's energy budget.

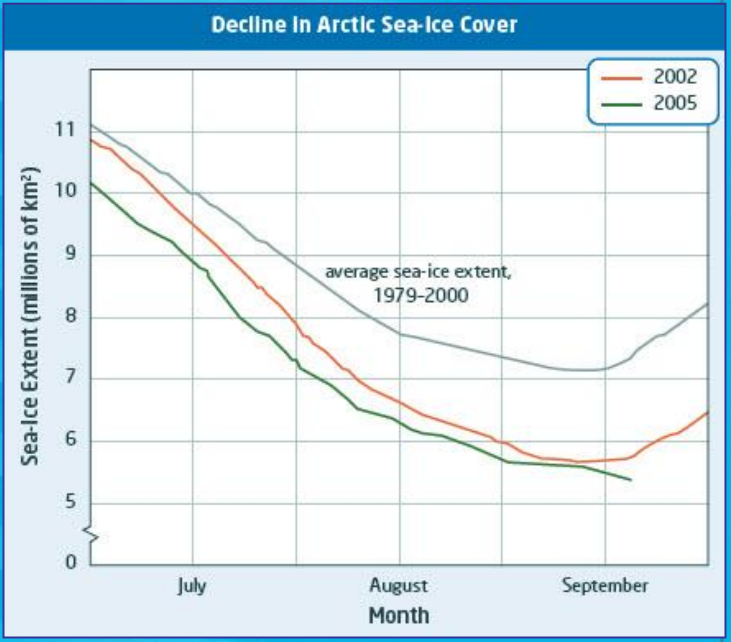


Changing Albedo and the Energy Budget

Earth’s **albedo** (the ability to reflect solar radiation) is most influenced by cloud cover, snow, and ice. Changes in these factors can produce a change in the amount of energy in the atmosphere.



Less ice cover results in a lower albedo or less reflection.



With more open water in the Arctic, evaporation is increased, leading to more clouds that in turn increase reflection.

Less ice cover results in less reflection, thus the amount of reflection in Earth’s atmosphere system remains the same.

Section 8.1 Review

(Page 322)

Concepts to be reviewed:

- *an understanding of the components making up the Earth system and how they are interrelated*
- *how positive and negative feedback loops affect the global climate system*
- *the role of the atmosphere in redistributing heat, energy, and moisture around Earth's surface*
- *the ways that heat can be transferred through the atmosphere*
- *how the temperature and salinity of ocean water affects energy transfer*
- *how El Niño, and La Niña affect global climate*
- *maintaining balance in Earth's energy budget*

8.2 Greenhouse Gases and Human Activities

(Page 323)

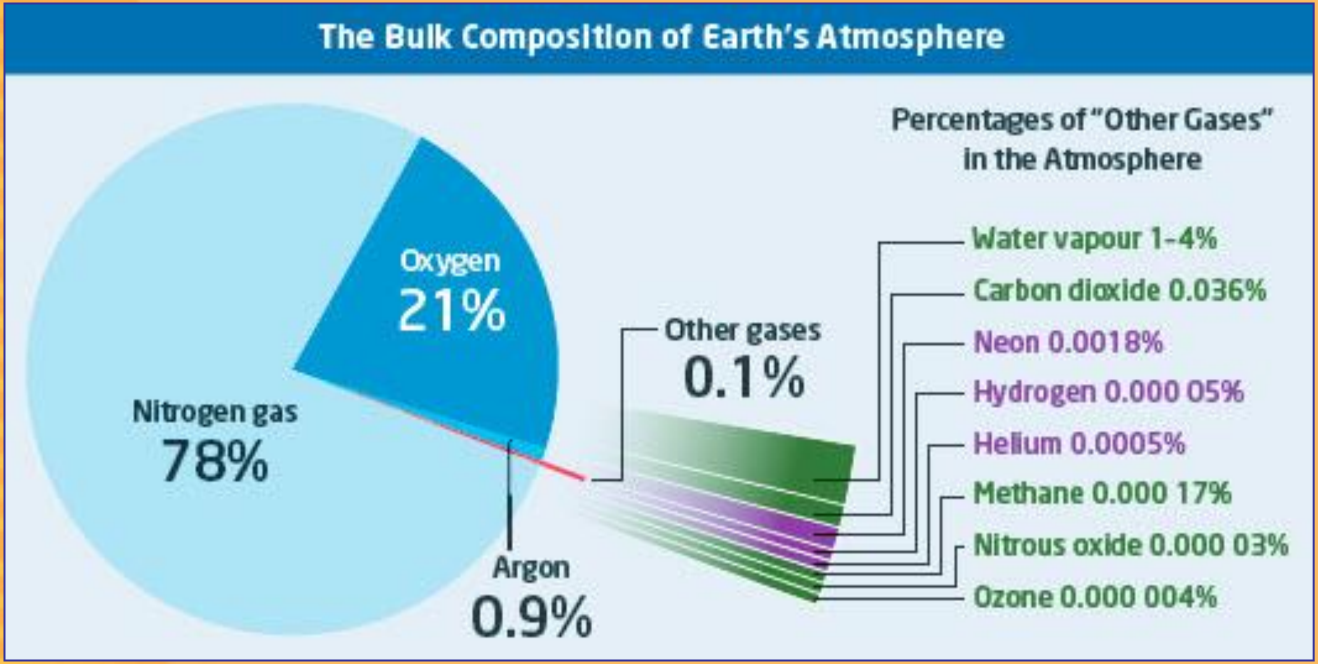
The **greenhouse effect** is necessary for Earth to remain warm enough to support life. That said, higher concentrations of greenhouse gases would result in Earth being warmer. Lower concentrations of greenhouse gases lead to Earth being cooler.

Concentration is the amount of a particular substance in a specific amount of another substance. Concentrations are often measured in **parts per million (ppm),** which represents the number of parts of a substance per million parts of another substance.

Measurement	Example
Parts per million (ppm)	1 mg per kg = 1 ppm
Parts per billion (ppb)	1 mg per tonne = 1 ppb
Parts per trillion (ppt)	1 mg per kilotonne = 1 ppt

Greenhouse Gases and Global Warming (Pages 324-325)

Greenhouse gases are gases in Earth's atmosphere that absorb and prevent the escape of radiation as thermal energy. Examples of greenhouse gases include carbon dioxide and methane.



Processes that **add greenhouse gases** to the atmosphere are called **sources** of greenhouse gases while processes that **absorb** or **remove** greenhouse gases from the atmosphere are called **sinks**.

Greenhouse Gases and Global Warming (Pages 324-325)

Water vapour is the most abundant greenhouse gas in the atmosphere and could be responsible for between **65** and **85%** of the greenhouse effect.

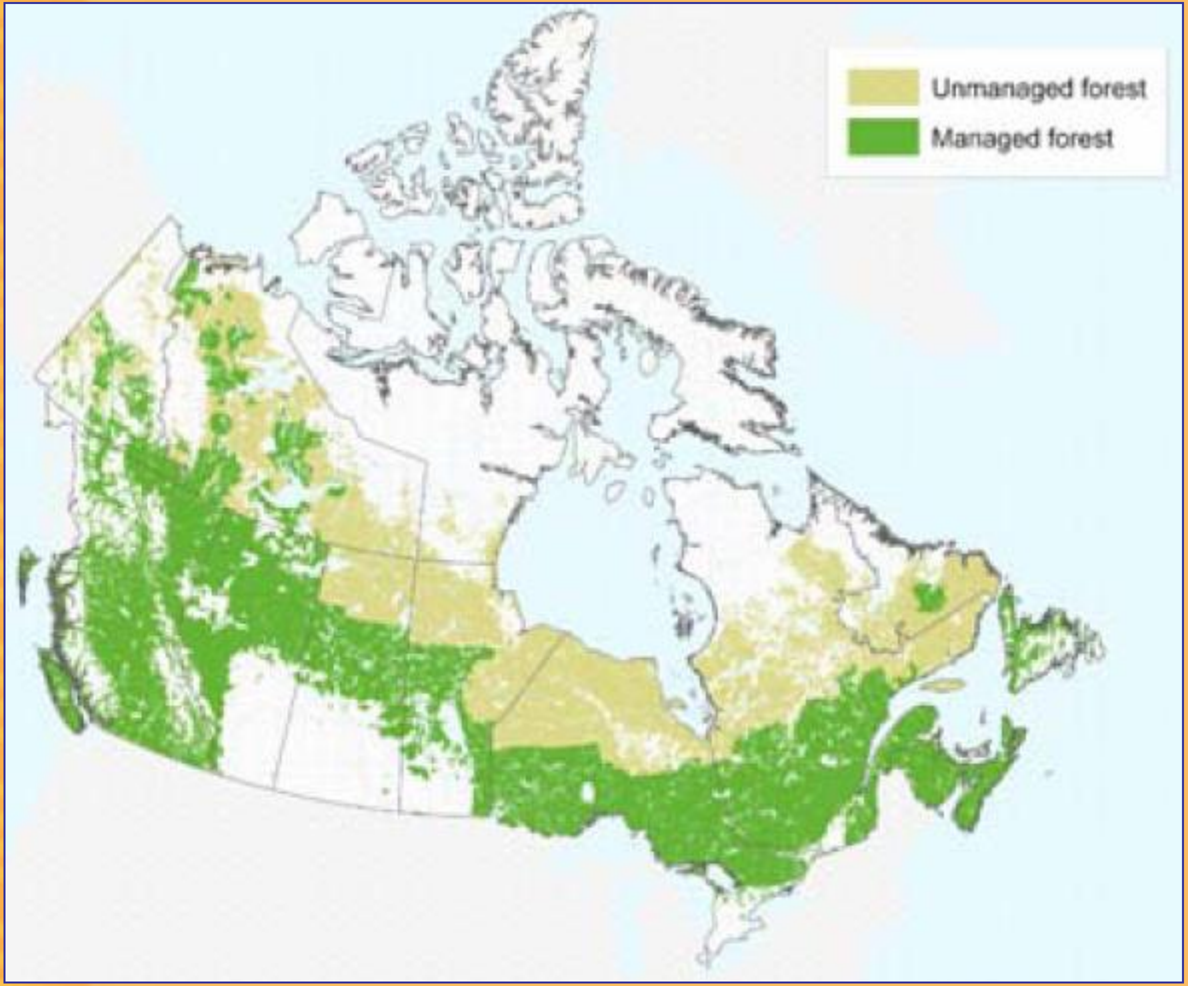
The main **human source of carbon dioxide** is the combustion of fossil fuels.

Volcanic eruptions release particles of ash and dust that increase Earth's albedo, cooling Earth. The eruptions also release gases that warm Earth.

Forests and phytoplankton in the oceans play a huge role in the absorption and storage of carbon dioxide.

Forests (Natural Carbon Sinks) in Canada

(Page 325)

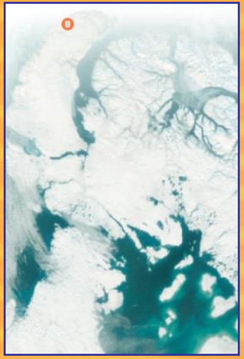


http://www.ec.gc.ca/pdb/ghg/inventory_report/2006_report/2006_report_e.pdf

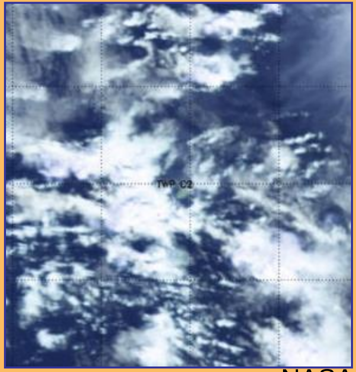
Interaction of Water Vapour and Carbon Dioxide

(Page 325)

If Earth warms up due to higher levels of carbon dioxide in the atmosphere, more water will evaporate from the oceans. This will lead to a higher level of water vapour (a greenhouse gas) in the atmosphere. Reduced albedo from melting ice would also occur. This positive feedback loop raises the atmospheric temperature even more.





NASA

NASA

Increased water vapour in the atmosphere would have cooling effects as more radiation from the Sun would be reflected by increased amounts of cloud cover. Dust and ash from volcanic eruptions can also interact with water vapour to increase cloud formation.

Sources of Methane

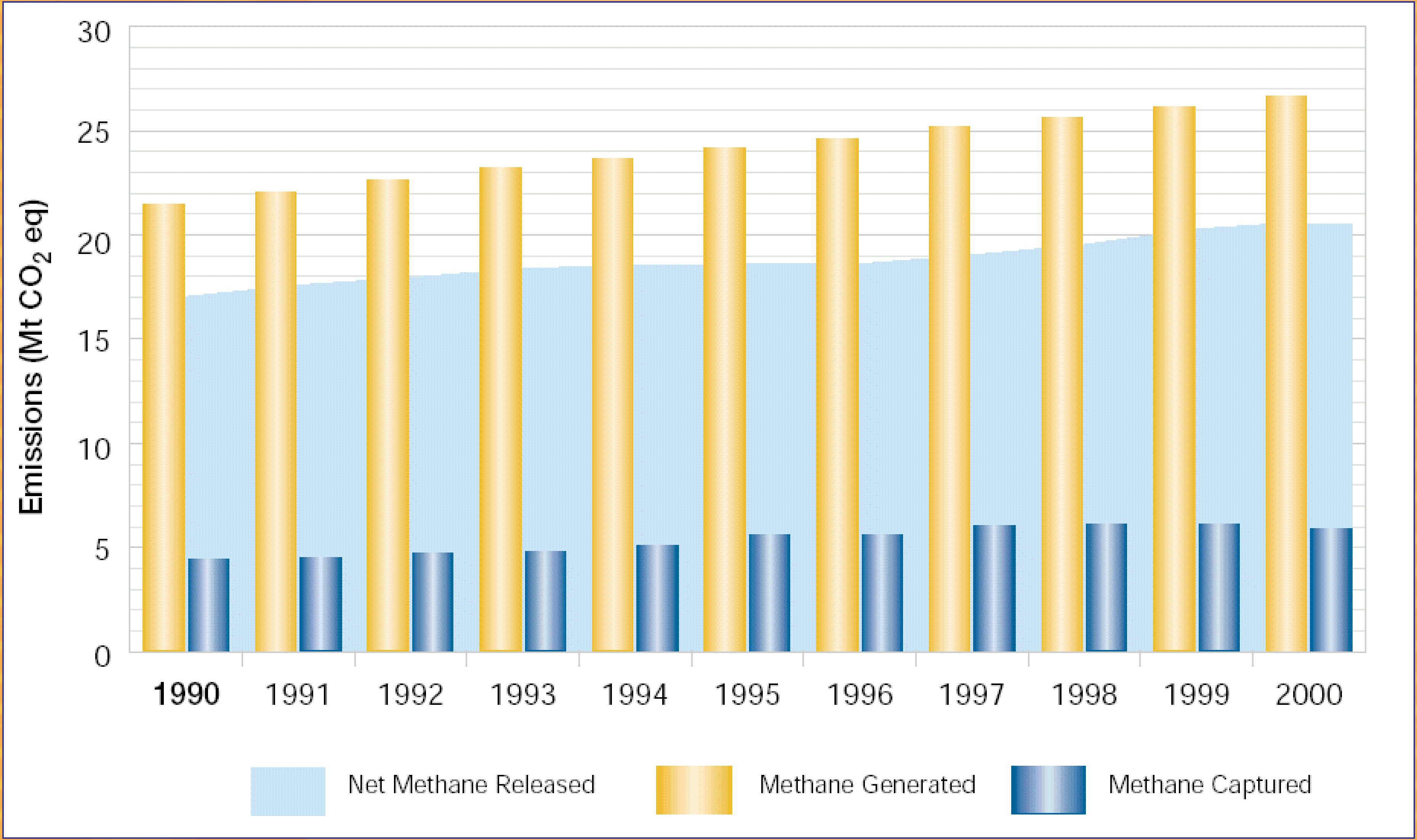
(Page 326)

Methane (CH_4) is produced by bacteria that break down waste matter in oxygen-free environments. Major sources of methane include:

- **wetlands** (bogs and swamps)
- **rice paddies**
- **termites and cattle** (during their digestive processes)
- **decomposing garbage** in landfills
- the **processing of coal and natural gas**
- **tanks of liquid manure** from livestock production

Feeding cattle special diets or having them wear methane-collecting backpacks is one strategy that has been suggested to reduce the levels of methane entering the atmosphere.

Canadian Methane Production



http://www.ec.gc.ca/pdb/ghg/inventory_report/1990_00_factsheet/images/figure29a_e.gif

Nitrous Oxide and Ozone

(Page 327)

Nitrous oxide (NO_2) is one of the gases that also contribute to the greenhouse effect. It is produced naturally from damp soils, the oceans, and by the breakdown of nitrogen-rich compounds by bacteria. Human sources include chemical fertilizers, manure and sewage treatment, and vehicle exhaust.

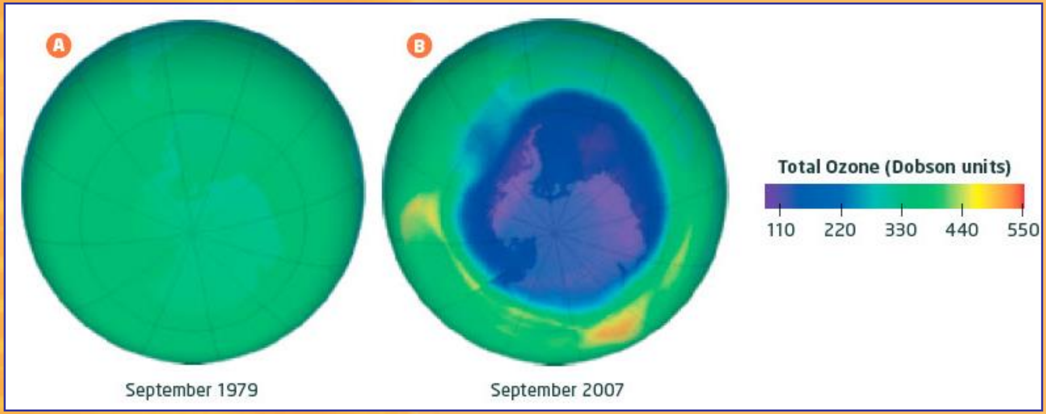
Source: iStock

Source: iStock

Ozone

(Pages 327-328)

Ozone (O_3) is a greenhouse gas found in a concentrated layer in the stratosphere (between 10 and 50 km). The ozone layer blocks harmful ultraviolet radiation from the Sun, preventing it from reaching Earth.



Since the **1970s,** there has been a slow and steady decline in the total volume of ozone in the atmosphere. An **ozone "hole"** has appeared in the Antarctic each year from September to January.

Ground-level ozone, produced by a reaction between sunlight and chemicals in vehicle exhaust, occurs near ground level as a smog-forming pollutant.

Halocarbons

Halocarbons are a large group of chemicals formed from carbon and one or more halogens. This powerful group of greenhouse gases is formed only by industrial processes. Halocarbon molecules are more efficient than carbon at absorbing infrared radiation and can persist in the atmosphere for thousands of years before they are broken down.

The natural cycle of ozone production and destruction in the stratosphere

1. O_2 is split into 2 atoms.
2. Oxygen atoms attach themselves to oxygen molecules to form ozone.
3. Trace substance X destroys ozone, releasing an oxygen molecule.
4. Trace substance X released to destroy more ozone molecules.

The best-known **halocarbons** are **chlorofluorocarbons (CFCs)**. **CFCs** contain chlorine, fluorine, and carbon. When released into the atmosphere, they may be a leading cause of the depletion of the ozone layer.

The **Montreal Protocol** was the first global treaty to protect the atmosphere from the impact of human activities.

http://www.ec.gc.ca/ozone/docs/UO/Primer/EN/index.cfm?p=16

The Anthropogenic Greenhouse Effect

Human activities have increased the quantities of carbon dioxide and other greenhouse gases significantly since about 1750.

Table 8.4 Greenhouse Gas Concentration Before and After the Industrial Revolution

Greenhouse Gas	Level Before 1750	Current Level	Increase Since 1750
carbon dioxide	280 ppm	384 ppm	104 ppm
methane	700 ppb	1745 ppb	1045 ppb
nitrous oxide	270 ppb	314 ppb	44 ppb
CFCs	0 ppt	533 ppt	553 ppt

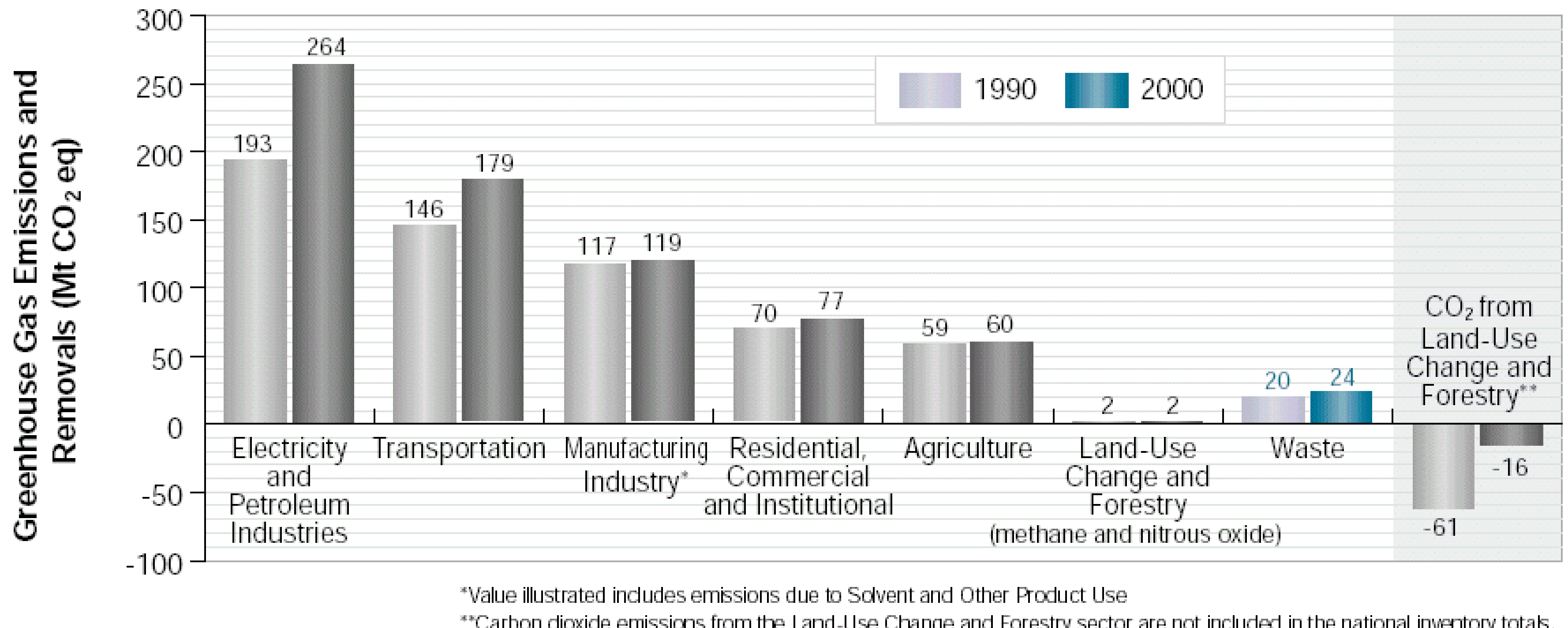
The increase in global average temperature since the 1960s is likely due to an increase in greenhouse gases produced by humans. The result is known as the **anthropogenic greenhouse effect**.

Changes in Carbon Dioxide and Average Global Temperature

Year	Industrial CO_2 Emissions (gigatonnes)*	CO_2 Concentration (ppm per volume)	Temperature Increase Since 1861 (°C)
1861	0.67	285	0.00
1880	1.15	292	0.00
1900	2.63	298	0.05
1920	3.42	303	0.29
1940	4.95	307	0.46
1960	9.98	318	0.35
1980	20.72	340	0.41
2000	23.42	365	0.63

Source: Carbon Dioxide Information Analysis Center (CDIAC)
* 1 gigatonne = 1 billion tonnes

The Anthropogenic Greenhouse Effect (Page 329)



http://www.ec.gc.ca/pdb/ghg/inventory_report/1990_00_factsheet/images/figure27a_e.gif

The Anthropogenic Greenhouse Effect (Page 329)

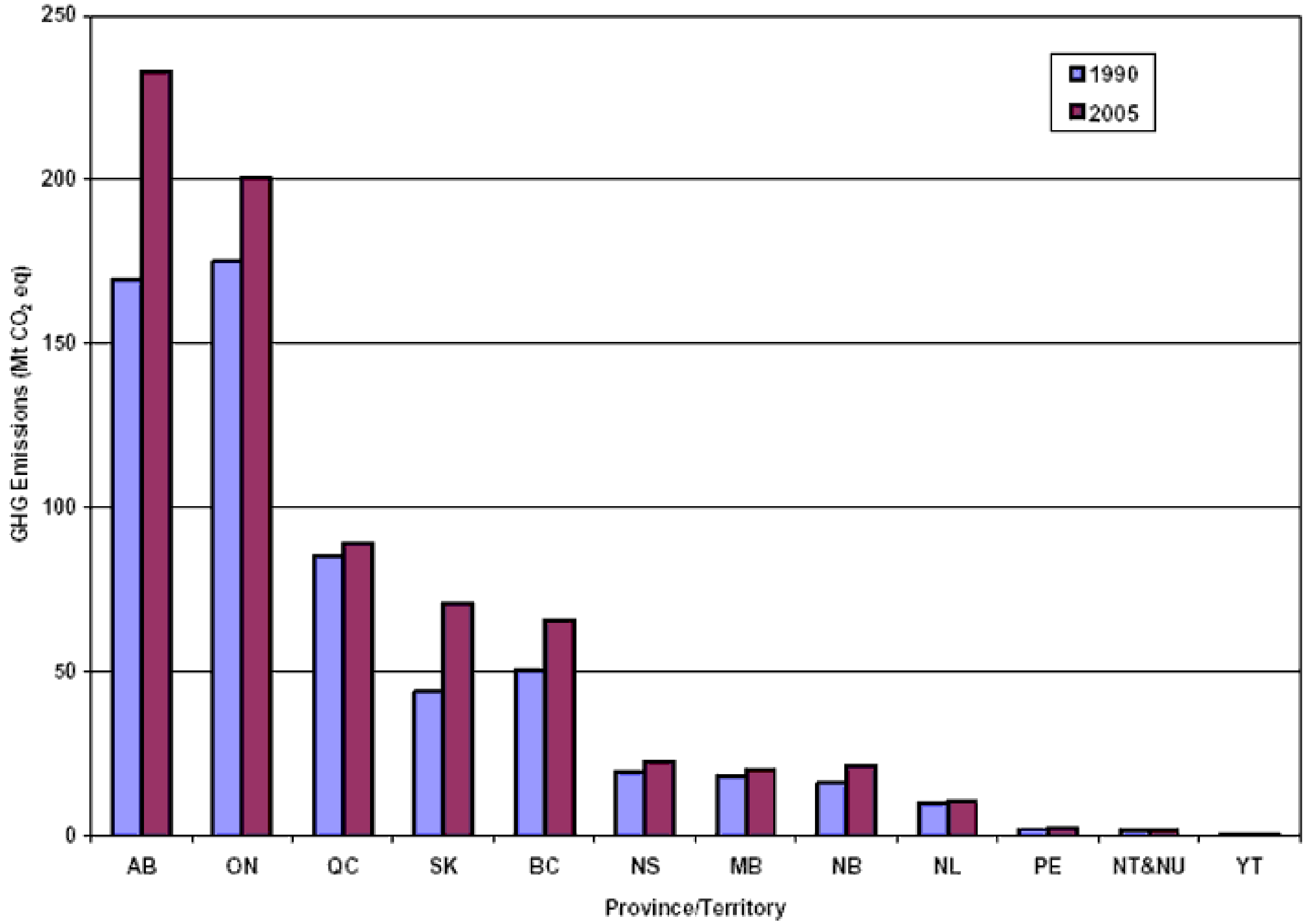


Figure S-1: Total Provincial/Territorial GHG Emissions, 1990 and 2005

http://www.ec.gc.ca/pdb/ghg/inventory_report/2005_report/images/fs_4_l_eng.gif

Global Warming Potential

(Pages 330-331)

The **global warming potential (GWP)** refers to the ability of a substance to warm the atmosphere by absorbing thermal energy.

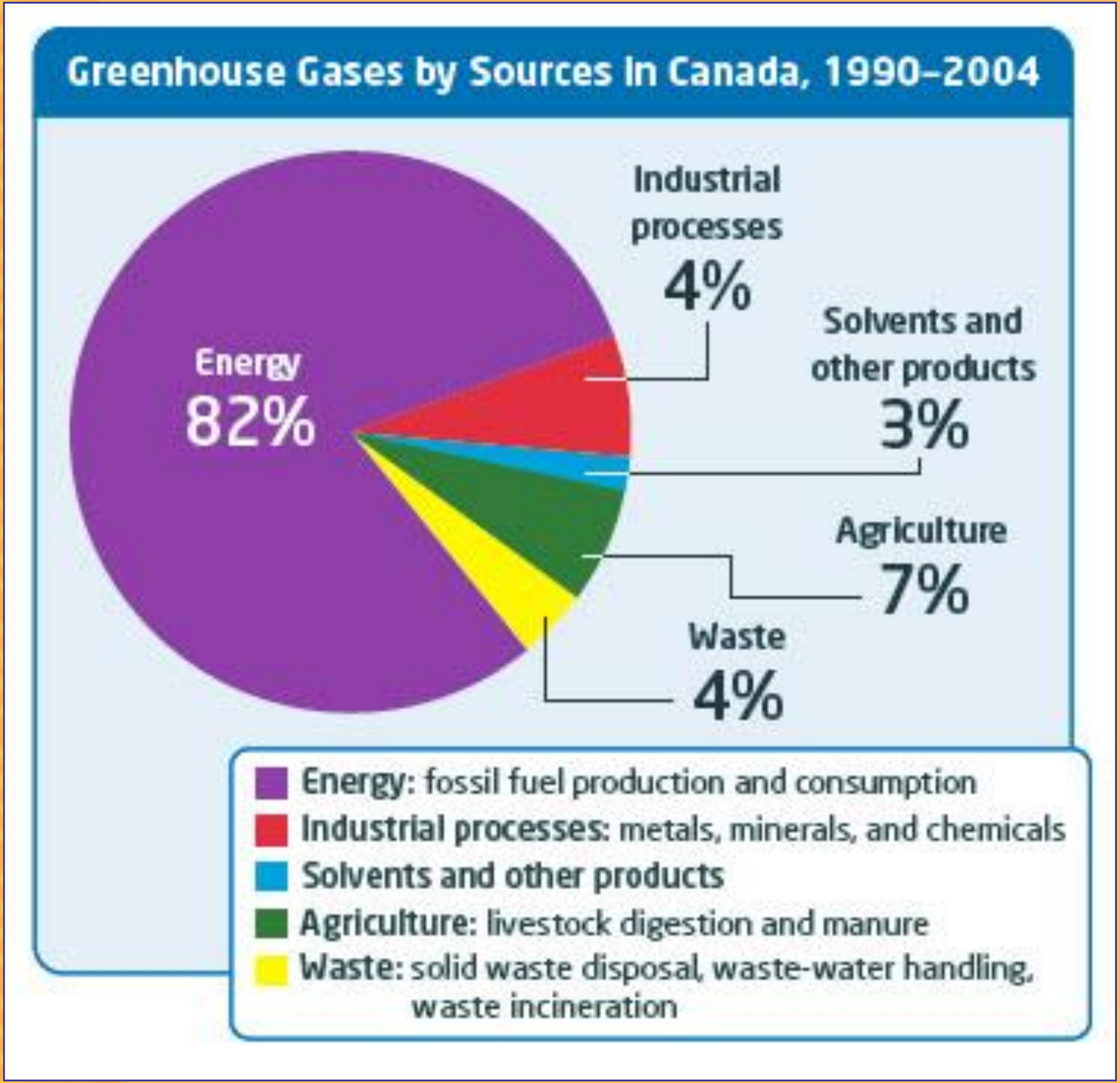
The contribution of a particular gas to global warming depends on:

- **the concentration of the gas in the atmosphere**
- **the ability of the gas to absorb heat**
- **the length of time the gas remains in the atmosphere**

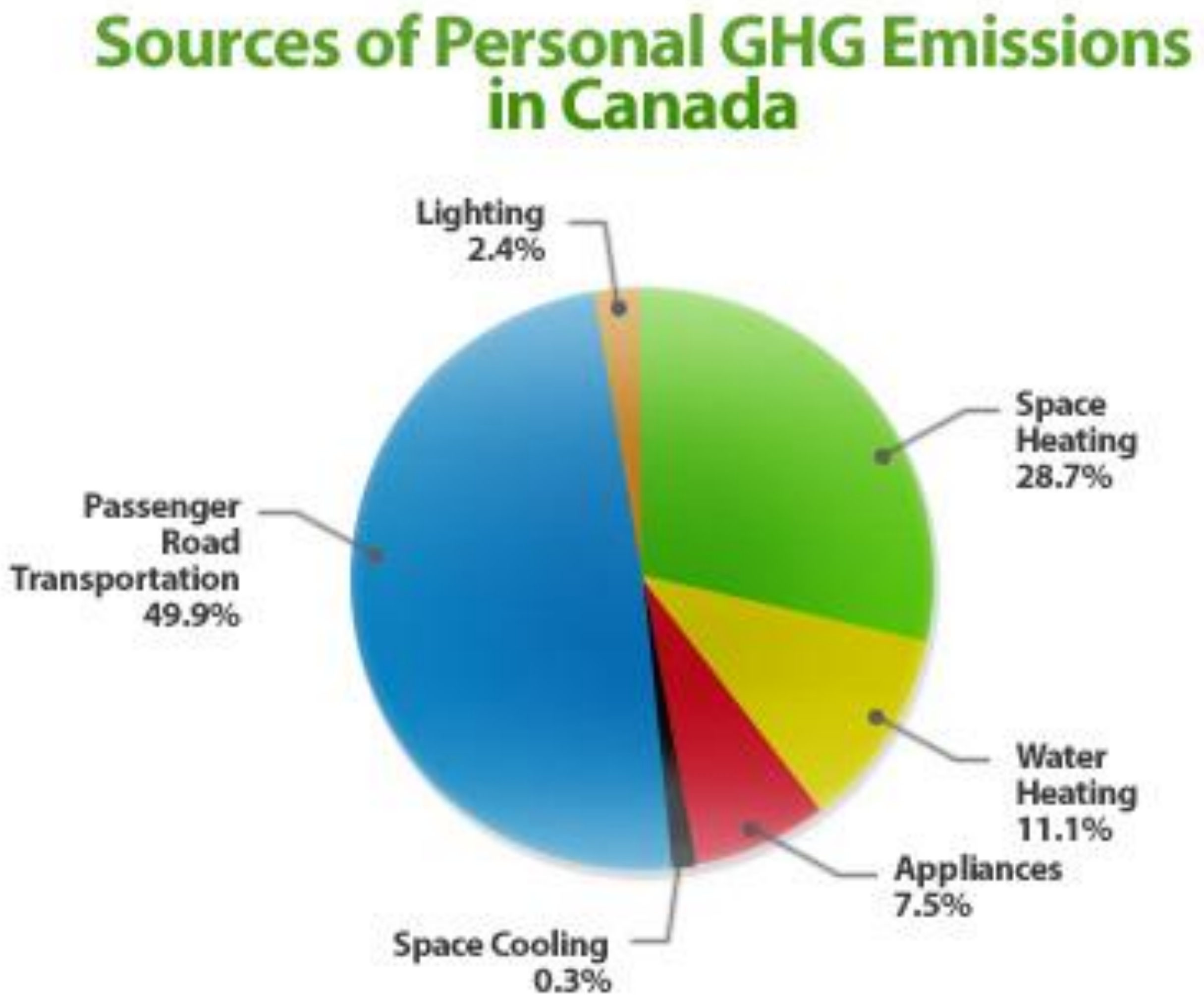
Table 8.5 Global Warming Potential of Major Greenhouse Gases

Greenhouse Gas	Chemical Formula	Atmospheric Lifetime (years)	Global Warming Potential (GWP) over 100 Years
carbon dioxide	CO_2	variable	1
methane	CH_4	12	25
nitrous oxide	N_2O	115	298
chlorofluorocarbons (CFCs)	various	indefinite	4750-5310

Sources of GHG Emissions



Sources of Personal GHG Emissions (Page 331)



http://www.housesmartheating.com/furnaces.html

Ways to Reduce Greenhouse Gases

(Page 331)

Almost one fifth of Canada's total greenhouse gas emissions come from people's homes. Some ways to reduce these emissions include the following:

Conserve electricity by using energy-efficient appliances and light bulbs

Improve home heating efficiency

http://www.housesmartheating.com/hcc.jpg

http://www.ewswa.org/pages/recycle/3rsintro.html

Reduce amounts of garbage by following the three "Rs"

Section 8.2 Review

(Page 332)

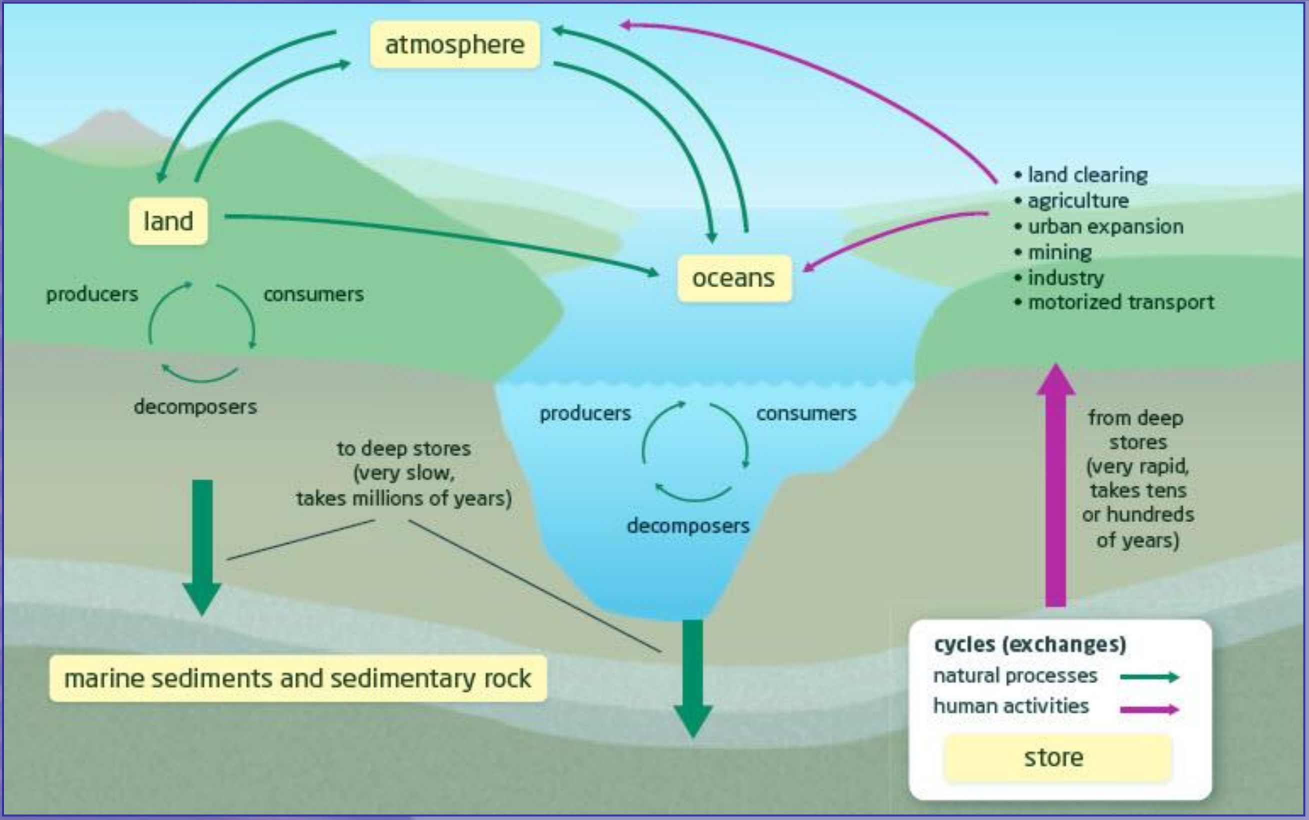
Concepts to be reviewed:

- *how greenhouse gases give rise to the greenhouse effect*
- *the types and concentrations of various greenhouse gases in the atmosphere*
- *the sources (natural and anthropogenic) of greenhouse gases*
- *how the anthropogenic greenhouse effect is contributing to climate change*
- *how humans can reduce their personal contribution of greenhouse gases*

8.3 Cycling of Matter and the Climate System

(Page 333)

Earth and its atmosphere behave as a closed system. The amount of matter that exists in this system cannot increase or decrease, but it can be transferred continuously among the atmosphere, land, water, and living things.



This circulation of matter is called the **biogeochemical cycle**.

Places where matter is stored for longer periods are known as **stores**.

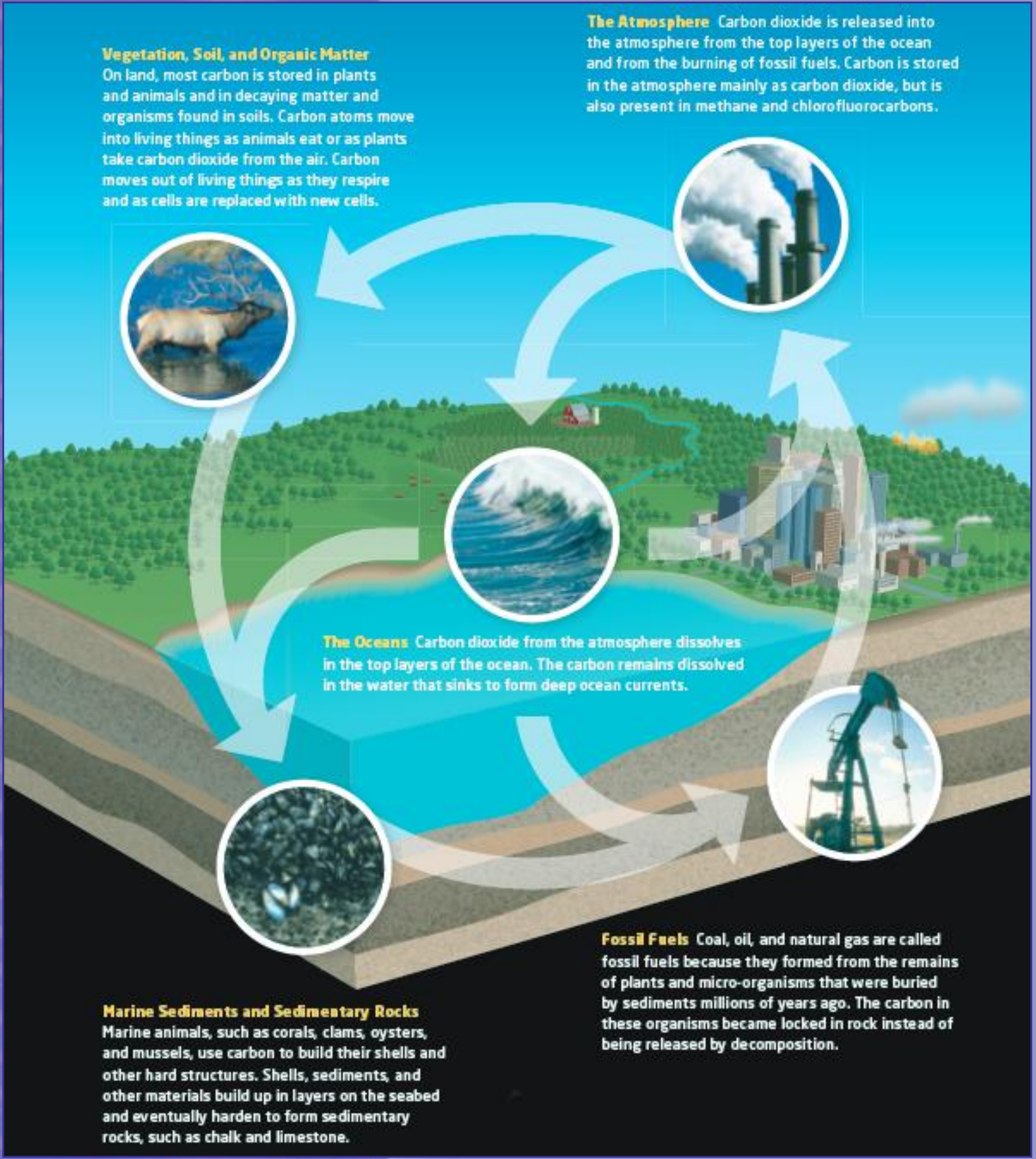
The Carbon Cycle and Climate Change

(Page 334)

Carbon compounds are found in several stores on Earth. Carbon can exist as a solid, liquid, or gas as it moves through the carbon cycle.

Store	Estimated amount of carbon (gigatonnes)	Residence time
Marine sediments and sedimentary rock	68 000 000 to100 000 000	Carbon is trapped in these rocks for millions or billions of years.
Oceans	39 000	Much of the dissolved carbon may remain in the ocean for 500 to 1000 years as the cold, slow-moving, deep currents move along the ocean floor.
Fossil fuels (coal, oil, and gas)	3 300	Converted into fossil fuels, the carbon can not cycle back into the atmosphere or into living things for hundreds of millions of years.
Vegetation, soil, and organic matter	2 115	Studies indicate that carbon stays in living things for an average of 5 years and in soil for approximately 25 years.
Atmosphere	750	Carbon dioxide remains in the atmosphere for a long time—between 50 and 500 years. Methane has a short atmospheric lifetime of only about 12 years. Nitrous oxide remains in the atmosphere for about 115 years.

The Carbon Cycle and Global Carbon Budget



(Page 335)

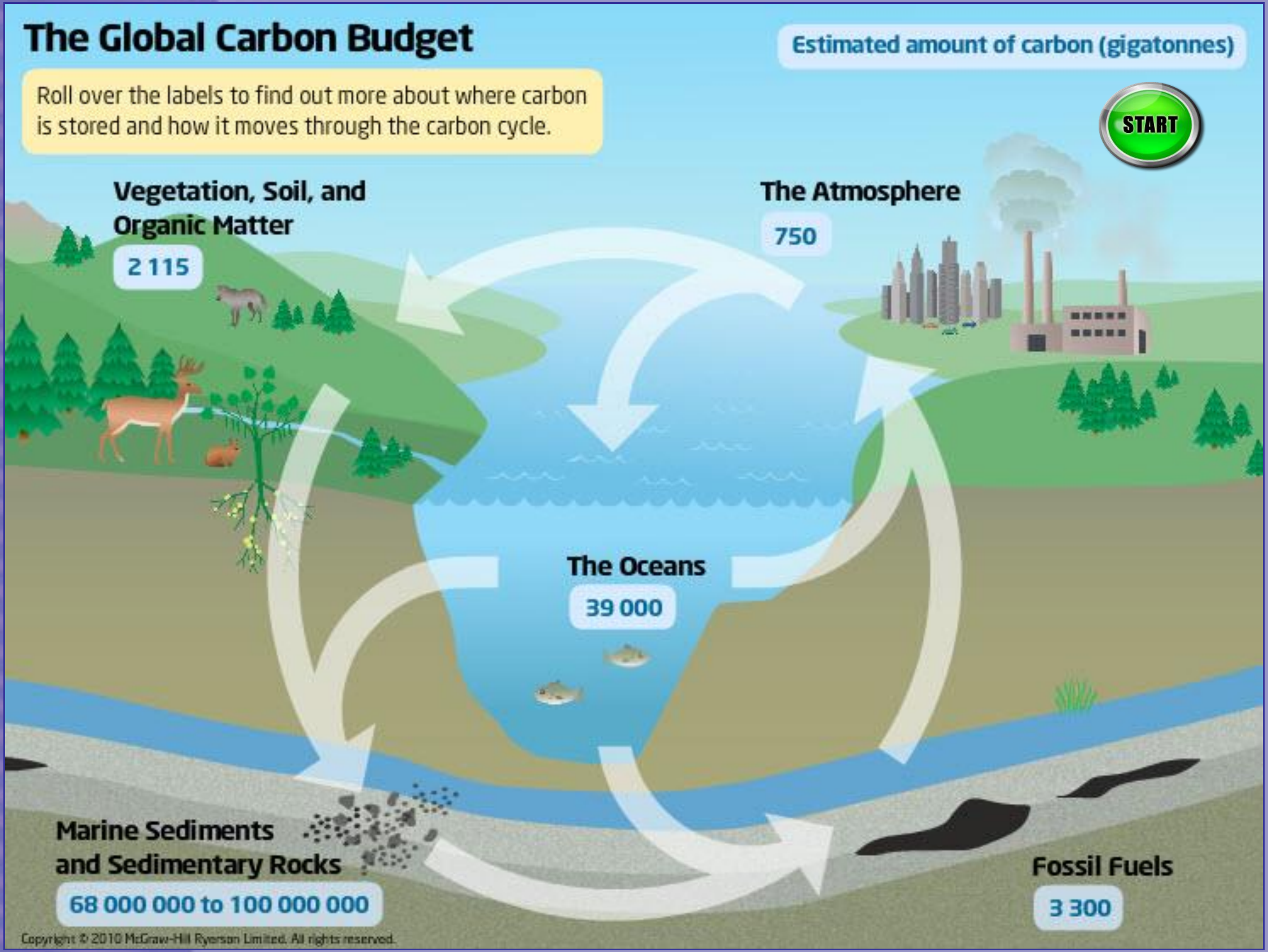
The **carbon cycle** involves the movement of carbon among oceans, atmosphere, rock, and living things on Earth.

The **global carbon budget** represents the relative amounts of carbon in different stores. It is also an accounting of the exchanges (incomes and losses) of carbon between the stores of the carbon cycle.

The Global Carbon Budget

(Page 335)

Click the "Start" button to review the global carbon budget.



The Nitrogen Cycle and Climate Change

(Page 337)

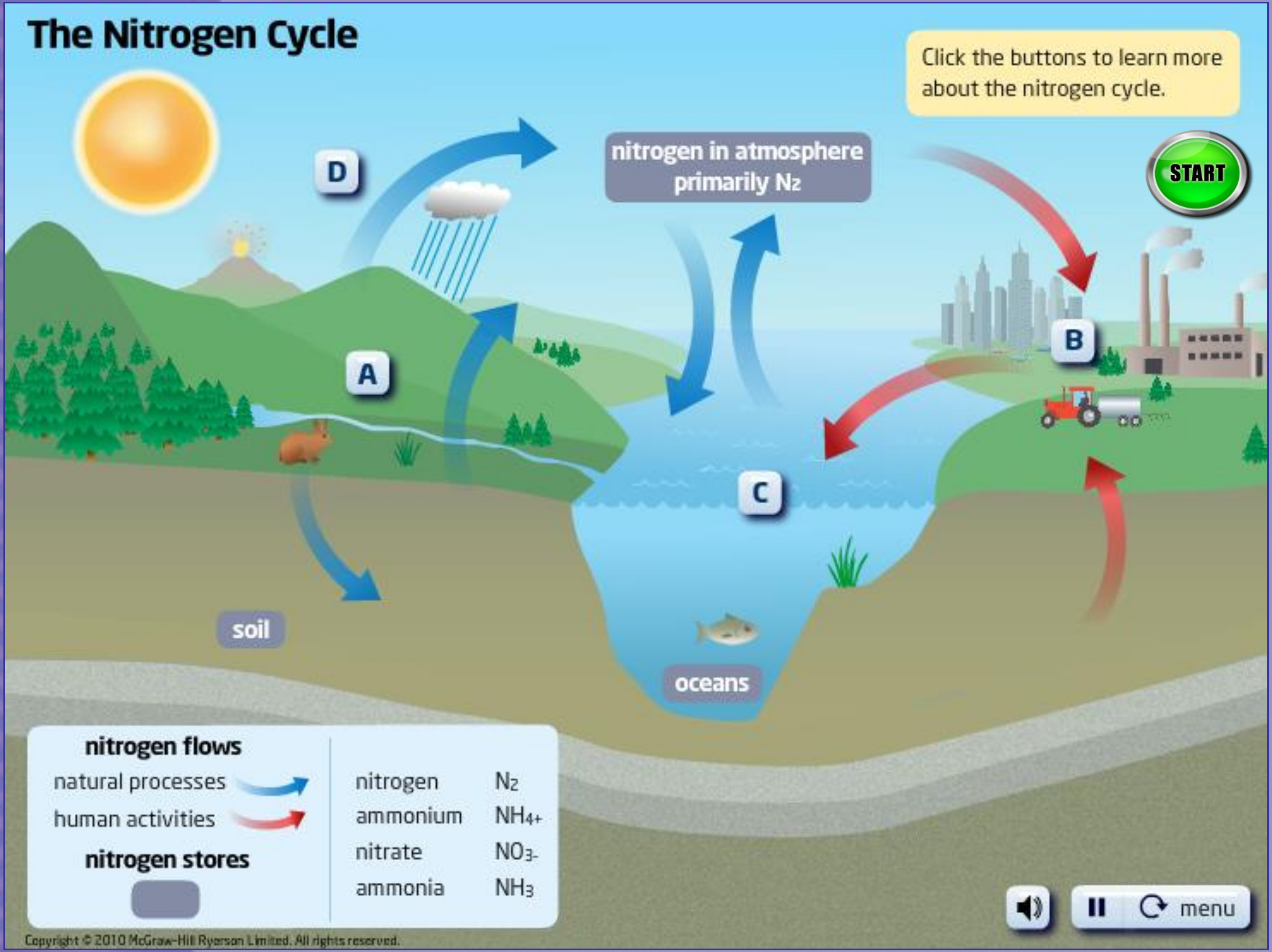
Almost 80 percent of the atmosphere is composed of **nitrogen gas (N_2)** that is very stable and unreactive.

In order to be used by living things, atmospheric nitrogen must be converted into a chemically active form such as **ammonium (NH_4^+)** or **nitrate (NO_3^-)**. In these forms, and in gases such as **nitrous oxide (N_2O)**, nitrogen plays a significant role in climate change.

Lightning supplies energy for the creation of nitrates. Bacteria in the soil and in plant roots can convert soil nitrogen into a usable form. Both of these processes are called **nitrogen fixation**.

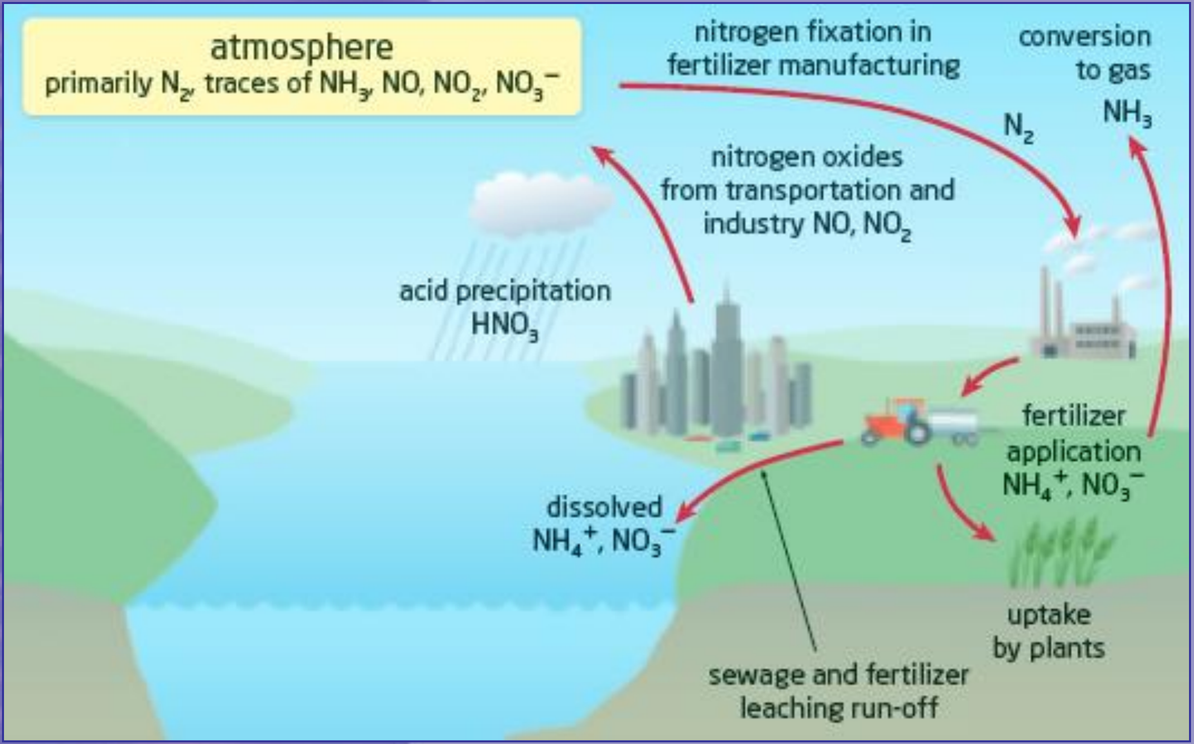
The Nitrogen Cycle

Click the "Start" button to review the nitrogen cycle.



How Humans Affect the Nitrogen Cycle (Pages 338-339)

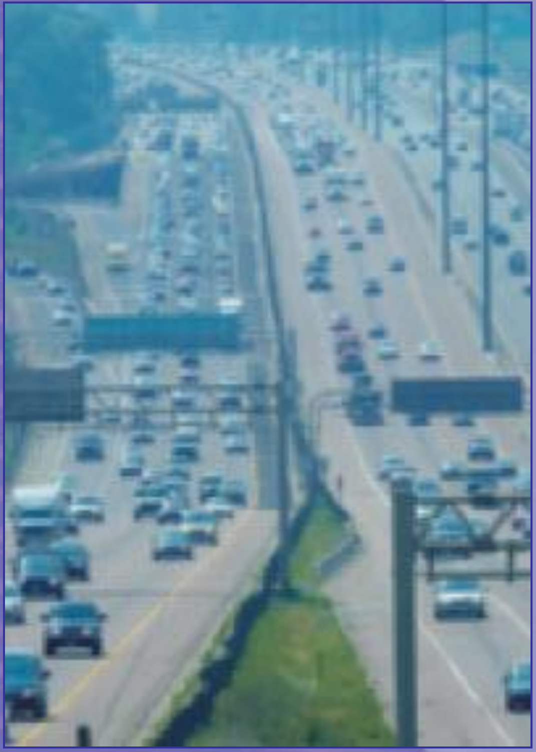
In the early 20th century a new industrial method called the **Haber-Bosch Process** used high temperatures and pressure to combine nitrogen from the atmosphere with hydrogen to make **ammonia (NH_3)**. Ammonia was used to make nitrate fertilizers, which now account for as much as half the **nitrogen fixation** on Earth.



Nitrogen in run-off from fertilizer that is not taken up by plants can lead to rapid plant growth that clogs waterways and reduces oxygen levels in the water. Nitrates in drinking water can lead to health problems.

How Air Pollution Affects the Nitrogen Cycle (Page 339)

Ammonia (NH_3) reacts with other compounds in the air to form smog. Agriculture is also a source of the greenhouse gas **nitrous oxide (N_2O)**. **Nitric Oxide (NO)** from vehicle exhaust is a common ingredient in smog and ground-level ozone. These forms of nitrogen can also combine with water vapour in the atmosphere to form **nitric acid (HNO_3),** which falls to Earth as acid rain.



Some methods for reducing the levels of reactive nitrogen in the atmosphere are listed below.

Course of Action	Estimated Maximum Reduction in Reactive Nitrogen Emissions
Controlling nitrogen oxide emissions from the burning of fossil fuels	25 billion kg/year
Increasing the efficiency of fertilizing crops	15 billion kg/year
Improving management of livestock	15 billion kg/year
Providing sewage treatment for half the world's urban population	5 billion kg/year

Section 8.3 Review

(Page 340)

Concepts to be reviewed:

- *how the carbon and nitrogen cycles work to cycle these elements quickly or to store them for extended periods*
- *the different stores for carbon on Earth*
- *how human activities affect the carbon cycle*
- *how nitrogen is converted into a useful form for living things*
- *how human activities affect the nitrogen cycle and the impact it has on Earth's ecosystems*

CHAPTER 9 *Addressing Climate Change*

In this chapter, you will:

- ***identify*** *the tools used to measure past and present climate change*
- ***investigate*** *how scientists predict future climate*
- ***describe*** *Canada's contribution to climate change*
- ***analyze*** *different sources of scientific data for evidence of climate change*
- ***assess*** *the effectiveness of programs and initiatives to address the issue of climate change*
- ***investigate*** *cause-and-effect relationships related to climate change*

Who is Responsible for Responding to Climate Change?

(Page 349)

If climate change causes the island nation of **Kiribati** to be submerged by rising seas, who should be held responsible?

Canada is one of the top 10 producers of compounds related to climate change. What should Canada's responsibility be to those most seriously affected?

9.1 Discovering Past Climates (Page 351)

Scientists who study past climates are called **paleoclimatologists**. These people are interested in how Earth's climate system has changed throughout Earth's history.

Trees grow an additional ring each year. Analysis of tree rings gives scientists an insight into past temperatures and amounts of rainfall.

Dendrochronologists study details about the size, colour, and shape of each ring.

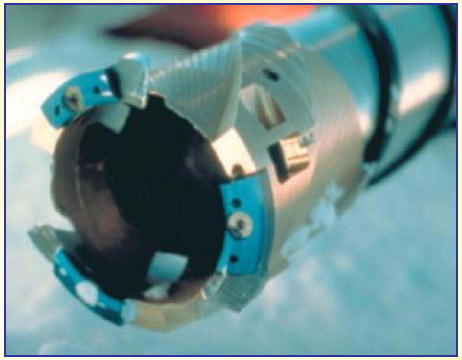
Ice Cores – Records of Past Climates

(Pages 352-353)

Ice cores are long cylinders of ice obtained by drilling into a glacier. The cores have layers like tree rings. Scientists study the thickness and composition of the ice in each layer in order to make inferences about past climates.

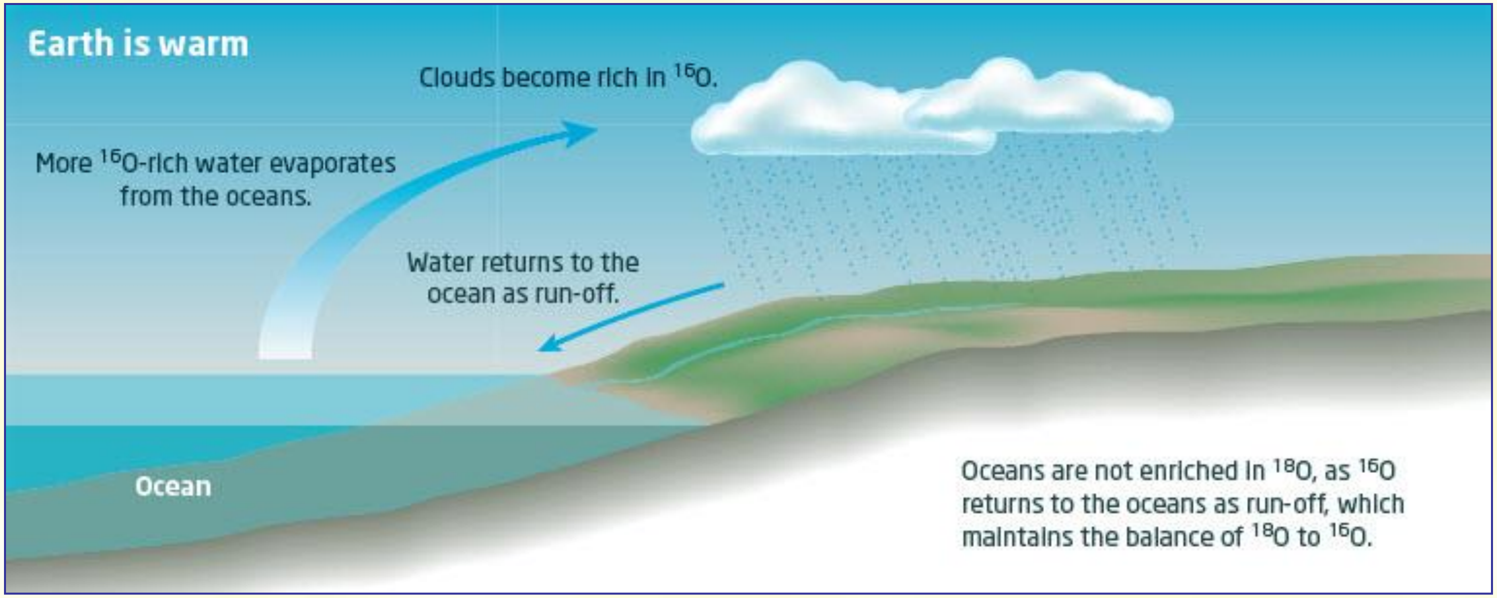
Climatic evidence trapped in the ice cores is uncovered by analyzing the following characteristics of the ice.

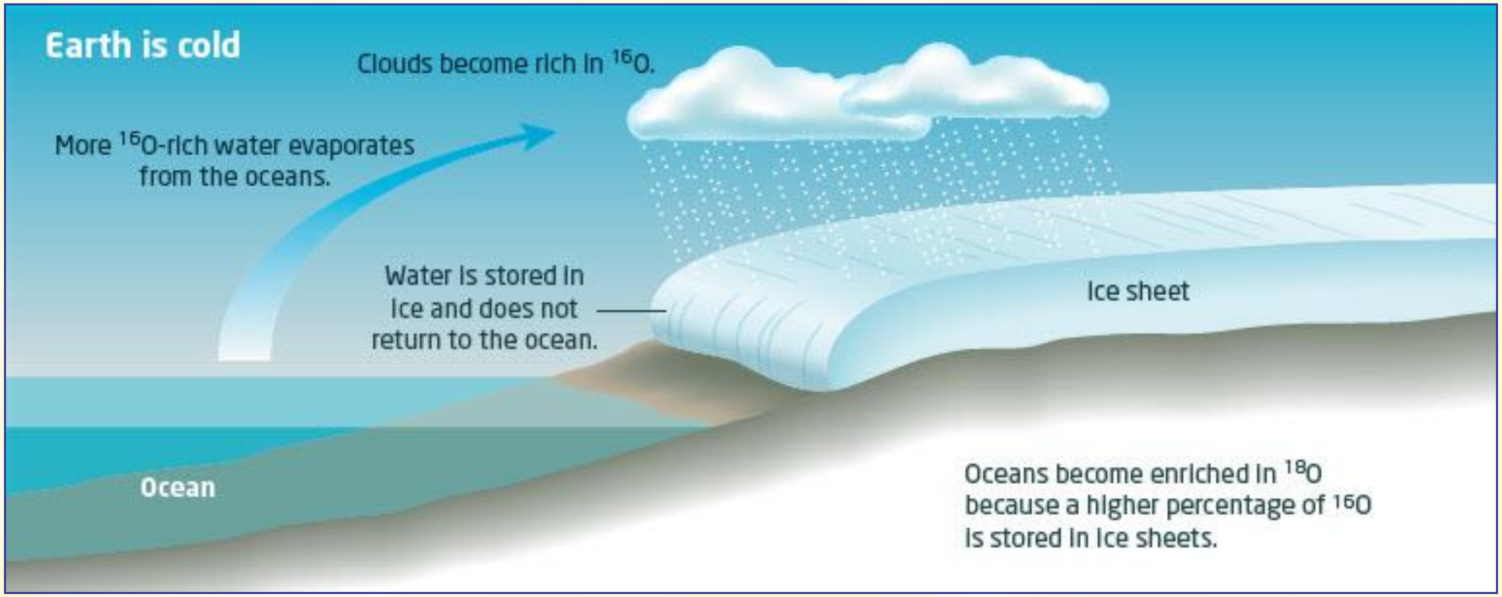
1. **Dissolved and particulate matter** (dust, ash, salts, plant pollen, and other material)
2. **Physical characteristics** (crystal size and shape)
3. **The composition of trapped air bubbles** (past greenhouse gas concentrations)
4. **The composition of the ice** (proportions of hydrogen and oxygen isotopes)



Ice Cores – Records of Past Climates

(Page 354)

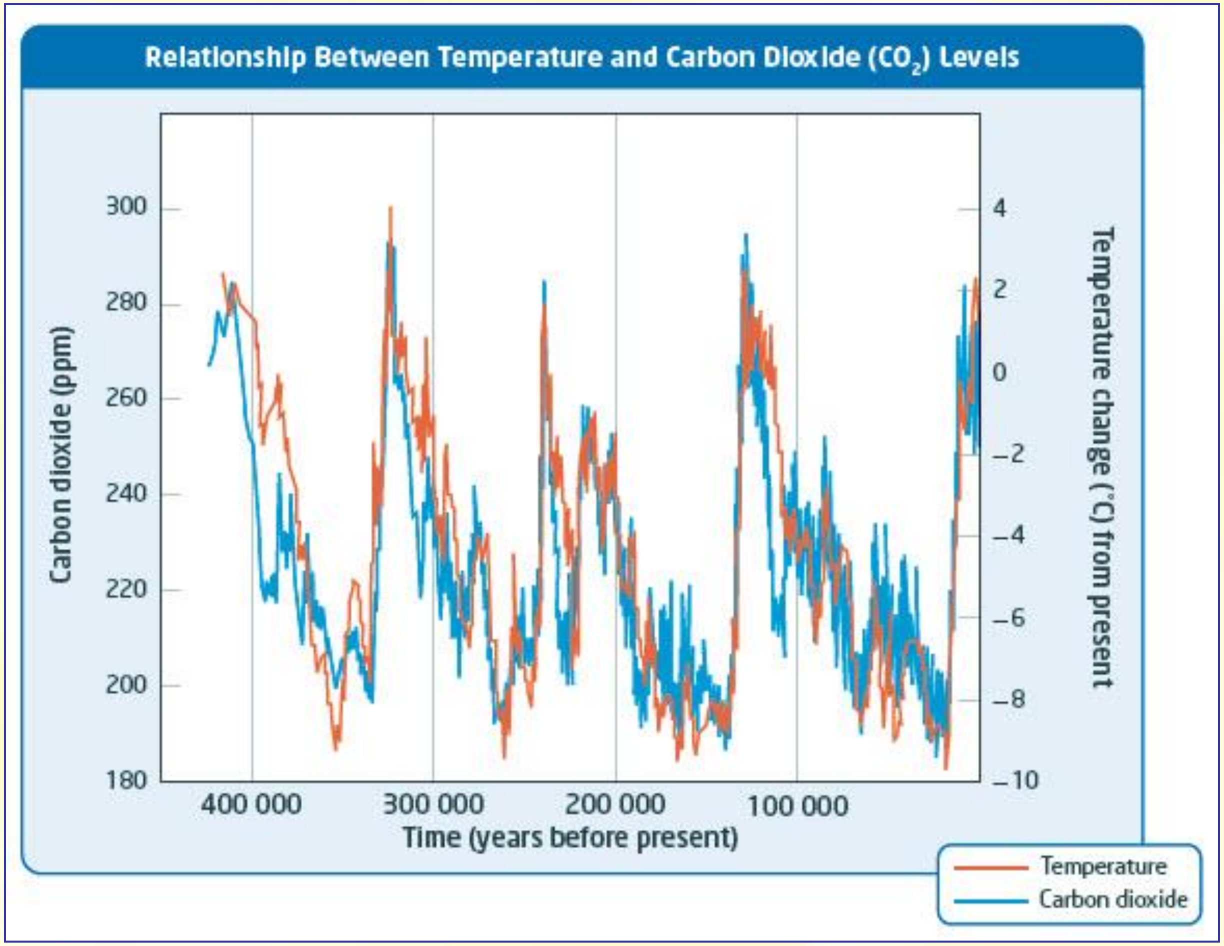




How Scientists Determine Patterns of Past Climates

(Page 355)

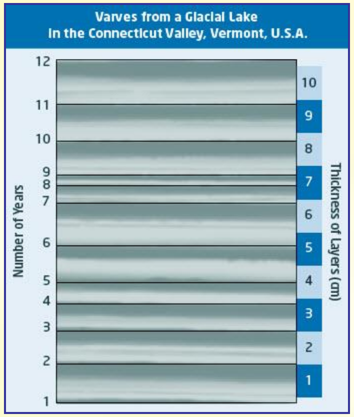
Changes in carbon dioxide concentration and temperature can be graphed based on data from ice cores. The graphs show a strong relationship between CO_2 concentrations and temperature.



Evidence of Past Climates from Sedimentary Rock

(Page 356)

Sedimentary rock is rock formed by the deposition of sediment. Particles in the sediment (such as pollen and parts of microscopic organisms) can hold clues to past climates.



Data from the study of sediment cores gives insight into:

- **global temperatures** (by indicating the most common plants)
- the **temperature of the water** in which an organism lived
- the **amount of rainfall and temperature levels** (by analyzing the composition and amount of sediment in layers called "**varves**")

Evidence of Past Climates from Fossils and Preserved Organisms

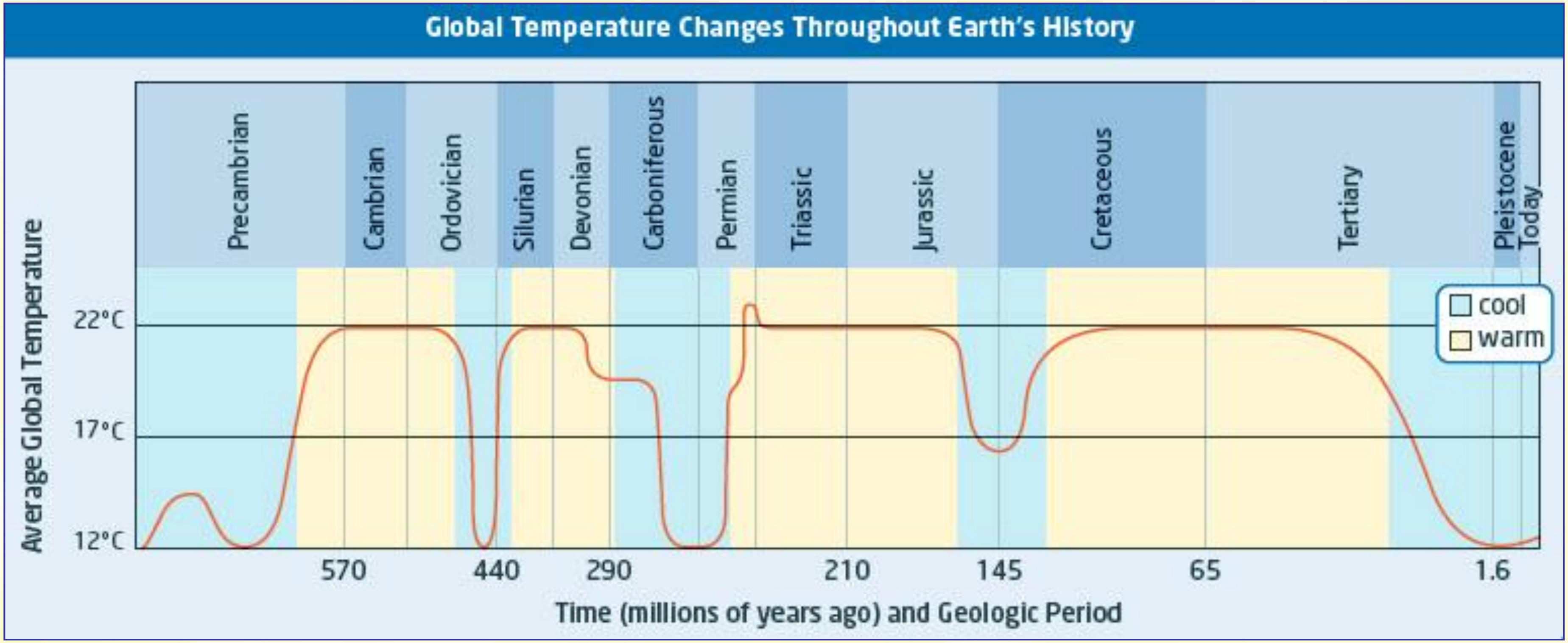
(Page 357)

Fossils are the traces or remains of a once-living organism. The types and abundance of fossilized remains in each rock layer help scientists reconstruct the environment—including the climate—at the time the fossil formed.

How Scientists Infer the Rate of Climate Change

(Page 358)

The rate of climate change in the past is still a matter for debate. Was it gradual or was it sudden and catastrophic? As illustrated below, there have been cooling and warming phases in the past. Some climate changes in the past took millions of years to occur; others happened in only a few years.



Section 9.1 Review

Concepts to be reviewed:

- *the evidence studied by paleoclimatologists to reconstruct past climates*
- *the use of tree-ring data to interpret past climatic conditions*
- *the use of ice cores to provide climatic and atmospheric composition data*
- *the analysis of sediment cores to reconstruct past conditions of the atmosphere and hydrosphere*
- *the analysis of rocks to interpret the conditions that existed when they formed*
- *how fossil distribution and characteristics can provide clues about the climate conditions at the time the organisms lived*

9.2 Monitoring and Modelling Climate Change

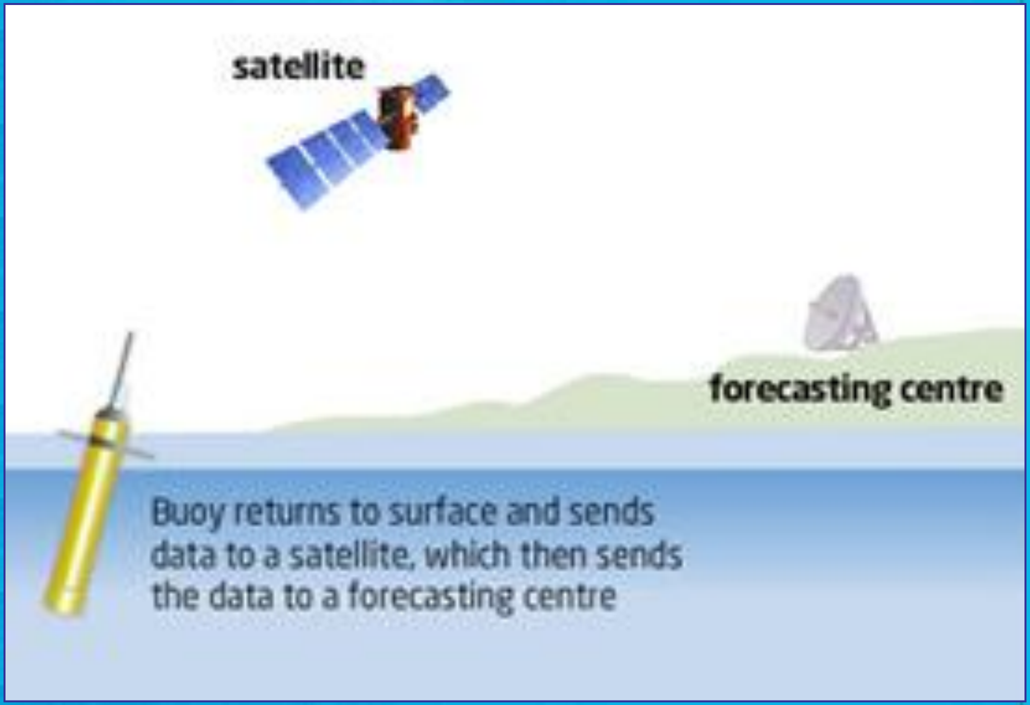
(Page 360)

In order to make reasonable predictions about future trends related to climate change scientists **monitor** current climatic conditions on a regular basis. They do this by measuring conditions systematically and repeatedly in order to track changes. Measurements of **atmospheric temperature**, **humidity**, **precipitation**, and **other weather data** have been collected for 200 years or more.

Buoys, **radar**, and an assortment of **satellites** are used to monitor current climatic conditions.

Ocean Buoys

(Pages 360-361)

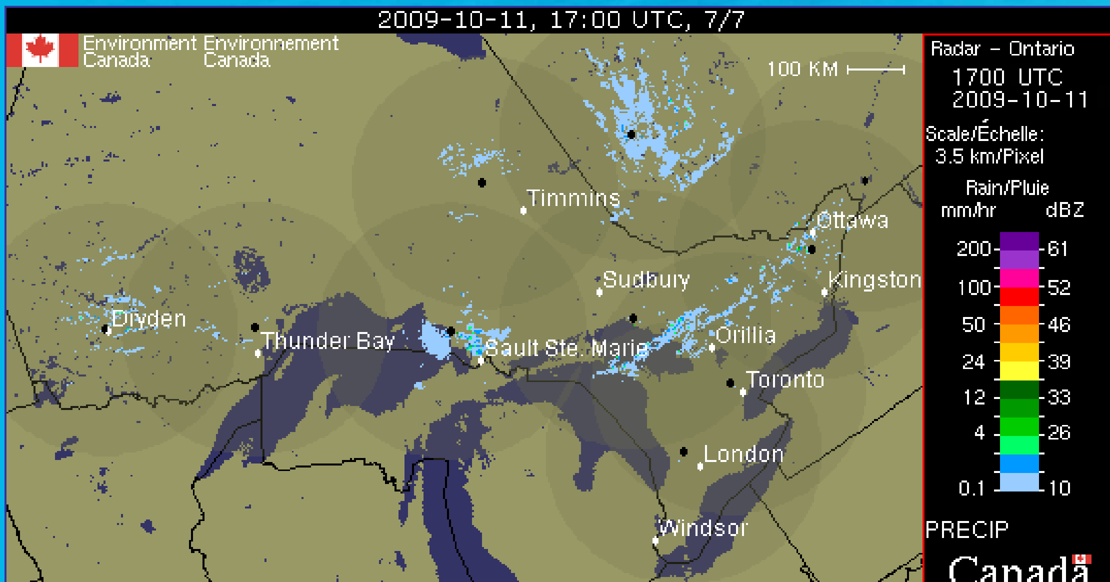


Ocean **buoys** monitor meteorological and oceanographic data, including ocean temperature and salinity. Some buoys sink to various depths in the ocean and then rise to the surface, transmitting data they have collected to land-based stations via satellite.

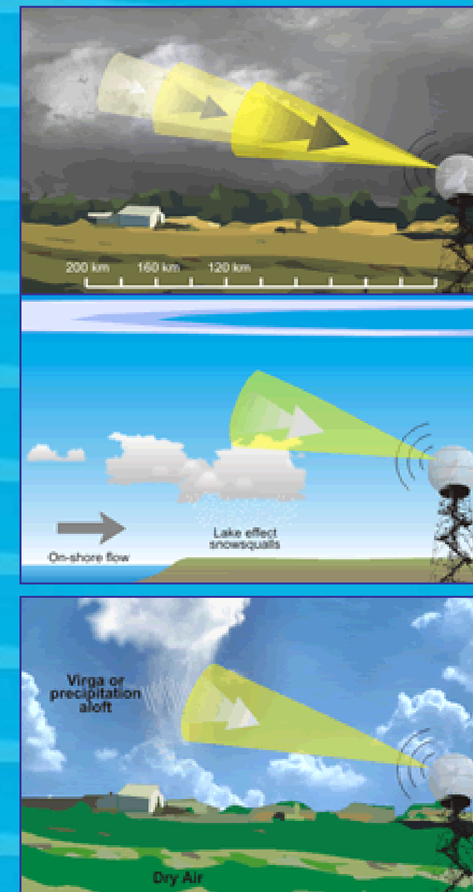
Using Radar to Gather Weather and Climate Data

(Page 361)

Radar data is used to forecast weather and estimate global average climate factors such as humidity and precipitation.



http://www.weatheroffice.gc.ca/radar/index_e.html?id=ONT



Radar systems take measurements by emitting short pulses of microwaves that are reflected by water droplets and ice crystals in the atmosphere. Computers analyze the returning waves and generate an image of clouds or precipitation.

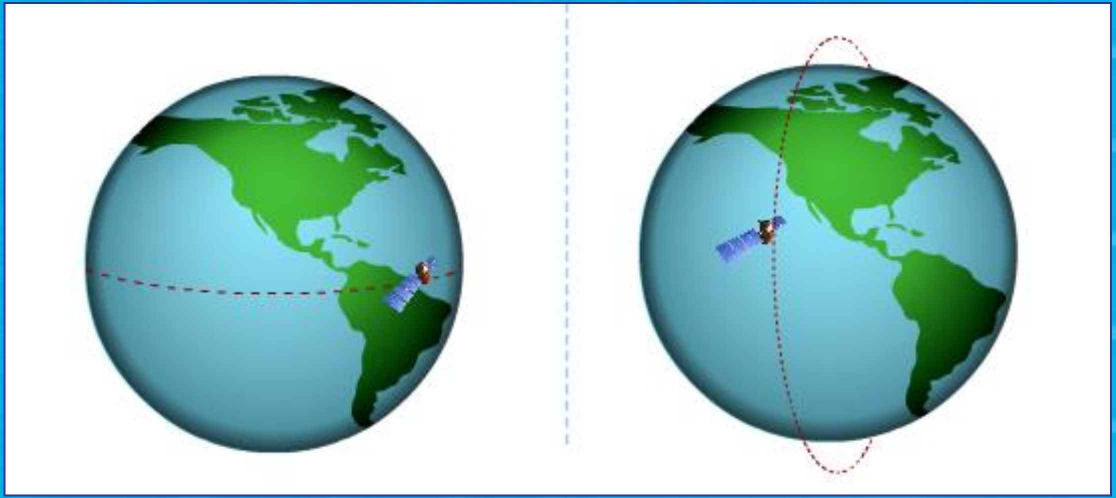
http://www.msc-smc.ec.gc.ca/cd/factsheets/weather_radar/index_e.cfm

Climate Data from Weather Satellites

(Page 361)

The development of **weather satellites** marked a major advance in our ability to monitor climatic conditions. Today hundreds of satellites orbiting Earth measure many different components of our climate system with great accuracy.

Two types of climate-monitoring satellites are **geostationary satellites** (satellites that remain in the same position relative to Earth's surface) and **polar orbiting satellites** (satellites that move north and south over the poles as Earth turns beneath them).



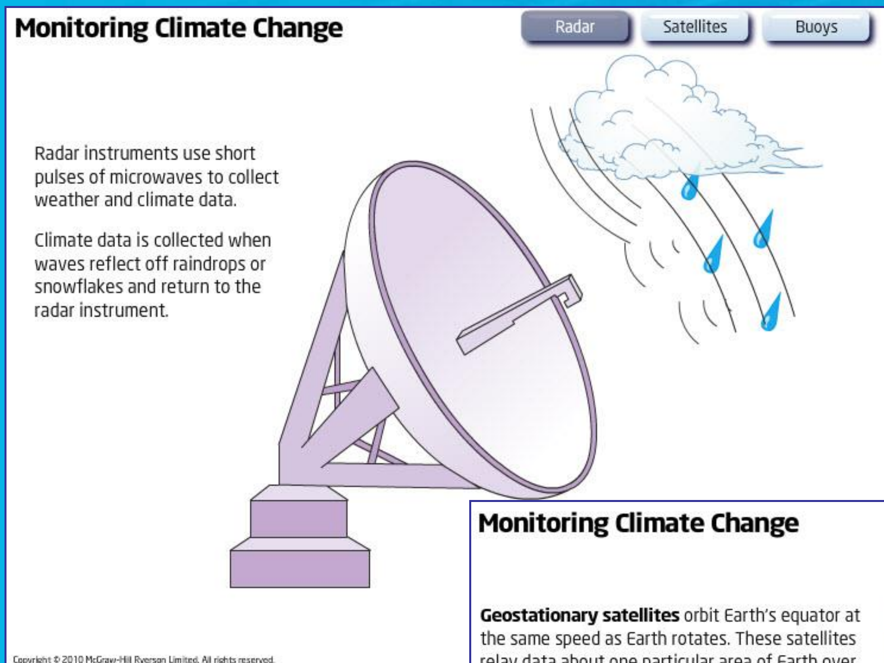
The Earth Observing System (EOS)

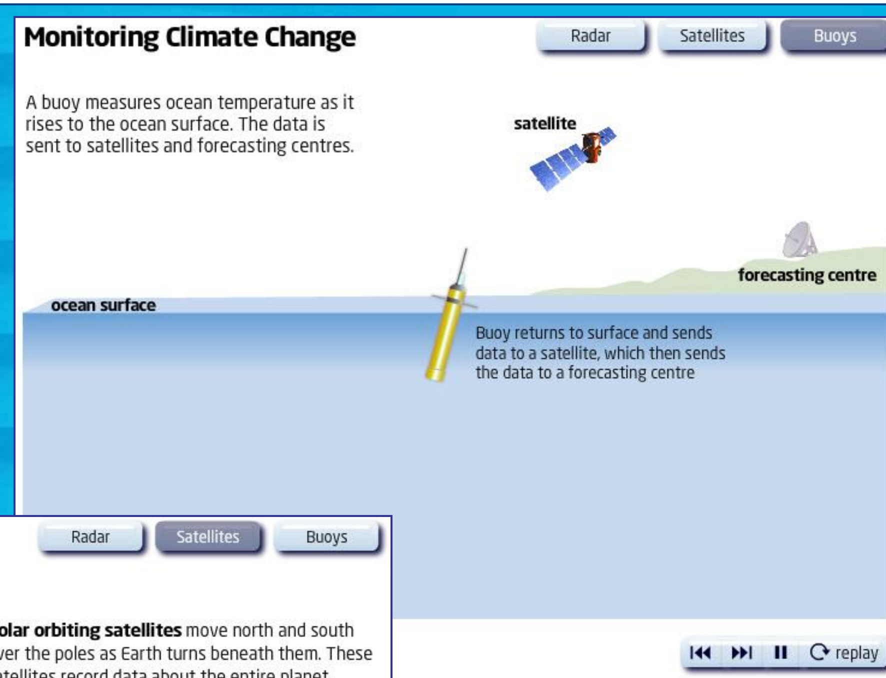
(Page 362)

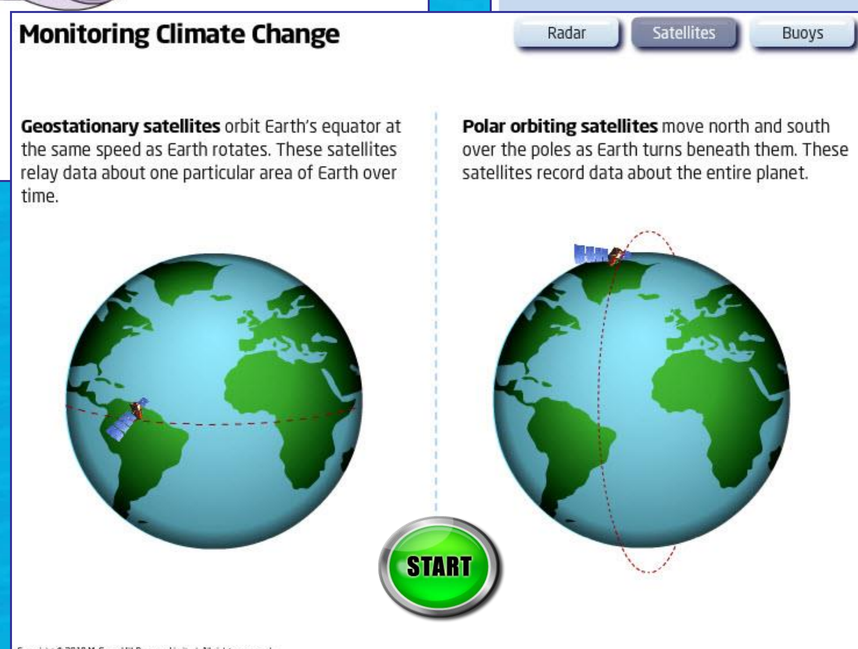
In 1997, Canada, the United States, and Japan launched the first of a series of satellites intended to make long-term observations of Earth's changing atmosphere, land, and ecosystems. There are over 20 satellites currently in orbit as part of this program.

Monitoring Technologies

Click the “Start” buttons to review climate-monitoring technologies.







Modelling Climates and Climate Change

(Page 364)

A **climate model** is a mathematical or computer program that describes, simulates, and predicts the interactions of the atmosphere, oceans, land surface, and ice of Earth to simulate past, present, and future climatic conditions.

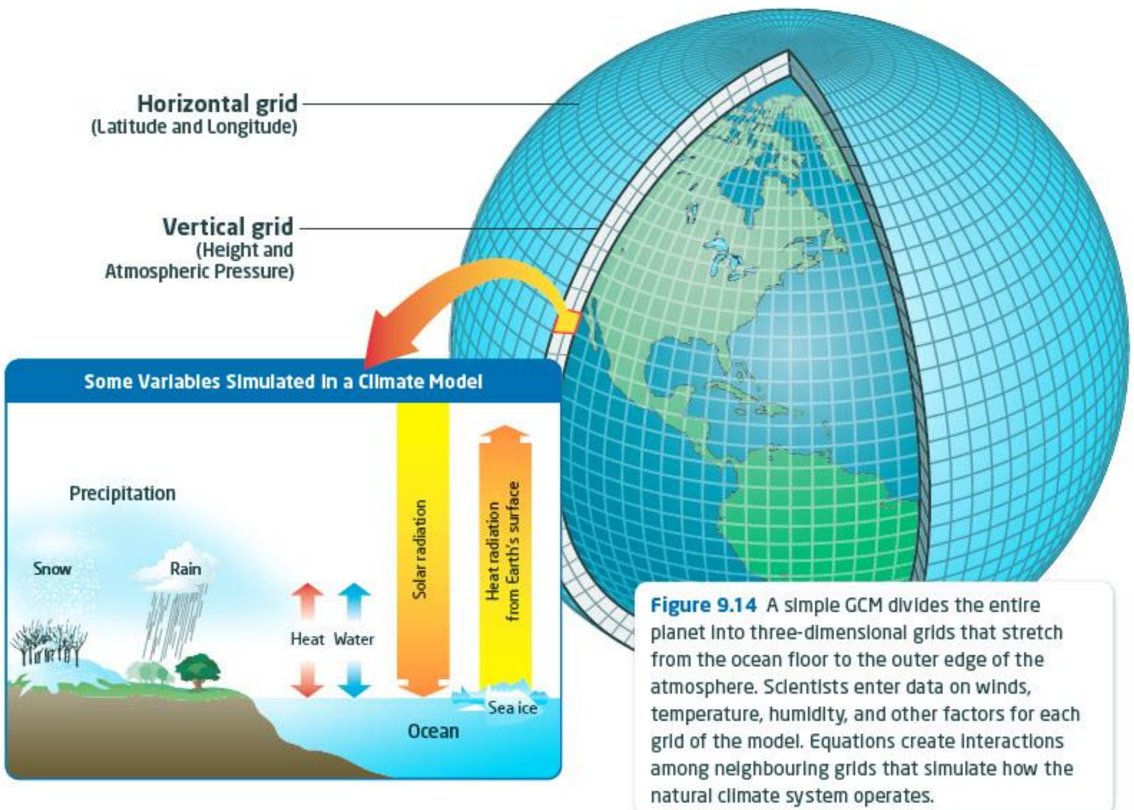


Figure 9.14 A simple GCM divides the entire planet into three-dimensional grids that stretch from the ocean floor to the outer edge of the atmosphere. Scientists enter data on winds, temperature, humidity, and other factors for each grid of the model. Equations create interactions among neighbouring grids that simulate how the natural climate system operates.

A **general circulation model (**GCM) is a complex computer program that uses mathematical equations to describe the physical processes of the atmosphere and manipulates the variables that affect the system.

Limitations and Sources of Uncertainty in Climate Models

(Pages 365-366)

Climate models are not without margins of uncertainty or error. These uncertainties must be taken into account when using the models to make predictions of future climatic conditions. In addition to the **precision of the Earth based measurements taken** other sources of uncertainty include the:

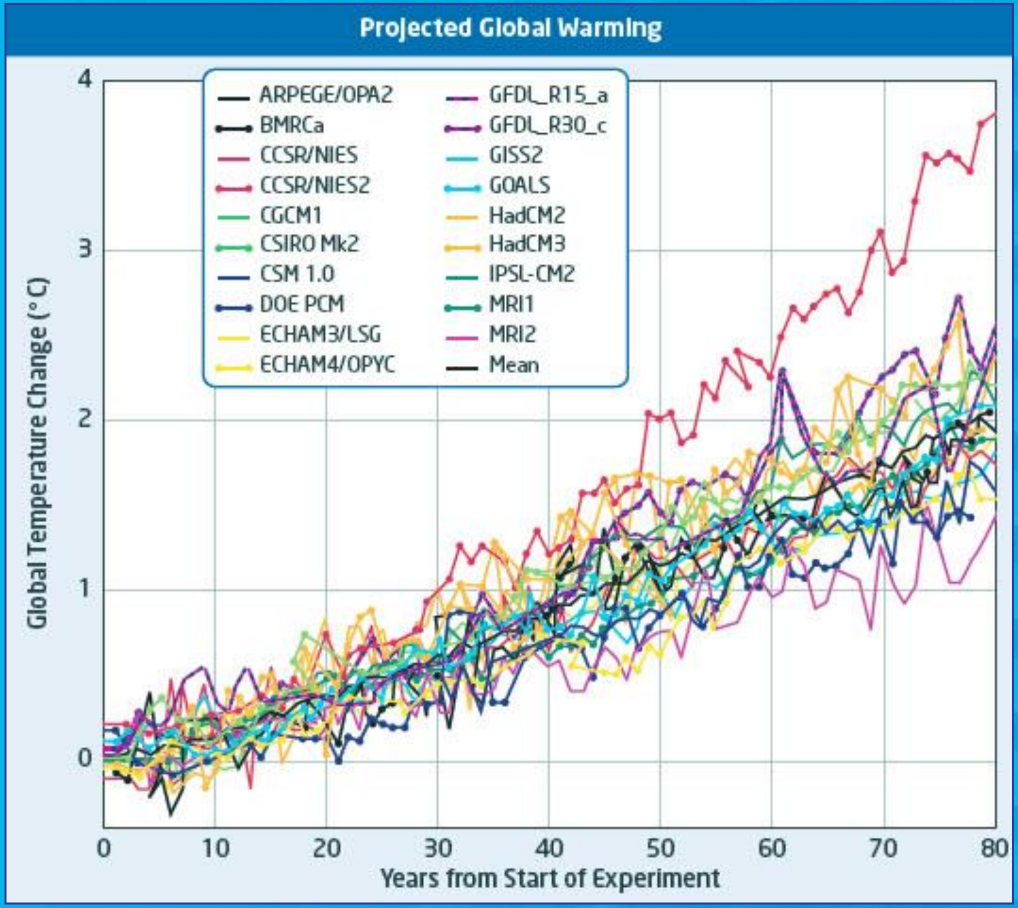
- **sophistication of the model**
- **quality and quantity of data**
- **complexity of the variables**

Clouds represent a challenge to the designers of climate models as they can both trap heat (causing warming) and reflect heat (causing cooling).

Comparing the Accuracy of Climate Models

(Page 367)

The accuracy of different climate models is often based on the model's ability to predict changes that have already occurred. The more closely the model matches actual measurements, the more confidence scientists have in the accuracy of the model.

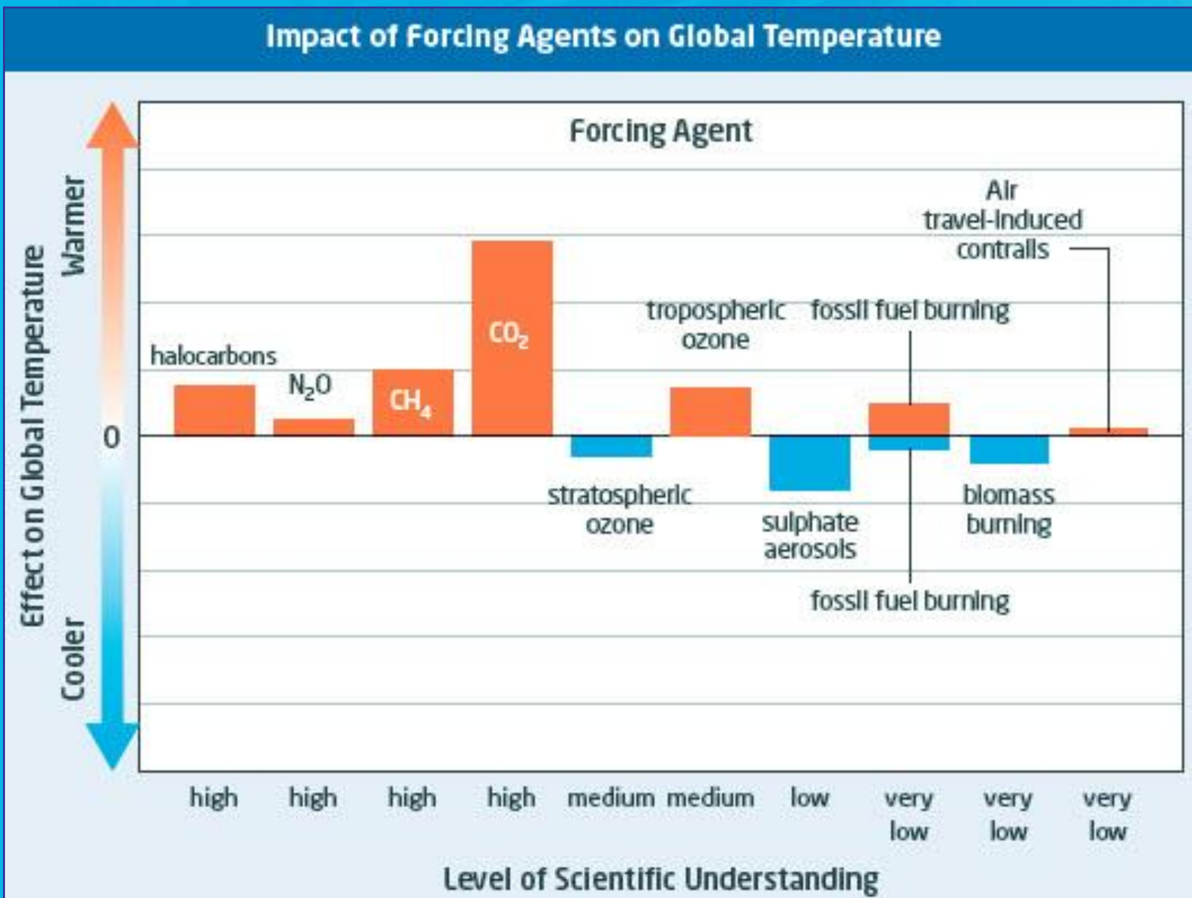


The graph on the left compares 19 different models that attempt to predict how temperatures will change over an eighty-year period.

Climate Forcing Agents

(Page 368)

A **forcing agent** is any substance or process that alters the global energy balance and causes climate to change. The effects of a variety of forcing agents are examined in the model below.



The condensed water vapour trails left by airplanes are called **contrails**.

Section 9.2 Review

(Page 369)

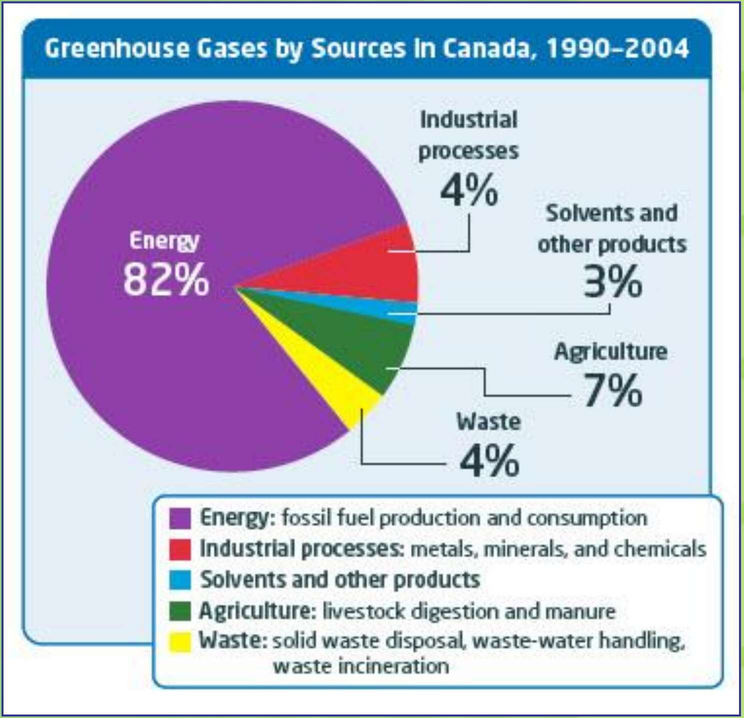
Concepts to be reviewed:

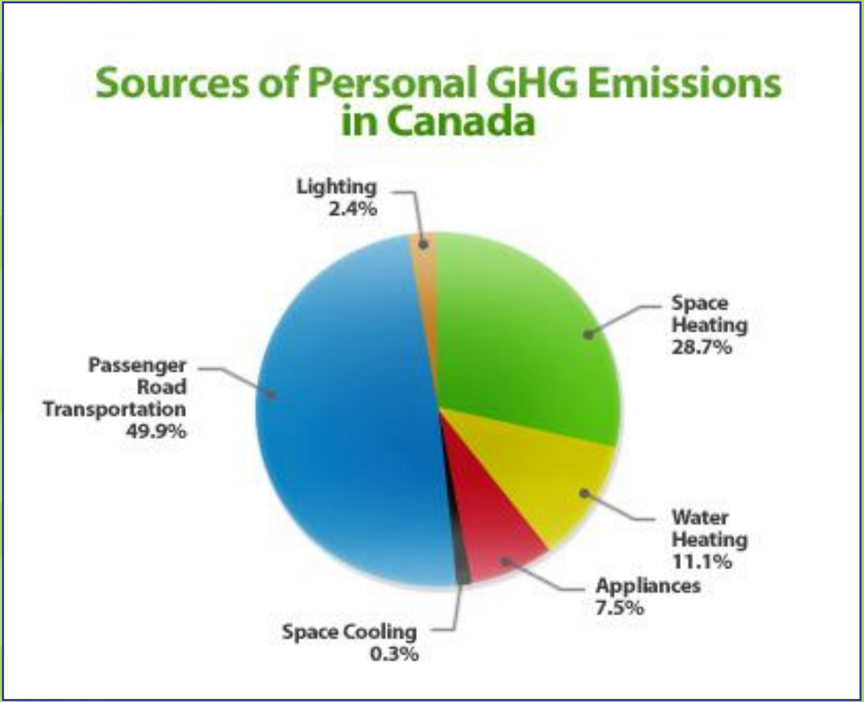
- *the role of satellites in collecting data to help monitor Earth's climate*
- *how computer simulations can be used to predict future climates*
- *a general circulation model (GCM) and how it is used to predict climatic change*
- *the accuracy and uncertainty related to computer models*
- *the factors that most computer models suggest contribute to climate change*

9.3 Taking Action to Slow Climate Change

(Page 370)

Although scientists do not know exactly how rapidly climate change may occur or how much damage it may cause to ecosystems and human society, they do know that **human activities affect climate**.





http://www.housesmartheating.com/furnaces.html

What can humans do to reduce these effects?

Educating Yourself About Climate Change

(Page 371)

There are many different perspectives, both scientific and non-scientific, related to climate change. In order to make well-informed personal choices, you must become familiar with this issue.

The Internet is a valuable source of current data and interpretations of the data from a variety of sources. Possible solutions and/or actions that can be taken are also suggested.

Detecting Bias in Information About Climate Change

(Page 372)

A **bias** is a tendency toward a particular perspective or point of view that prevents objective assessment of a topic.

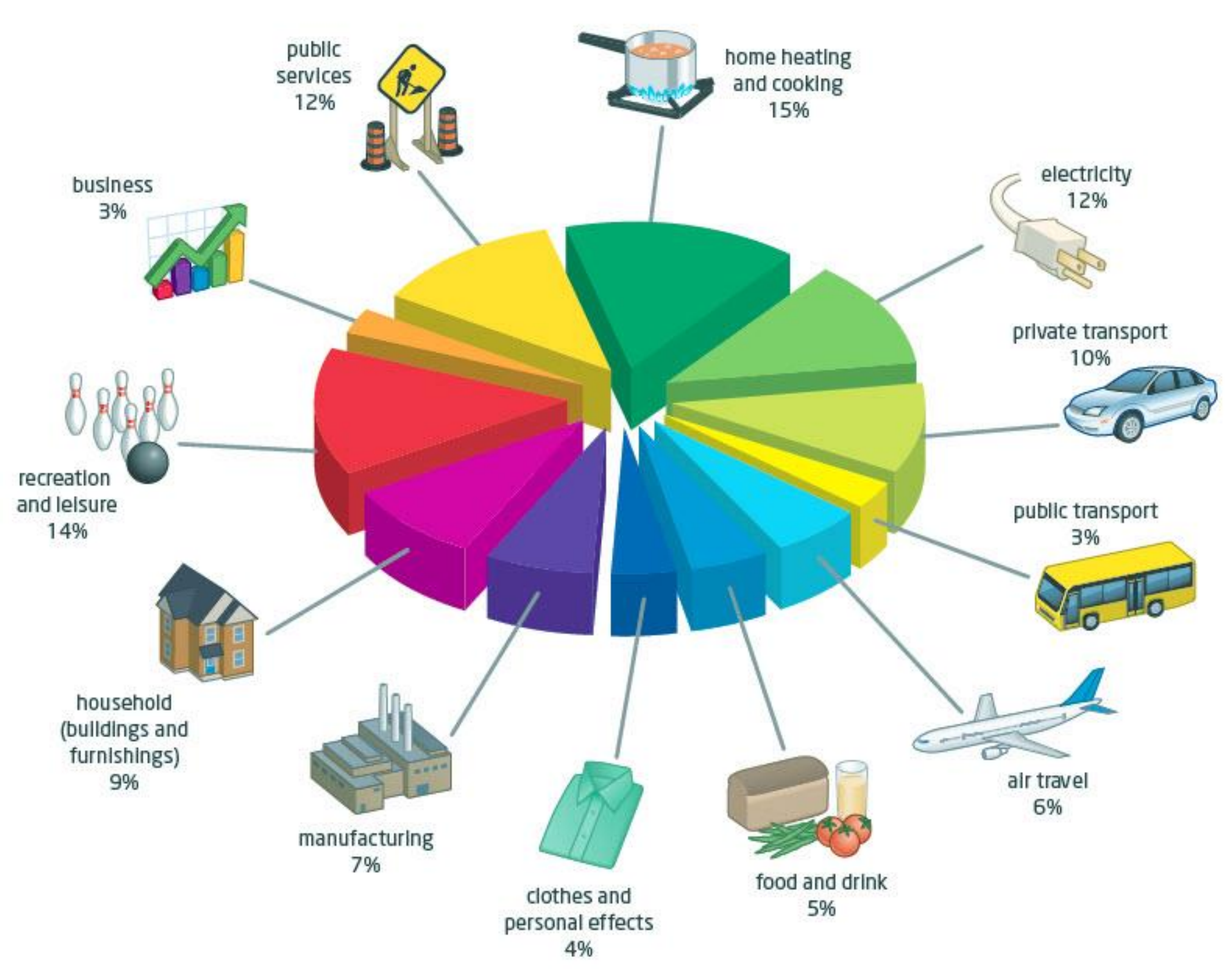
The following questions can help you evaluate information sources for **bias**.

- Is the information from a **respected scientific journal** that is reviewed by professional scientists?
- What is the **source** of the information? (An educational institution, government department, or private corporation or institute?)
- Does the author of the source have an **agenda**? (A political or organization affiliation, or is he or she selling a product/service?)

Calculating Your Carbon Footprint

(Page 373)

A **carbon footprint** represents the effect that human activities have on the environment in terms of the amount of greenhouse gases produced. It is measured in units of carbon dioxide.



Analyzing your own **carbon footprint** is a useful way to determine how you could make a difference in terms of altering activities or behaviours that might be driving climate change.

Reducing Your Carbon Footprint

(Page 374)

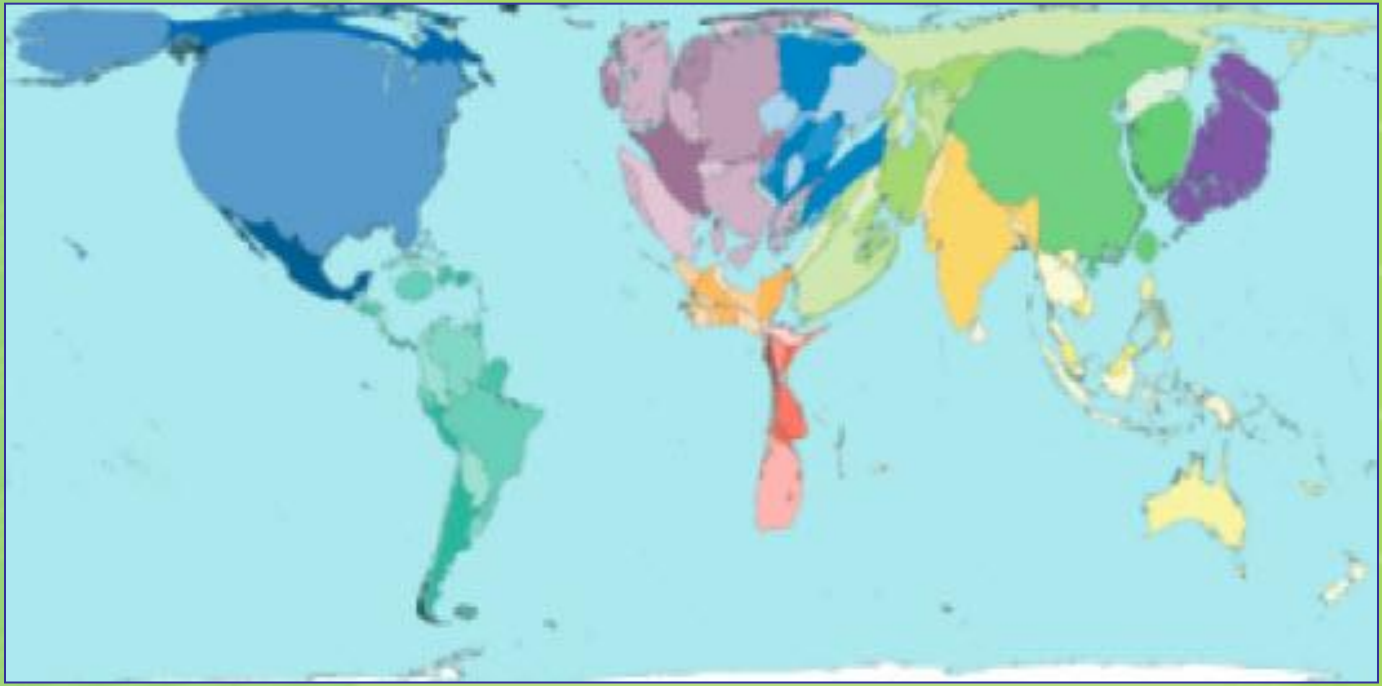
A **carbon offset** is a means of reducing or avoiding greenhouse gas emissions by purchasing credits to reduce a carbon footprint.

Although the impact of one person altering their habits might seem insignificant, the impact of every person taking the same action will be substantial.

Actions that reduce or eliminate the need to burn fossil fuels and contributions to programs that help compensate for carbon-producing behaviours (such as tree planting) can have immediate effects on the size of your carbon footprint.

Global Contributions to Climate Change (Page 376)

The **global warming potential (GWP)**, as illustrated in the image below, is disproportionate among different global regions because of differences in population and lifestyle.



As lifestyles change and/or populations grow, the GWP of regions can change as well.

International Initiatives to Combat Climate Change

(Pages 376-377)

Effective solutions to climate change must involve a great deal of international cooperation. The chart below summarizes some of the key steps taken to date.

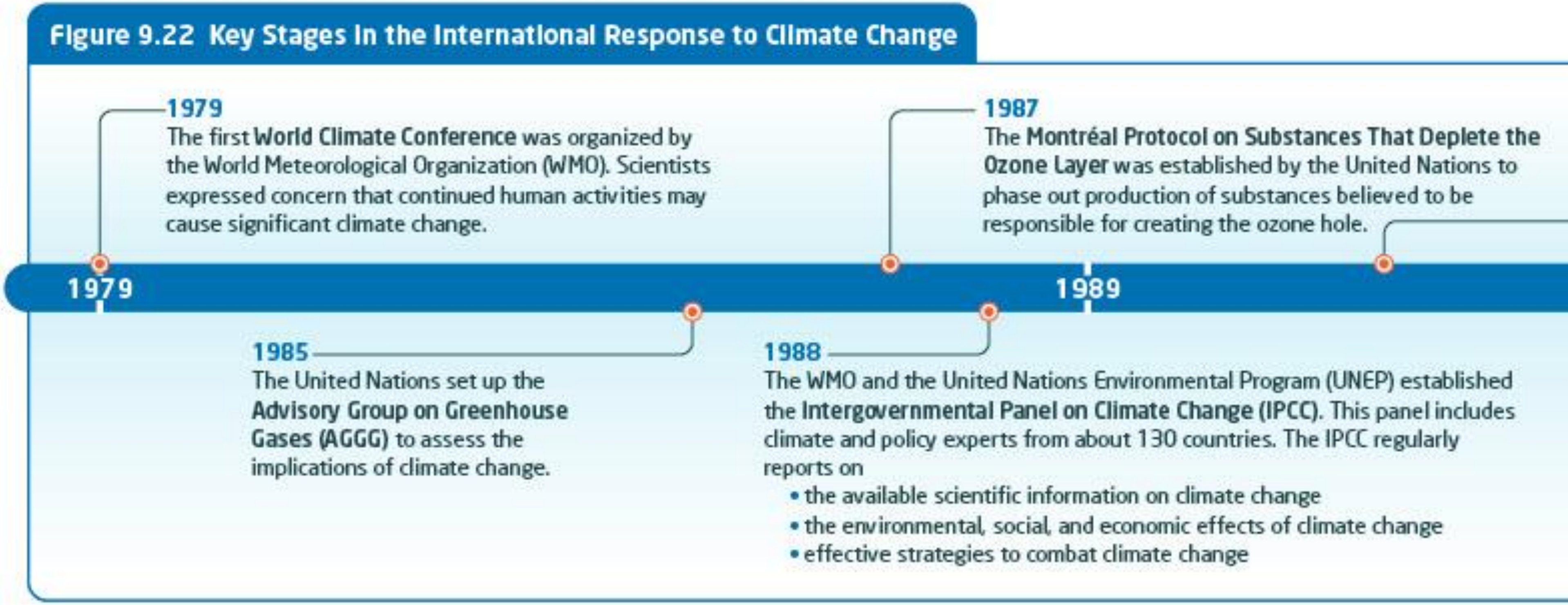


Figure 9.22 Key Stages in the International Response to Climate Change

International Initiatives to Combat Climate Change

(Pages 376-377)

1992
An international treaty called the **United Nations Framework Convention on Climate Change (UNFCCC)** was produced at the Earth Summit held in Rio de Janeiro. Its aim was to stabilize greenhouse gas concentrations in the atmosphere by imposing limits on emissions from individual nations.

1999 — 2009

1997
The **Kyoto Protocol** was an update of the UNFCCC that commits participating nations to reducing emissions of greenhouse gases to levels specified for each country. The Kyoto Protocol has been signed and approved by 181 countries and the European Union. Together, these countries produce only 60 percent of global greenhouse gas emissions. Participating countries must meet their commitments by December 2012 or face penalties.

2007
The **IPCC Fourth Assessment Report:** Climate Change 2007 concluded that the global climate is warming and that most of the increase in average global temperature since the mid-20th century was due to an increase in anthropogenic greenhouse gas concentrations. It predicted future increases in heat waves and rainfall, and a rise in sea levels.

Countries will continue to meet and attempt to come to a consensus as to what actions must be taken to combat climate change globally.

COP15 COPENHAGEN
UNITED NATIONS CLIMATE CHANGE CONFERENCE DEC 7-DEC 18 2009

Future conferences will attempt to develop a comprehensive approach to dealing with climate change that all countries can agree on.

The Intergovernmental Panel on Climate Change

(Page 377)

Established in 1988, the **IPCC** assesses human activities related to climate change and regularly meets and reports on the issue.

http://www.ipcc.ch/

Educating and Empowering Consumers (Page 378)

Governments can help individuals combat climate change by passing laws or regulations and sponsoring incentive programs and by educating consumers to make choices that benefit the environment.

energy

ENERGY STAR

HIGH EFFICIENCY

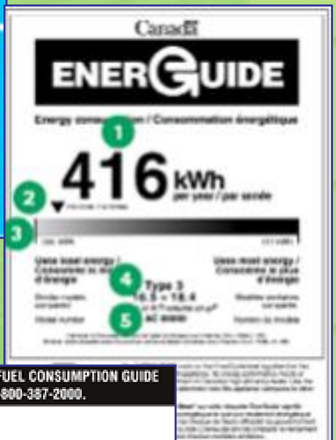
HAUTE EFFICACITÉ

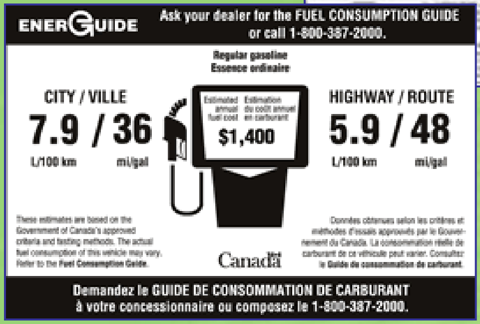
REDUCE

REUSE

RECYCLE

3Rs





ecoENERGY

an ecoACTION initiative

Save NOW with a home retrofit grant – Save LATER on your energy bills

http://www.oee.nrcan.gc.ca/residential/personal/retrofit-homes/pdf/retrofit-homes-eng.pdf

Retire Your Ride

Canada's Vehicle Recycling Program

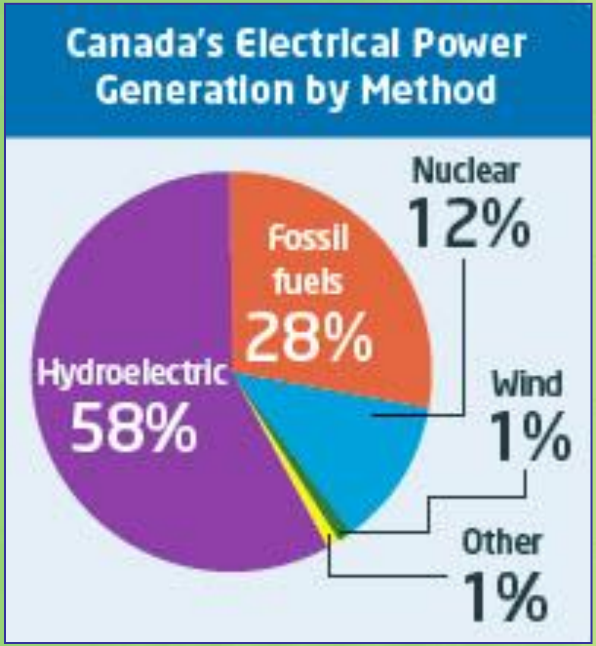
http://www.retireyourride.ca/home.aspx

Using Alternative Sources of Energy

(Page 380)

One of the best long-term ways to reduce the emission of greenhouse gases is to develop sources of energy that produce fewer greenhouse gases or none at all.

Alternate methods of generating power for Canadians include using **wind**, **solar**, **biomass**, **hydroelectric**, **tidal**, and **nuclear** sources.



Consumers can use energy sources such as **wind** and **solar** on a single-home basis and can also heat and cool their homes using currently available **geothermal** systems.

Section 9.3 Review

(Page 381)

Concepts to be reviewed:

- *educating yourself about the issue of climate change in order to make informed decisions*
- *knowing the size of your carbon footprint*
- *finding ways to reduce the size of your carbon footprint*
- *actions governments and international panels can take to combat climate change*