Section 7.1 Factors That Affect Climate Change

Specific Expectations

- **D2.1** use appropriate terminology related to climate change, including, but not limited to: *albedo*, *anthropogenic*, *atmosphere*, *cycles*, *heat sinks*, and *hydrosphere*
- **D2.4** investigate a popular hypothesis on a cause-and-effect relationship having to do with climate change, using simulations and/or time-trend data that model climate profiles
- **B2.5** investigate, through laboratory inquiry or simulations, the effects of heat transfer within the hydrosphere and atmosphere
- **D2.6** investigate, through laboratory inquiry or simulations, how water in its various states influences climate patterns
- **D3.1** describe the principal components of Earth's climate system and how the system works
- **D3.2** describe and explain heat transfer in the hydrosphere and atmosphere and its effects on air and water currents
- **D3.3** describe the natural greenhouse effect, explain its importance for life, and distinguish it from the anthropogenic greenhouse effect
- **D3.4** identify natural phenomena and human activities known to affect climate, and describe the role of both in Canada's contribution to climate change

In this section, students will learn what climate is. They will be introduced to factors that determine the climate of a location. Students will learn about the important role solar energy plays in determining the climate of different locations on Earth. Students will also learn more about the relationship between climate and weather.

Common Misconceptions

- Students may not understand the difference between *climate* and *weather.* Point out that weather is what you see outside the window on any given day. Climate is a long-term average of the weather in a region.
- Students may assume that ice makes things cold. They may be confused by the fact that ice reflects solar radiation, making the atmosphere warmer. Investigation 7-A may clarify this idea.
- Students may have heard that climate change is not occurring. Climate refers to the expected average weather, but extreme weather has always been a part of climate. The challenge is to determine the difference between normal climate variability and evidence of a changing climate. Distinguishing between these two things can be arbitrary because it depends on the time frame studied. For example, given the extremes in geological history (e.g., ice ages), the climate may be seen to be entering into another natural shift. At the moment, there is consensus in the scientific community that the climate is changing. The debate is over what is driving this change—natural or human forces. This topic will come up throughout the unit. Students must be challenged to look at the evidence presented. Some may feel strongly human actions are not causing climate change. Demonstrate and encourage respect for different opinions. Encourage students to support their views with scientific evidence.
- Students may think there are no seasons in the tropics because they do not have the same temperature fluctuations as temperate regions do. The seasonal fluctuation in the tropics comes in the form of precipitation, with distinct rainy and dry seasons, rather than winter and summer seasons.
- Students may conclude that some pollutants effectively counter the greenhouse effect. For example, releasing aerosols (solids such as sooty particles suspended in a gas) clouds the atmosphere, reducing the greenhouse effect. Remind students that though this may be true, these particles only stay in the atmosphere for days to weeks, so they have no long-term effect on climate. Regulation of air pollution has also decreased aerosol pollution.
- Students may think that Earth orbits the Sun in an elongated elliptical path and that this is what causes Earth's distance from the Sun to vary enough to cause seasons. Explain that, showing the concentric circles of an overhead view of the orbit (rather than an elongated side view) may help clarify the shape of the orbit. It is actually the tilt of the Earth on its axis that causes our seasons.

Background Knowledge

The last ice age was recent, in geologic time. Scientists have been able to collect significant data on how climate changed during the last ice age. As recently as 21 000 years ago, ice sheets up to 3 km thick covered most of North America, Scandinavia, parts of the United Kingdom, and the Urals Region of Russia. In the Southern Hemisphere, much of Argentina, Chile, New Zealand, Australia, and South Africa were under ice sheets. The total volume of water frozen as ice was approximately 90 million km^3. As a result, the average global sea level was 90 to 120 m lower than it is today. Many reference maps of the last ice age show land masses much larger than they are today because of lower sea levels. Today's ice sheets hold about 30 million km^3 of water.

The word *climate* has its roots in the Greek word *klima,* which means inclination. It refers to the angle of the Sun's rays relative to the horizon. Milutin Milankovic (1879–1958) developed a mathematical theory of climate. Milankovic's theory linked the fluctuations in the ice ages to three variations in the relative position of Earth and the Sun. These variations can cause changes of up to 15 percent in the amount of radiation received at high latitudes.

The Sun is a middle-aged star. It shines because of chemical reactions occurring in the gases at its core. These thermonuclear reactions fuse hydrogen atoms together, making helium atoms and releasing huge amounts of electromagnetic energy at temperatures of approximately 15 000 000°C. The Sun has an outer atmosphere called the corona, which has a temperature of about 1 000 000°C. About 46 percent of the Sun's radiation is emitted as visible light. Another 46 percent is emitted as infrared or near-infrared radiation, which we feel as heat. The remaining 8 percent is ultraviolet radiation. The Sun contains 99.9 percent of the Solar system's mass.

Because Earth is spherical, the majority of incoming solar radiation is absorbed at the low latitudes, near the equator. However, the majority of solar radiation is reflected back out from the polar regions. Therefore, there is net gain of energy near the equator, and a net loss of energy near the poles. This difference is balanced by a transfer of energy from low to high latitudes. It is this transfer of energy from the equator to the poles via the atmosphere and the oceans that ultimately drives Earth's climate system.

Dramatic seasonal changes occur because the equator and Earth's orbital plane are not parallel. At different times of the year, different regions of Earth receive different amounts of sunlight. In the tropics, there is at least one day each year when the Sun is straight overhead at noon. Shadows are only cast directly underneath objects on this day. In the Arctic, there is at least one day each year on which the Sun does not set, and technically, one on which the Sun does not rise. However, Earth's atmosphere slightly bends the Sun's rays, so a person in the Arctic Circle or Antarctic Circle would be able to see sunlight for a few minutes on the day that the Sun does not rise.

Earth's atmosphere has no exact boundary; however, 99.9 percent of the atmosphere occurs within 100 km of Earth's surface. This is relatively very small: if Earth were an onion, the atmosphere would be the thickness of the onion skin. Earth's atmosphere is divided into five layers:

- troposphere—0 to 10 km above the surface. Ninety-nine percent of weather happens in the troposphere and 50 percent of the mass of the atmosphere is contained in this layer. Air in the troposphere is heated from the ground up because Earth's surface absorbs energy and heats up faster than the air. The air in the troposphere is unstable and, therefore, moves around.
- stratosphere—10 to 50 km. High altitude weather balloons and jets fly in the stratosphere. The temperature at the top of the stratosphere is relatively warm because the oxygen and ozone in the layer absorb solar radiation. Air is about 1000 times thinner at the top of the stratosphere than it is at ground level. This limits weather balloon and jet flight above the stratosphere.
- mesosphere—50 to 80 km. Most meteors from space burn up in the mesosphere. This is the coldest layer of the atmosphere. The temperature at the top of the layer is –90°C.
- thermosphere—80 to 500 km. Temperatures climb significantly in the thermosphere because of solar radiation. Air density is so low in the thermosphere that it is often considered to be "outer space." The International Space Station and the space shuttle orbit Earth in the thermosphere. Much of the x-ray and ultraviolet radiation from the Sun is absorbed in the thermosphere. The Northern and Southern Lights occur in this level of the atmosphere.
- exosphere—above 500 km. This layer is where atoms and molecules escape the atmosphere and enter into space. Satellites orbit Earth at the bottom of the exosphere.

Atmospheric pressure at a particular location on Earth is caused by the weight of the atmosphere above that point. When air pressure readings at specific locations are joined together, they form lines called *isobars.* Isobars show bands of high and low pressure circulating around Earth in pressure systems. These pressure systems are primary drivers of weather. The atmosphere works to restore balance, and air from high-pressure areas moves into low-pressure areas, creating wind. Use **BLM 7-5 Air Pressure and Climate** to help students with this material.

The circulation of air in the troposphere near the surface of Earth features semi-permanent regions of low pressure (where the air is rising) and high pressure (where the air is descending). These regions are a response to the temperature of the land; so in the tropics, the air is warmed and it rises, creating a low-pressure zone. The Intertropical Convergence Zone (ITCZ) is the band of low pressure surrounding Earth over the equator. This warm air rises, gradually cools, and by 30° latitude (north and south) descends back to the surface, creating bands of high pressure. At the upper boundary of this high-pressure zone are jet streams, which occur in both the Northern and Southern Hemispheres. These are "rivers of air" that occur at altitudes of 9 to 12 km. Wind speeds in the jet streams average about 180 km/h.

There are two types of ocean current: surface currents and deep currents. Surface currents are driven by wind, Earth's spin, and the shape of continents. **BLM 7-4 Winds and Ocean Currents** will help students understand the link between them, as well as the link to climate. Deep currents are driven by the temperature and salinity of the water. These will be addressed in Chapter 8.

Surface currents in the ocean transport about the same amount of energy towards the poles as the atmosphere does. As well, the temperature of the ocean's surface determines the rate of evaporation into the atmosphere and the nature and form of clouds. Winds associated with tropical storms (e.g., cyclones) accelerate evaporation into the atmosphere, ultimately resulting in precipitation.

The water cycle also moves energy around the atmosphere. Ice in the climate system requires energy to melt it, and water requires even more energy in order to evaporate, so as the water cycle continues, energy gets moved around Earth.

The term *albedo* is derived from the latin word *albus*, meaning white. Albedo is a number reflecting the percent of all wavelengths of solar radiation that is reflected by a surface. The ideal white object would have an albedo of 100 percent, while the ideal black object would have an albedo of 0 percent. Albedo is often expressed as a number, representing the ratio alone (not multiplied by 100 to become a percent). In which case the range would be 0.0 to 1.0.

All together, volcanoes release about 150 million tonnes of carbon dioxide (CO_2) into the atmosphere every year. Mount Etna in Italy is estimated to be the largest volcanic emitter, at 25 million tonnes of carbon dioxide per year. Following the 1980 eruption of Mount St. Helens in the United States, the emissions were less than 2 million tonnes of carbon dioxide per year.

Literacy Support

Using the Text

Many of the concepts in this section refer to a 3-D understanding of Earth and our solar system. Have a globe on hand, and a model of the solar system, to aid understanding. As students read the text, stop frequently and have students model the situations using either props or themselves.

Before Reading

- Have students preview the text features including headings. Have them look at the key terms and consider if they are familiar with any. This will help them identify the main ideas in the section.

During Reading

- As students are reading, have them make connections to prior knowledge. Students may be familiar with some of the topics. Encourage them to identify what they already know.
- Have students compile a list of questions as they read. This will help focus their reading and will serve as an organizer for information they still need to learn.

After Reading

- To consolidate learning, have students create a word web or other graphic organizer to show the relationship between two key concepts they learned about in the section. They can use this graphic organizer as a starting point for the graphic organizer they develop in the Chapter Review.

Using the Images

- DI Encourage spatial learners to summarize the illustrations throughout the section as a preview to the material.
- Combine the images in this section with the associated text headings. This can serve as an organizer as students progress through the section.
- As students read through the text, have them summarize the captions of the diagrams in their own words. They can combine these summaries into an organizer for the section.

Assessment FOR Learning

Tool	Evidence of Student Understanding	Supporting Leaners
Learning Check questions, page 272	Students correctly define *climate.*	Have students create a Venn diagram for the terms *climate* and *weather.*
Activity 7-2 Modelling the Effects of Volcanoes on Climate	Students link the blocking of light to cooling of the atmosphere.	Compile class results to identify patterns and extend the analogy as a group.
Section 7.1 Review, page 278	Mountains are shown to affect wind and precipitation, which affects climate. Students summarize the major factors affecting Earth's Climate. Students link the effects of atmosphere and ocean on climate.	Have students complete **BLM 7-4 Wind and Ocean Currents.** Remind students of the impact that specific heat capacity has on how much thermal energy air and water hold.

Instructional Strategies

- DI Challenge students, especially spatial and bodily-kinesthetic learners, to develop a model of Earth and the Sun. They can do a classroom skit showing the position of Earth throughout the year and how Earth rotates and tilts around the Sun.
- ELL Create a word wall that includes visuals to support the vocabulary in this section. Have students create first language translations so the word wall supports their vocabulary.
- ELL Use a variety of concrete and visual aids to help with the material. Models and manipulatives will be helpful to all students.
- Students will benefit from exploring online animations, particularly of the orbit and rotation of Earth around the Sun. Go to **www. scienceontario.ca** for links.

- Model the relationship between solar energy and latitude with a small flashlight and a globe. Roll a piece of black paper into a tube and attach it to the bulb end of the flashlight. Hold the edge of the tube about 3 to 5 cm away from the globe's surface. While keeping the beam perpendicular to the equator, move it up so the bottom edge of the beam aligns with higher and higher latitudes to show that the same beam of light spreads over a larger area as latitude increases.
- Auditory learners may need to read the text aloud to understand the information. Provide a space for them that will not distract other students. Alternately, read the headings throughout the section to the class and have them discuss the content.
- **BLM 7-9 How Does a Lake Affect Climate?** can be used to help students consider the specific heat capacity of water and how it influences local conditions. The organizer can be saved and used as a study tool.
- Check often for comprehension, Students may need to demonstrate their understanding of the concepts in a variety of ways. In addition to written summaries, allow students to construct models, design presentations, or act out the concepts.

Activity 7-2 Modelling the Effects of Volcanoes on Climate

(Student textbook page 276)

Pedagogical Purpose

This activity models the affect that ash (creamer) from a volcano has on the dispersion of light in the atmosphere (water).

Planning	
Materials	Overhead projector (or another light source) Small aquarium (5 L to 10 L) 5 mL measuring spoon Water 20 mL coffee creamer This activity can work with any strong light source. Ensure adequate counter or desk space for the aquarium and the light source.
Time	20 min
Safety	This activity involves using electrical devices near water. Use extra caution to make sure the area is clear of tripping hazards. Be prepared with a water clean-up kit and a glass clean-up kit.

Background

Volcanoes emit carbon dioxide into the atmosphere. Volcanic eruptions also release large volumes of sulphate aerosols (particulate matter) into the atmosphere. Depending on the size of the eruption, these aerosols circulate in the atmosphere and can reflect incoming sunlight for several years. The aerosols ultimately settle to the ground due to gravity, but while they are reflecting incoming sunlight, they contribute to global cooling.

Activity Notes and Troubleshooting

- Before the activity, have students discuss what they think will happen. Encourage students of differing abilities to provide their answers in a variety of forms, such as diagrams or charts.
- This activity may be done as a demonstration. If there are adequate materials, divide the class into groups and vary the concentration of creamer in the aquarium. Students can share their results after they have cleaned up.
- If you are not using an overhead projector, position the light source to one side of the aquarium and shine the light through. Depending on the strength of the light, there may not be remarkable changes in the reflection of the light on the wall, because creamer will be forming a filter on the top of the water. Students can still get results by stirring the water and looking at the side of the aquarium opposite the light source.

Additional Support

- DI This is an excellent activity for bodily-kinesthetic and spatial learners. Have students work in cooperative mixed-ability groups to answer the questions.
- ELL Before beginning the activity, check that students understand what is being modelled. Continue to check during and after the activity.

Answers

1. The light got darker and darker.
2. The creamer acts in the same capacity as the dust and ash (particulate matter) would act in the atmosphere. The water represents the atmosphere.
3. It could stimulate global cooling.

Learning Check Answers (Student textbook page 272)

1. Climate is the long-term average of the weather in a region.
2. Fluctuations may have caused climate change in the past.
3. Diagrams should show that at high latitudes, the Sun's rays are spread over a larger area and, therefore, heat (solar radiation) is more diffuse, resulting in less warming of the ground and atmosphere and the cooler temperatures that brings.
4. Earth's tilted axis means that the Sun is at a smaller angle to Canada in the summer, resulting in more direct radiation than in winter.

Section 7.1 Review Answers (Student textbook page 278)

Please also see **BLM 7-7 Section 7.1 Review (Alternative Format).**

1. Climate is the long-term average of the weather in a region and weather refers only to short-term (or present) conditions.
2. Energy from the Sun enters the atmosphere and heats the surface of the planet. This heat produces wind, rain, and other climate features.
3. Toronto is located on the Great Lakes coast, whereas Pierre is landlocked. Because water has a large specific heat capacity, it requires a large quantity of energy to raise its temperature compared with the energy needed to change the temperature of land. As a result, the temperature of large bodies of water tends to change slowly and by small amounts trapping more heat in the region.
4. As mountain chains rise, they affect the pattern of wind flow, because air must blow around a mountain barrier or rise to flow over it. This change in wind patterns changes the temperature and precipitation of the surrounding regions.
5. The eruption caused the average global temperature to drop by about 0.2°C for at least three years.
6. Diagrams should show the Sun, atmosphere, oceans, Earth's continents, volcanoes, meteorite impacts, and human activity.
7. Example: The high specific heat capacity of water means that oceans influence climate more strongly than the atmosphere does.
8. The human practice of burning fossil fuels, such as oil and coal, may have caused global temperature to rise by changing the composition of the atmosphere.