Section 9.2 Monitoring and Modelling Climate Change

(Student textbook pages 360 to 369)

Specific Expectations

- **D2.1** use appropriate terminology related to climate change, including, but not limited to: *albedo, anthropogenic, atmosphere, cycles, heat sinks,* and *hydrosphere*
- **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 how scientists monitor climate change, including the technology they use to help collect their data. Students will also find out how scientists predict future climate using computer simulations of Earth and the components of climate. They will learn about the sources of error in computer models, and why climate modelling cannot be 100 percent accurate.

Common Misconceptions

- Students may believe that it should be easy to model climate because of technology. Most students will be familiar with satellite technology, at least in terms of television and cellphone applications, so they may not recognize the limitations of technology when it comes to modelling a system as large as global climate. Have students look at Figure 9.14, a simple general circulation model (GCM). Have a discussion about how challenging it would be to have adequate data for a model.
- Students may not understand the difference between modelling and monitoring. Explain that modelling attempts to simulate what will happen, whereas monitoring involves recording ongoing information about changes in the climate. Have students recall what they learned previously about environmental monitoring, which involves long-term studies used to track changes in ecosystems. Students can relate this concept of monitoring to climate change.

Background Knowledge

Many components of the global weather measurement system began in the 1800s. The invention of the telegraph allowed networks to expand and share data, and led to standardization of data collection. The emphasis was on temperature, pressure, humidity, wind speed, wind direction, and precipitation data. Some stations were equipped to gather enhanced data, including information about solar radiation, evaporation and soil temperatures. It is important to note that many basic weather records have been collected using technology that has not changed significantly over the past 200 years. This means that observations are directly comparable.

Constructing the historical global record has been a huge challenge for researchers. The first "century data set" was released in 1997. It is made up of monthly observations from over 7000 land stations around the world. Version 2, the Global Historical Climatology Network is the most complete digitized climate data set available.

The Global Climate Observing System is an international effort sponsored by the World Meteorological Organization, the Intergovernmental Oceanographic Commission, the International Council for Science, and the United Nations Environmental Program. It was developed to ensure there is enough data for seasonal climate prediction, and to detect and attribute long-term climate trends. The system is an effort to fill geographic gaps that still exist and expand data collection to completely cover the oceans and land surfaces. Part of this system includes the pilot project that will include positioning over 3000 ocean buoys around Earth's oceans.

When weather radar was first developed, it was not always possible to differentiate between a clear sky and a whiteout. This was because the radar would take a few milliseconds to shift from send to receive mode when trying to get an indication of cloud height. If the radar pulse was reflected by objects within 2 m of the radar station, the pulse would not be received and the radar would signal "clear skies." Between 1994 and 1996 there were four plane crashes, because a better method of radar was not available. The incorrect "clear skies" data was transmitted from an automated ground station to pilots making approaches to the runway. The improved method involves checking the radar data against probable clouds due to fronts and other weather conditions.

Weather satellites give views of large parts of Earth's surface, allowing meteorologists to peer above the clouds. Infrared satellite photos always appear in black and white because the data that is returned is reading the intensity of the absorbance of the water. Absorbance is a measure of how well water absorbs infrared light.

The first true weather satellite was the TIROS (Television Infrared Observation Satellite), a polar-orbiting satellite launched in April 1960. This, and other satellites like it, began the era of providing broad pictures of cloud formations across the globe. By 1963 these satellites could send photographs to Earth as they passed overhead.

EOS, the Earth Observing System, is run through NASA. Its observations of land surface, biosphere, atmosphere, and oceans are major components of NASA's Science Mission Directorate. The goal of EOS is to provide a better understanding of Earth as a whole system.

The use of mathematical equations to predict the behaviour of the weather was proposed by Lewis Richardson in the 1920s. His idea was highly impractical in that it required approximately 64 000 mathematicians working in a "fantasy factory"—a giant globe—solving mathematical equations. His idea was to have the mathematicians pass their answers to the equations to each other and continue to calculate answers. The answers would then be papered around the globe to represent weather in different parts of the world. The advent of high-speed computers makes the use of these mathematical equations a practical reality.

The challenge of all climate and weather modelling is to work much faster than the real Earth systems they are representing, in order to give a representation of what will happen. To do this, many simplifying assumptions must be made and this affects the accuracy of the models.

Climate change models of the globe are very useful. However, for policy making in different countries and regions, more accurate local information is needed. Regional Climate Models (RCMs) simulate climate change at smaller geographical areas to assess the real impact of future climate on particular regions.

Literacy Support

Using the Text

- This section contains a lot of new terminology and descriptions of technology that some students may be completely unfamiliar with. Ensure that students keep a running summary of the different techniques and technologies in their notes. They can name the concept or technology and summarize the important points concerning it and use their notes as a study tool later.

Before Reading

- Have students look at the headings to figure out what the main ideas in the section are. This will help students identify the most important information in the text. Students can use this information to organize their learning.

During Reading

- Have students write down a question and an answer at the end of each subsection. The questions can be shared with the class and answered during a class discussion.
- Ask students to visualize the different technologies that are discussed as they read through the section. This can transform the chunk of text students read into an image in their mind. The actual text then becomes supporting material that adds detail to the visual.

After Reading

- Ask each student to write a short, two-sentence summary of the main points of the section. Have students work in groups to compare their summaries and agree on one. This can be shared with the class and recorded so it can be used as a review.

Using the Images

- DI Encourage spatial learners to summarize the illustrations throughout the section as a preview to the material.
- Have students read the graphic text represented in the general circulation model (GCM) shown in Figure 9.14. Have them consider the three-dimensional grids and the data that could be collected in each small grid.
- Have students consider Figure 9.14 while working in pairs or groups. They should come up with a verbal or written summary of what exactly is shown with respect to the simple global circulation model. These summaries can be shared with the class for general discussion.
- After reading, gather students in groups and have them look through the photographs and illustrations in the section. Students can come up with a summary of the section based on what is presented in the visuals. Each student can record the group's summary and use it as a study tool later.

Assessment FOR Learning		
Tool	**Evidence of Student Understanding**	**Supporting Learners**
Learning Check questions, page 363	Students explain the importance of monitoring weather, create a flowchart illustrating how radar works, and explain the benefits of using satellites to monitor weather.	Allow students to make models or other manipulatives to show their understanding, particularly of question 4.
Activity 9-3 Pennies from Heaven, page 365	Students follow instructions to simulate a simple system and explain how they would improve the simulation.	Spatial, logical-mathematical and bodily-kinesthetic learners may particularly enjoy this section and may be able to provide support for students who are having difficulty.
Section 9.2 Review questions, page 369	Students identify weather features measured by radar. They explain how fossil fuels affect average global temperature. Students interpret a graph of temperature change over time. Students correctly identify and organize sources of uncertainty in models. Students describe tests used to determine reliability of models and explain why no model can be 100 percent accurate. They explain how inferences about future climate are made, and the importance of analyzing several forcing agents when determining cause and effect.	Refer students to Study Toolkit 4 on pages 565 and 566 of the appendix in the student textbook to help them answer question 3. Allow students to make models or other manipulatives to show their understanding.

Instructional Strategies

- DI Spatial and logical-mathematical learners may particularly enjoy this section. In any group activities, try to ensure that there is at least one of each of these types of learner in every group. You may wish to create study groups and assign different types of learners to work together.
- ELL Simplify the vocabulary whenever possible. If you have already created a word wall with first language translations, continue to add to it. This will reinforce section and chapter-specific vocabulary.

- ELL For English language learners in particular, use a variety of concrete and visual aids to help with this material. Models and manipulatives will be helpful to all students, particularly if they are involved in creating them. For example, use a globe and have students create mini-satellites that can be held in the air to simulate the placement of the different types of satellites. Refer students to Science Skills Toolkit 9 Using Models and Analogies in Science in the appendix of the student textbook.
- Some students may need to read the text aloud in order to capture the information. Provide a space for them that will not distract other students. Alternately, read the headings throughout the section aloud to the class and have them discuss the content.
- This material is excellent for encouraging independent study or for continuing to develop interest centres. Encourage students to explore an aspect of this section based on their own interests.
- Enrichment—Have students research a specific hurricane that has occurred within the last few years. Have them look for information on how satellites helped track the storm from beginning to end, on a day-by-day analysis. Provide students with **BLM G-20 Research Worksheet.**
- Enrichment—Provide students with **BLM 9-6 Earth Observing System.** Students can do independent research about different Earth Observing Missions and find out what types of data are collected for what purpose. Have students share their findings with the class. Provide these students with **BLM A-21 Project Self-Assessment Checklist.** Refer students to Science Skills Toolkit 10 How to Do a Research-Based Project in the appendix of the student textbook.
- **BLM 9-7 General Circulation Models and Regional Circulation Models** will help students consider what climate forecasts and modelling can be used for. Bringing the future climate data to a more local area helps decision makers as they strive to plan for and accommodate to climate change.
- Enrichment—Encourage students to research regional climate modelling online. Provide students with **BLM G-21 Internet Research Tips, BLM G-22 Internet Research Worksheet (A),** and **BLM G-23 Internet Research Worksheet (B).**
- Use **BLM 9–8 Comparing Weather Satellites** to help students consider the technologies involved in collecting climate data.
- Check often for comprehension. Have students engage in discussion or questioning about the topics.

Activity 9-3 Pennies from Heaven (Student textbook pages 365)

Pedagogical Purpose

Students will simulate how computers model climate change using a simple climate system game. Using the rules of the game, they will appreciate how difficult it is to model complex, large systems.

Planning		
Materials	About 200 pennies or other small markers	Large surface
Time	20–30 min	

Background

Weather and climate forecasting is based on detailed analysis and empirical rules. These rules are based on the laws of nature, particularly those of physics, chemistry, and motion. Some critical scientific discoveries include Blaise Pascal's 1642 discovery that air pressure changes with height (air pressure is measured in Pascals), and the work of Isaac Newton, who defined many laws of physics and motion.

Current weather forecasting is based on

- the principles of conservation of momentum, mass, energy, and water in all its phases
- Newtonian equations of motion as they apply to air masses
- the laws of thermodynamics and radiation (for incoming and outgoing solar radiation)
- equations of states for different atmospheric gases.

Factors that stay constant are

- the size and rotation of Earth
- the geography and topography of Earth
- thermodynamic conducting properties and the surface temperature of the oceans.

Activity Notes and Troubleshooting

- Make sure that there is a surface large enough to accommodate the students in each group and their pennies or markers. If there is crowding, the pennies might get mixed up on the grid, skewing results.
- Discuss the rules before beginning the activity. You may wish to post them at the front of the class, as students need to continually refer to them and this will free them from having their textbook in front of them.
- You may wish to time each move so that students do not fall behind or go too fast through the activity. Adjust the time to the speed with which students are able to figure out how to apply the current rule to their grid.
- Have students discuss the questions before they begin the activity. This will give them a point of reference when they need to answer the questions after completing the activity.
- Instruct students to make the decision about how many pennies will be in each stack. There should, however, be a difference in the numbers among the different stacks. This will make each group's grid different.

Additional Support

- ELL Have English language learners speak the instructions back to you to ensure that they understand the rules and how the modelling will take place.
- Some students may wish to explore computerized simulations of weather. Allow them time and access to computers in order to do this in more depth. They could report back to the class on what they discovered about algorithms in simple climate models.
- Check often for comprehension. Have students engage in discussion or questioning about modelling weather and climate to ensure they understand what is being done and why.
- Use Assessment Process Skills Rubric **BLM A-26 Developing Models Rubric** to assess students' answers to the questions.

Answers

1. Students' answers will vary depending on how they originally set up the stacks of pennies in the grids. Have students compare any patterns they saw with patterns from other groups. If everyone follows the rules, there should ultimately be similar patterns among groups.

2. Answers should indicate an understanding of the limits of the data used with the original penny model. A refinement to the model might include putting a form of terrain onto the grid underneath the pennies. For example, blue squares could be used to represent a lake or ocean, where, at every turn, an additional penny could be added. Green squares could represent land areas where the rules are the same as in the original model. Brown squares could represent a desert, where, at every turn, a penny is removed. Students could also suggest introducing a wind that moves one penny from each square on the paper one grid square to the right immediately after the other rules have been enacted. The main idea is not any specific improvement. The main idea is that, once there is a basic model, a new and more accurate simulation can be created by adding complexity and new rules.

Learning Check Answers (Student textbook page 363)

1. Only by tracking weather data over long periods of time can people understand how weather patterns are changing. Weather patterns largely define the climate of a region and determine global averages.
2. Flowcharts should illustrate that a radar instrument transmits microwave pulses, which move through the air until they strike an object. The object then reflects some of the waves back to the radar instrument and communicates information about conditions in the atmosphere.
3. Satellites can allow scientists to constantly monitor conditions at one particular location on Earth or can monitor the conditions on the entire planet several times each day.
4. As their names imply, the *Terra* satellite is dedicated to monitoring changes in heat emission and reflection from the land, whereas *Aqua* is dedicated to studying the cycling of water.

Section 9.2 Review Answers (Student textbook pages 369)

Please also see **BLM 9-9 Section 9.2 Review (Alternative Format).**

1. Radar can locate the amount and motion of water in the atmosphere. For example, it can record the amount of precipitation, types and thicknesses of clouds, and even the wind speeds inside those clouds.
2. The largest predicted change in temperature is 4.5°C degrees. The smallest predicted temperature change is about 2°C. The models may have projected different results based on the types of variables used and the precision of the data entered.
3. Some data have not been collected for very many years, so it is hard to know how those data change over time. Some interactions are not well understood. Feedback loops and effects have not yet been seen or are very hard to predict and program. Important factors, like clouds, that operate on sizes smaller than the grid are not well modeled in all circumstances. There are limits on the amount of data available to input into a model and on how long any model can be run.
4. To test the reliability of computer models, scientists can run tests in which the models 'predict' changes that have already occurred by entering past data and comparing the results to observed events in the "real world." Another way to assess the reliability of a climate model is to compare several different models when they are all given the same test.
5. Burning fossil fuels releases greenhouse gases and aerosols. Greenhouse gases absorb heat, but aerosols in the atmosphere reflect heat, which cools the atmosphere.

6. Although scientists do not completely understand the climate, some of the factors are well understood, and models have shown the approximate size of each contribution. The factors that are understood fairly well are more important in terms of total contribution to heat in the atmosphere than are the factors that scientists do not understand.

7. Computer models are constrained by the data that are input. The future may involve unanticipated variables, such as volcanic eruptions, meteorite impacts, or human activities. Without knowing the choices of future people, even the best model will have some assumptions that may prove to be incorrect.

8. Student answers may vary. Dr. Peltier's work shows that several factors combine to cause a change in climate.