GLACIERS AND FEEDBACK (Part II)

GRADE Grade 8

PART 2 of 3

TOPICS Climate change, glaciers, water cycle, feedback loops, greenhouse effect

CURRICULAR CONNECTIONS

Grade 8 Science

Unit E – Freshwater and Saltwater Systems

2. Investigate and interpret linkages among landforms, water and climate
    - Identify evidence of glacial action, and analyze factors affecting the growth and attrition of glaciers and polar ice caps
4. Analyze human impacts on aquatic systems; and identify the roles of science and technology in addressing related questions, problems and issues
    - Illustrate the role of scientific research in monitoring environments and supporting development of appropriate environmental technologies
    - Provide examples of problems that cannot be solved using scientific and technological knowledge alone

OVERVIEW

Students begin this lesson by learning about the impact that the enhanced greenhouse effect is having on glaciers and how this is expected to change in the future. By studying the retreat of the Athabasca Glacier they will gain a deeper appreciation for the ways in which climate change is having tangible consequences for local landscapes and people. Following this students will connect the immediate impacts of climate change to the knock-on effects that are expected to happen through climate feedback loops.

OBJECTIVES

- Students will understand how rising global temperatures impact glaciers
- Students will explore the possible consequences of glacier retreat for downstream users
- Students will understand how climate feedback loops amplify or diminish the initial drivers of climate

KEY TERMS

- **Climate –** the weather conditions in an area of the earth for a long period of time (generally defined as about 30 years). Weather conditions include temperature, humidity, wind and rainfall
- **Climate feedback loop** – processes that can either amplify or diminish the effects of the initial drivers of climate
- **Enhanced greenhouse effect** – human activities adding to the warming of the atmosphere due to the greenhouse effect
- **Greenhouse gas** – gases in the atmosphere that trap energy from the sun. These include water vapour, carbon dioxide and methane

GUIDING QUESTIONS

- How is climate change impacting glaciers?
- How are the effects of climate change made worse by climate feedback loops?

BACKGROUND ESSAY

Mountain ecosystems are among some of the environments most hard hit by rising average surface temperatures on Earth. These rising temperatures are the result of the **enhanced greenhouse effect**, which refers to greenhouse gas producing human activities that are adding to the warming of the atmosphere due to the greenhouse effect. While heat-trapping **greenhouse gases** like carbon dioxide are necessary to sustain life on Earth, the concentration of carbon dioxide in the atmosphere has increased by 30% since the industrial revolution in the mid-eighteenth century. This has led to changes in the earth's **climate**, including temperature rises and altered rainfall patterns.

The impact of global warming on glaciers is twofold. Remember that glaciers are formed when more snow falls in the winter than melts in the summer. Warmer temperatures in the summer are expected to increase the amount of melting and indeed have already been doing so for decades. At the same time, more precipitation is expected to fall as rain rather than snow in the winter. This means that less snow is accumulating on glaciers over time to replace the ice that has been lost to melting. The combined impact is unprecedented rates of glacial retreat that are being observed around the world.

When glaciers shrink, they release water that was previously being stored within the glacier. Eventually, as the glacier shrinks further, it no longer acts as a reservoir of water resources. This could lead to more severe droughts during dry years and increased risk of forest fires. What could shrinking glaciers mean for people who rely on them for drinking water, irrigation, hydropower or recreation?

Researchers studying glaciers take core samples which provide year-by-year information about past climate and allow them to make predictions about how climate may change in the future. Photographer James Balog has described glacier ice as the canary in the coal mine, where we can hear, see, feel and measure climate change as it occurs. Alpine glaciers are simultaneously our record of climate change and a visualization of the consequences of human activities.

DURATION 30 minutes

MATERIALS

- Overhead transparency grid
- Athabasca Glacier images
- Dry erase marker
- Cloth/paper towel
- Measuring Glacial Retreat Student Activity Sheet

ACTIVITY – MEASURING GLACIAL RETREAT

The Athabasca Glacier is one of the most visited glaciers in North America. Every year, thousands of tourists climb aboard snow-coaches that drive onto the glacier. Glacier monitoring provides researchers with valuable information about the effects of global and regional climate change. Students will measure the extent to which the Athabasca Glacier has retreated and estimate the rate of change.

1. Divide the class into groups based on the number of sets of glacier images and overhead transparency grids that you have available.

2. Place a transparency grid over the image of the Athabasca Glacier from 1870 and tape the corners of the transparency down.

3. With one person holding the image in place, trace the outline of the glacier onto the transparency grid. Remove the transparency grid and count the number of squares contained within the outline.

4. Working from the upper left to the upper right across each row, put a dot in each square that you have counted. *Discuss with*

students how they will count squares that are only partially covered by adding multiple squares together.

5. Erase the dots and outline from the transparency grid and repeat steps 2 to 4 for the image of the glacier from 2019.

6. Use the information that you have collected to calculate the percentage change in glacier cover and the rate of change from 1870 to 2019.

7. Collect all of the students' results and write them on the board. Use these to calculate class averages. Based on the rate of change and the remaining ice, ask students to calculate how many years it will take for the Athabasca Glacier to melt entirely (*assuming a constant rate of change*).

8. Lead a discussion about the students' results. Did your results differ from the class average? How could you improve the accuracy of your map? Is this an accurate method for determining glacier cover?

9. In this activity, students are only asked to consider the surface area of the glacier. Ask students to think about the volume of the glacier. Depth of the glacier is arguably a more important variable to consider than surface area. How could we measure the depth of a glacier? Students can research some of the different ways that glaciologists are studying glaciers.

10. *Extension: Have students visually investigate how other glaciers in their area have changed over time. The Mountain Legacy Project Explorer (explore.mountainlegacy.ca) contrasts historical photos against modern day photos. Use the satellite view in the Google base map to identify which photos might show glaciers. How might the season or year that the photo was taken impact your observations? Have any glaciers disappeared entirely?*

In the past 125 years, the Athabasca Glacier has lost half of its volume and retreated more than 1.5 kilometres.

This activity has been adapted from "Glacial Retreat: Quantifying Changes in Glacier Cover over Time" from the NASA Landsat Education Team. View the original lesson plan at mynasadata.larc.nasa.gov/sites/default/files/2018-06/Day%207_Glacial%20Retreat.pdf.

BACKGROUND ESSAY

The earth's climate is a complex, interconnected system that exists in a delicate balance. It is comprised of many moving parts that respond to one another. The earth's climate is regulated by something called **climate feedback loops**. In these loops, a change in X will lead to a change in Y. The change in Y will lead back to a change in X. Another way of thinking about feedback is as a cause-and-effect loop that make the impact of key climate factors stronger or weaker, starting chain reactions that repeat again and again. What this means is our basic understanding of how the enhanced greenhouse effect is affecting glaciers becomes a whole lot more complicated.

There are both negative and positive feedback loops. A positive feedback loop will amplify the impact of the original change, potentially leading to large-scale, lasting system changes. Positive climate feedback loops can create vicious cycles that lead to accelerated or runaway rates of warming. The melting of glaciers is an example of a positive feedback loop. When ice melts, open water or land is left in its place. Both land and water are less reflective than ice, so they absorb solar radiation which in turn increases surface temperatures even more. This leads to additional melting and the cycle repeats itself.

Negative feedback loops on the other hand maintain balance within a system. Some of the best understood negative feedback loops are predator-prey relationships. For example when snowshoe hare populations increase, there is more food for lynx whose populations subsequently also increase. With increased predation from lynx, hare populations will decline thus leading to a decline in lynx populations, and so on.

A negative feedback loop with respect to climate change would be an impact that reverses the increased concentrations of CO_2 in the atmosphere that are a main driver of climate change. For example, it is possible that warming will allow trees to grow at higher latitudes where it has previously been too cold for them to survive. The growth of new trees captures CO_2, removing it from the atmosphere and potentially mitigating the greenhouse effect. Positive climate feedback loops are a big concern that could lead to a tipping point, whereas negative feedback loops are not expected to alter our current climate change trajectory.

DURATION 30+ minutes

MATERIALS

- Internet access
- Chart paper
- Markers

ACTIVITY – COMPLETING THE LOOP

Students will brainstorm and visualize the feedback loops that are predicted to ensue from different climate change effects by creating systems diagrams. This can be a very challenging activity for some students and it may be beneficial to work through one or several examples as a class to demonstrate how to approach the activity.

1. Assign the following climate feedback mechanisms to individual or groups of students and ask them to predict how they will increase (positive feedback) or decrease (negative feedback) the effects of climate change and/or global warming. As they work through their feedback mechanism, ask the students to consider how the predicted changes could ultimately effect glaciers.

Explain to students that there are many possible outcomes for the same mechanism.

- Increased forest fire activity
- Melting glaciers
- Permafrost melting
- Melting sea ice
- Forest loss
- Increased productivity in forests
- Increased storm activity
- Increased evaporation

2. Ask students to start by brainstorming the consequences of their assigned feedback mechanism. For example, forest fires produce smoke and ash, release carbon dioxide and change the species composition of the forest. Which – if any – of the consequences could contribute to further climate change? Which consequences are not expected to intensify climate change?

3. Encourage students to create as many steps in their feedback loops as possible. They may find that there are multiple loops that spin-off from the original mechanism. Ultimately they should aim to arrive back at a change in temperature and/or greenhouse gases with at least one of these loops. *Students may need to do additional online research into their feedback mechanism to understand how it will ultimately intensify climate change.*

4. Create a systems diagram, using boxes and arrows to show cause and effect within the system. Refer to Figure 1 for an example of a systems diagram describing climate feedback loops.

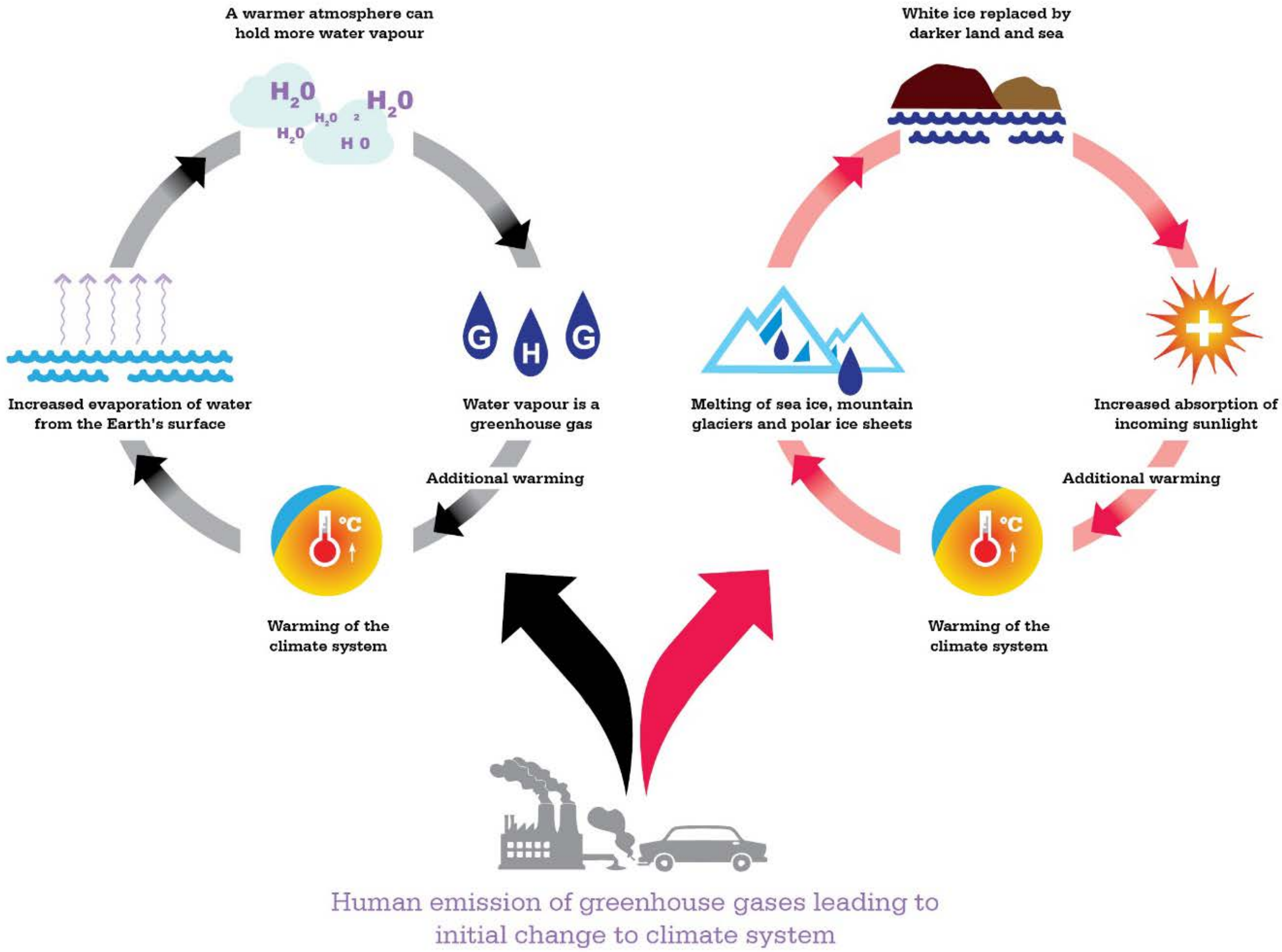
5. *Extension: SageModeler (www.sagemodeler.concord.org) is a free, web-based modeling software. It is a useful tool for getting students to think about systems and feedback loops. Students can start by browsing examples, then research and create their own climate change feedback loops.*

REFERENCES

Climate Reality Project. (2020, January 07). *How feedback loops are making the climate crisis worse.* Accessed 31 March 2020. climaterealityproject.org/blog/how-feedback-loops-are-making-climate-crisis-worse

National Snow & Ice Data Center. (2020). *All About Glaciers.* Accessed 28 March 2020. nsidc.org/cryosphere/glaciers.

Figure 1: Examples of climate change induced positive feedback loops (*Source: Climate Council, 2020*)



MEASURING GLACIAL RETREAT STUDENT ACTIVITY SHEET

PART 1: Results

What is the glacier cover of the Athabasca glacier in 1870? = _______ grid squares (a)

What is the glacier cover of the Athabasca glacier in 2019? = _______ grid squares (b)

What is the difference in glacier cover from 1870 – 2019? = a – b = _______ grid squares (c)

PART 2: Calculating the percentage cover change in the Athabasca Glacier

You can calculate the cover change of the Athabasca Glacier as a percent (x) of the original size (a). This can represented mathematically as $^{x}/_{100}$. The formula for this is:

$$\frac{x}{100} = \frac{c}{a}$$

Plug in your values for (a) and (c) and solve for (x) below (show your work):

PART 3: Calculating the rate of change in glacier cover

Number of years from 1870 – 2019 = _________ years

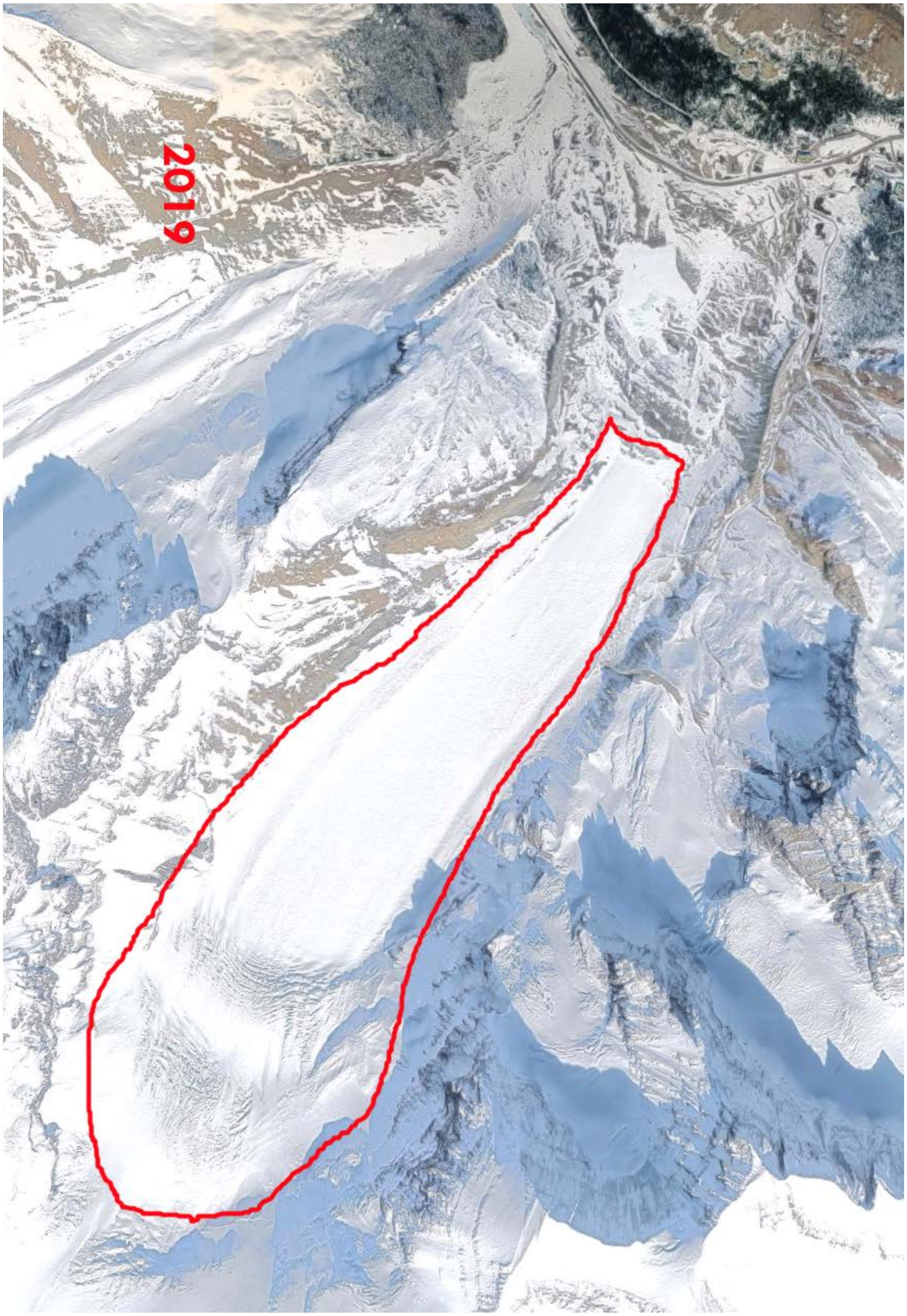
Rate of change = $\frac{\text{change in glacier cover (grid squares)}}{\text{\# of years}} = \frac{c}{\text{\# of years}}$ = __________ grid squares/year

PART 4: Estimating time before Athabasca Glacier disappearance

By multiplying the rate of change that you calculated in Part 3 by the current glacier cover (b), we can estimate how much longer it will be before the Athabasca Glacier disappears

Rate of change _______ (grid squares/year) × 2019 glacier cover _______ (grid squares) = ____________ years

ATHABASCA GLACIER (2019)



ATHABASCA GLACIER (1870)