Science Unit: *Climate Change*
Lesson 7: *Glacier Dynamics*

School year:	2008/2009
Developed for:	Shaughnessy Elementary School, Vancouver School District
Developed by:	Tom-Pierre Frappé(scientist), Carol Church and Sharlene Steele (teachers)
Grade level:	Presented to grades 5 - 7; appropriate for grades 4 to 7 with age appropriate modifications.
Duration of lesson:	1 hour and 10 minutes
Notes:	Based on a lab by Leigh A. Stearns , Climate Change Institute / University of Maine

Objectives

1. Explore the factors affecting the flow of glacier using an analogous model
2. Explain how changes in glacier flow can affect the mass balance of glacier
3. Formulate a hypothesis, test for different factors, and analyze data.
4. Calculate a velocity from measurements of distance and time.

Background Information

This activity illustrates the factors affecting glacier mass balance in a changing climate. Glaciers and icesheets are a wildcard in our current understanding of climate. Because we don't fully understand how they flow, we cannot predict how they will respond to a warming climate. We understand how a rise in temperature increases melting at the surface. That is relatively simple. The part that is more complex is the effect of increased melting on the glacier flow. As a glacier flows, ice is moved to a lower elevation. Because temperature decreases with altitude (it is colder up the mountain), when ice flows down it also starts melting faster. If an environmental change causes the glacier to flow faster, more ice will be moved to the melt-region, and the glacier will melt faster. Thus, glacier dynamics, or how the glacier flows, has an important impact on how fast glaciers melt. In this activity, the students will make a glacier using "flubber," a silly-putty-like goo made from glue, water and detergent. They will construct a glacier valley using plastic tubes. They will then investigate the effect of valley slope, "flubber" temperature, and basal conditions on the glacier flow velocity. We will then compare these glacier models to the dynamics of real glaciers and discuss how and why they might be changing over time.

Vocabulary

<u>Glacier Mass Balance:</u>	The net gain or loss of mass a glacier experiences each year. A glacier that is loosing mass has a negative mass balance.
<u>Accumulation area</u>	Part of the glacier located above the equilibrium line. This is the part of the glacier where ice is formed by accumulation of snow. Snow accumulated in the winter does not completely melt in the summer because this part is at higher elevation, and therefore colder. Each year, more snow accumulates, and eventually is compressed under its own weight to form ice.
<u>Ablation area</u>	Part of the glacier below the equilibrium line, at lower (warmer) altitude. In the

ablation area, there is more melt in the summer than accumulation in the winter. Therefore, each year there is net mass loss. If the glacier wasn't flowing, the ablation area would disappear.

Equilibrium line — Elevation at which the summer melt is equal to the winter accumulation. There is no mass loss or gain at that elevation.

Ice flows from the accumulation area to the ablation area.

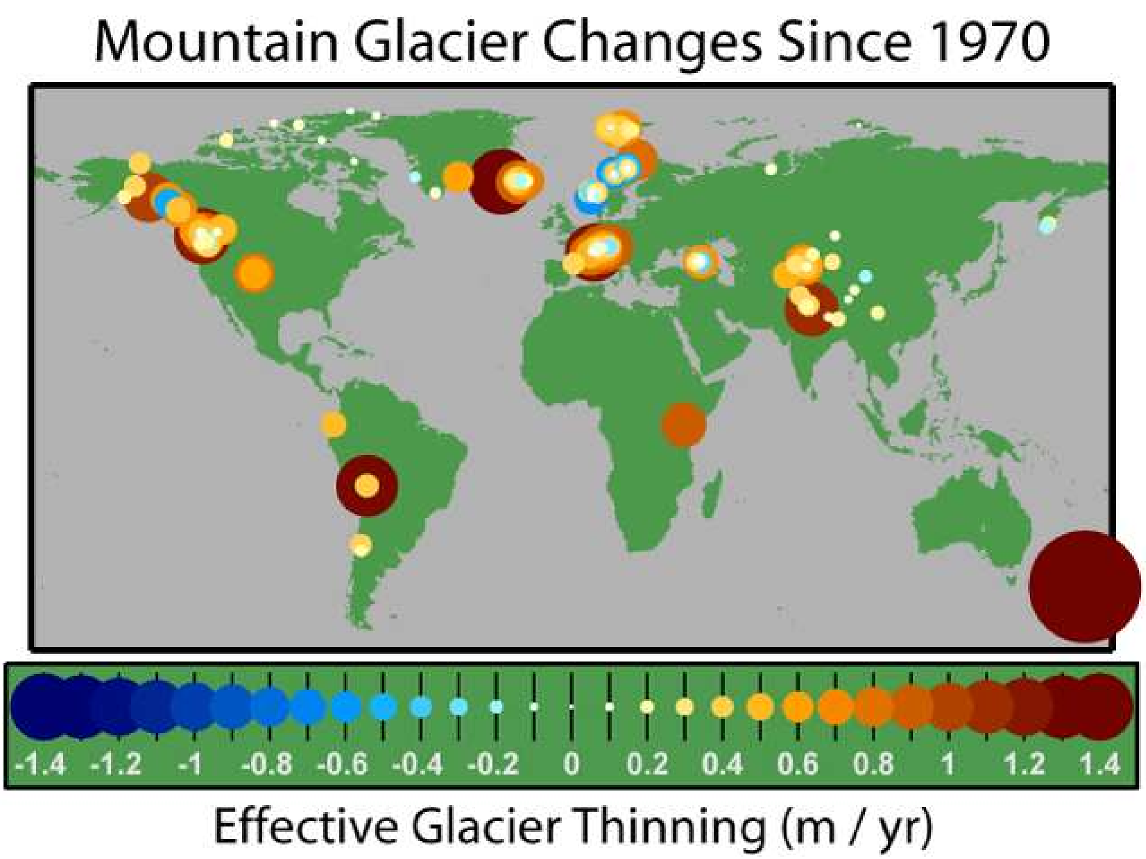
Materials

- Borax
- Elmer's white glue
- ABS or PVC plastic tubes, 3" diameter, cut in length of ~1.5' and cut in half lengthwise
- Tin foil
- Vegetable oil
- Stopwatches
- tape
- toothpicks
- Food coloring
- Sand paper
- rulers

In the Classroom

Introductory Discussion

We talk a lot about how the glaciers all over the world are thinning because of global warming. But I it true? This map[2] shows the average yearly thinning of glaciers all over the world, in meters per year:



- What do you notice? Are there some glaciers that are growing? Are there glaciers that are shrinking? [Some are growing, increase temperature leads to increase snow fall in some area, thus contributing to growth of glaciers. However, generally, they are melting because of the higher temperature.] Where are glaciers located? … Only at the poles? [No: everywhere where there are high mountains]

The link between the climate and the response of glaciers is both very simple and very complicated. In first approximation, the response is intuitive: if you increase the temperature of the Earth, glaciers are going to melt faster. This response is slow; slow changes in temperature create slow changes in glacier mass balance. However, things can be accelerated greatly because glaciers are dynamic, that is to say, the speed at which they flow can change. Have you been in the mountains? Have you notice how much colder it is up there? The temperature of the atmosphere decreases as we move higher. This is important because when ice moves down a glacier, it moves from a high altitude, which is cold, to a lower altitude, which is warmer. Therefore, if something increases the speed at which a glacier flows, it will also increase the speed at which it melts. It also increases the area of the glacier. This makes it melt faster, but also it means that the glacier reflects more light in space (remember, ice has a high albedo). When very big glaciers, called icesheets, change their flow regime, it can affect the energy balance of the entire planet. This is one of the mechanism that explains the ice ages.

Safety guidelines:

- Don't eat the flubber!

Experiment

Experiment Title: Flubber Glaciers

Purpose of Experiment: to determine which of the following parameters – slope, 'ice' temperature, or basal conditions – affects the glacier speed the most.

- slope:
    - shallow: 25 degree
    - medium : 45 degree
    - steep: 65 degree (don't go much beyond, or your flubber will roll instead of flowing!)
- Temperature
    - Cold: flubber put in freezer overnight
    - Medium: room temperature
    - Warm: flubber microwaved until warm to touch
- Base roughness
    - Lubricated: put some oil on a piece of tinfoil taped on ABS tubing.
    - Normal: ABS tube directly
    - Rough: sandpaper taped to the tube.

Prediction or Hypothesis: (For each factor) When I increase the slope/temperature/bed roughness I expect the glacier to flow more quickly/slowly. I think the most important of these three factors will be: __________.

Methods and Instructions:

Set-up prior to experiment:

Cut 3” diameter ABS or PVC tubing in lengths of ~1.5’, and cut these in half lengthwise. This will be the valley.

Make the flubber. This can be done in class with the students (more time and supervision required, but fun!) or ahead of time.

Mix #1	Mix #2
1.5 cup of warm water	4 tsp of Borax (20 ml)
2 cup of white glue	1 cup of warm water
food coloring (optional)	

Procedure:
Stir the mixtures separately until both are well mixed. Pour mix #1 into mix #2 and a big glob of flubber will form. Work it for 2-3 minutes and drain any excess water. You can store it in ziplock bags for a few months; just rework the liquid back in each time. This recipe makes about 3 glaciers.

Make 3 batches, and color one blue, one red, and leave one white (these will indicate flubber temperature, see below).

Brief description of how students will work in groups or pairs.

1. Each team is given a worksheet, a “valley,” sand paper, tinfoil, vegetable oil, and 3 portions of flubber at different temperature (blue is cold: flubber put in freezer overnight, white is room temperature, red is warm: microwaved until warm to touch).
2. If all these factors are to be investigated in a 1:30 hr period, the work must be divided. I found it best to have students in tables of 4, with 2 valleys and 2 glaciers at each table. Then each table investigates one factor (slope, basal conditions, ice temperature), and all tables report to the rest of the class at the end of the activity.
3. Using a ruler and a watch, they measure the distance the flubber travelled, and the time. From that, they will calculate the glacier average speed.

Closure Discussion

1. Return on experiment. How did each factor affect the flow of the glacier?

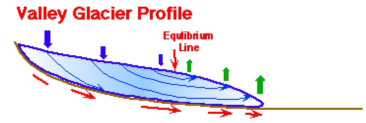
   [warm flubber should flow the fastest, and cold flubber flow the slowest (regardless of the basal conditions). Flubber flows faster over the ‘wet’ bed than the ‘rough’ one. flubber flowed faster over steep slopes,
2. Which factor was the most important? Any surprises?
3. How realistic is this? What differences exist with a real glacier? [glaciers don’t flow as fast. They are much more viscous. The temperature of a glacier doesn’t vary as much as what we have here, and the temperature effect isn’t that dramatic in reality. It exist, but it is much less important than the roughness of the bed. In reality, ice is constantly formed from snow accumulation at the top of a glacier, and melts at the bottom. That way, the glacier can flow constantly, without it’s shape

changing. This forms a dynamic equilibrium; there is movement, but it is balanced.Here, we have a finite quantity of “ice” that flows downstream, without melting. It is not in equilibrium.]

4. How does that relate back to climate change? Which of these factors may change with global warming? [Ice temperature won’t change much. However, basal friction can change a lot if there is more meltwater that comes from the surface because of increased melting. The meltwater acts a little bit like the oil in the experiement, lubricating the surface of the glacier bed.]

References

1. <http://nagt.org/nagt/programs/teachingmaterials/11337.html>, Modeling Glacier Dynamics with Flubber, Leigh A. Stearns , Climate Change Institute / University of Maine. Retrieved 26 May 2008.
2. From: Dyurgerov, Mark B. and Mark F. Meier (2005). "Glaciers and the Changing Earth System: A 2004 Snapshot". *Institute of Arctic and Alpine Research, Occasional Paper 58*. Figure is under creative commons license; http://en.wikipedia.org/wiki/Image:Glacier_Mass_Balance_Map.png.



Glacier flow… flubber experiments!!!

worksheet

<u>Objective</u>: to determine which of the following parameters – slope, 'ice' temperature, or basal conditions – affects the glacier speed the most.

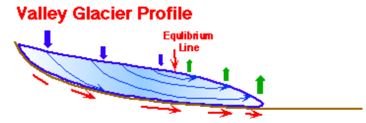
<u>Hypothesis:</u>

<u>Experiment:</u>

Design an experiment to test what influences glacier speed. You should test different temperatures of ice (flubber), different slopes and basal conditions. To determine the velocity, make sure you measure (with a ruler) how far the flubber moves in a given amount of time.

- For at least one of your experiments, push toothpicks (vertically) into the surface of the flubber. **<u>Draw</u>** how they move / change direction during the experiment. What do you think this means about how the flubber is flowing?

Flubber drawing



Velocity Table:

	Blue (cold)	***White (normal)***	***Red (warm)***
Sandpaper PVC	Dist: Time: Velocity:	Dist: Time: Velocity:	Dist: Time: Velocity:
Normal PVC	Dist: Time: Velocity:	Dist: Time: Velocity:	Dist: Time: Velocity:
Lubricated PVC	Dist: Time: Velocity:	Dist: Time: Velocity:	Dist: Time: Velocity:

	Blue (cold)	***White (normal)***	***Red (warm)***
Slope - shallow	Dist: Time: Velocity:	Dist: Time: Velocity:	Dist: Time: Velocity:
Slope - steep	Dist: Time: Velocity:	Dist: Time: Velocity:	Dist: Time: Velocity:

Conclusions: