The Melting of the Grinnell Glacier, Glacier National Park

Questions

Why do glaciers melt? What is the area of the current Grinnell Glacier? How much of the glacier has been "lost" over time? What is the current loss or recession of the glacier? Can this rate of change be correlated to changing atmospheric temperatures in the region? What data exist on the Grinnell Glacier?

Overview

In 2003 an international teacher workshop was hosted by the Wright Center (www.tufts.edu/as/wright_center) and the Crown of the Continent Learning Center (http://www.nps.gov/glac/learningcenter/learningcenter.htm) at Glacier National Park with the purpose of introducing teachers to the concept of using glaciers to understand environmental change. During this workshop teachers were instructed on new curricular materials and hiked to the Grinnell Glacier to see investigate the amount of recession that the glacier has had in the last 100+ years. This activity is one of the products of that workshop. Other materials and information can be viewed at the workshop website (www.tufts.edu/as/wright_center/iecws).

A few glaciers around the world are increasing in size but most glaciers are melting at incredible rates. Many of the world's glaciers are monitored by a number of organizations including the World Glacier Monitoring Service (http://www.geo.unizh.ch/wgms/) and the National Snow and Ice Data Center (http://nsidc.org/data/g01130.html). To monitor glaciers a number of techniques are employed including photography, aerial photography, remote sensing, and on-glacier surveying. For the Grinnell Glacier in Glacier National park, Montana, USA the use photography and common surveying technigues were employed for over 100 years to record the recession of the Grinnell Glacier.

The following is from a paper by the park geologist Dr. Dan Fagre on the importance of measuring glaciers in the Glacier National Park .

DESCRIPTION OF GLACIERS AND IMPORTANCE FOR STUDY

Glacier National Park has approximately 50 small glaciers. Some of these glaciers are relatively well known, having attracted the scientific attention of the first park advocates in 1887. Only 37 named glaciers existed in 1968 which met USGS criteria as perennial snow-ice masses larger than 0.1 km2. Ground measurements of glacier margins and termini were made sporadically on several glaciers by the National Park Service, U.S. Geological Survey, and several universities but ended by 1979. No comprehensive park-wide glacier monitoring program was ever established but excellent summaries by Johnson (1980) and Carrara (1989) focused on available data for the most-studied glaciers. The glaciers have receded since they were first described in 1901, and tree-ring

studies indicate that glacial retreat began about 1850. At that time there were more than 150 glaciers within Glacier National Park.

These glaciers are direct remnants from a period of glacier formation ending about 11,000 years ago. The largest of these range in size from Jackson Glacier (1.02 km2) and Blackfoot Glacier (1.74 km2) to Gem Glacier (6 ha). Because of their relatively low elevations (1695 - 3008 m) for glaciers in the northern Rockies and their inland geographic location, these small glaciers are highly sensitive to global climate change. The glaciers can provide an integrated signal of consistent shifts in regional weather patterns. These glaciers also constitute an important link in studying region-wide glacier dynamics because they are on a north-south gradient along the continental divide extending from Canada to Colorado. Additionally, glaciers are of inherent interest to park visitors because of the role glaciers played in shaping the landscape of present-day Glacier National Park.

Glacial fluctuations in Glacier National Park have been studied, with published reports dating back to 1914 and as recently as 1989 with USGS Bulletin 1902, by Paul Carrara, which summarized most of the glacial history for the park. From these studies, the glaciers of Glacier National Park appear to be excellent barometers of climate change. For instance, there was a drastic rate of glacial retreat during the period from 1920-1940 when this region had above average summer temperatures and below average annual precipitation. From 1960-1979, several of the larger glaciers advanced very slightly during a period of greater precipitation and lower temperatures. Thus, long-term reductions in glacier size reflect long-term increases in average temperature and/or reductions in winter snow.

The National Park Service made measurements of glaciers at various times during the 1930-1940 period and independent research scientists, USGS scientists, and others have made similar measurements in the course of carrying out a large body of related research during the 1970s. Given the significant historical research activity and relatively large information base on glaciers for the Glacier National Park region, the potential exists for a glacier monitoring program here to contribute to broader documentation of climate change.

ACCOMPLISHMENTS

During the past several years our major effort has been to draw together all existing information on all glaciers at Glacier National Park in a coherent manner, adding measurements of glacial extent for the period 1979 to present. Most past efforts have focused on only one or a few well-studied glaciers. We have found and incorporated previously unused information into a more extensive picture of glacier activity at Glacier National Park.

The area of each glacier was mapped in a standard spatial framework and digitized within a geographic information system to create a time series for interpretation and analysis. General shrinkage has occurred for every glacier for which we have

measurements but rates of change varied. The larger glaciers are now approximately 1/3 their size in 1850 (range - 23-38%) and numerous smaller glaciers have disappeared. There has been a 73% reduction in the area of Glacier National Park covered by glaciers from 1850-1993. Only 27 km2 of glaciers remain from the 99 km2 which previously existed. Out of 84 watersheds, only 18 have 1% glacier cover, 8 have 2% and 4 have 3%. Average glacier area in the accumulation zone for September 1993 was 35%, indicating negative mass balances for most glaciers and continued shrinkage.

A correlation between rates of glacial retreat and local climate is demonstrated with climate reports dating back to 1900. An increase of approximately 1o C in average summer temperatures is reflected in reduced glacier sizes. A computer model indicates that present rates of increasing warming will eliminate all glaciers in Glacier National Park by 2030 (Hall 1994). Even with no additional warming over that which has already occurred in the Glacier Park area, the glaciers are likely to be gone by 2100.

Grade Level
5^{th} – 8^{th}

Objectives
In this activity students will:

1. Estimate and graph the rate of recession of the Grinnell Glacier.
2. Understand how data on glaciers is collected.
3. Understand how glaciers are indicators of climate change.

National Standards
Content Standard B: Physical Science
Properties and changes of properties in matter

Maine Standards Learning results
Math – Measurements
Demonstrate understanding of length, area, volume and corresponding units, square unit and cubic units.

Science – Earth
Describe factors that can cause short-term and long-term changes to Earth

Inquiry and Problem Solving
Verify and evaluate scientific investigations and use the results in a purposeful way

Teacher Preparation
Students should be familiar with the terms length, area, and volume and metric units of measure.

Materials (assume student groups of 2)

1. Graph paper- print on a transparency (from download)
2. Grinnell Glacier map.
3. Temperature data.
4. Colored markers.

Time Frame

1-2 (45 minute) class period

TEACHING SEQUENCE

Engagement and Explanation

1. Print copies of the Grinnell Glacier map on plain paper and copies of the graph on a transparency. One copy of each for each pair of students.
2. Place the transparency graph over the map.
3. Use colored markers to color in the area (boxes) on the transparency graph for each recessional change. Use the area between the 1850-1887, 1887 – 1911, 1911- 1937, 1937-1966, 1966-1993.
4. Count the number of boxes for of each color, each box represents 0.1 kilometer, or 10 squares = 1 kilometer. Students should estimate partial filled boxes.
5. Use temperature data to compare to the area of the glacier's recession for each sets of years indicated on the recession map.
6. Teachers should encourage discussion about the "trend line" in the temperature graph which represents the overall changing climate trend as opposed to the great variability in the year to year data.

Figure 1: Local Temperature
http://www.tufts.edu/as/wright_center/iecws/dlese.html

Figure 2: Grinnell Glacier Recession map
http://www.tufts.edu/as/wright_center/iecws/dlese.html

Figure 3: Aerial photograph of the Grinnell Glacier
http://www.tufts.edu/as/wright_center/iecws/dlese.html

Figure 4: Graph paper
http://www.tufts.edu/as/wright_center/iecws/dlese.html
Graph paper (to be printed on a transparency)

Elaboration

Students can try and do similar investigations on other glaciers. They can also do additional research on the overall change in glaciers around the world as determined by the *World Glacier Monitoring Service* and other similar scientific groups.

Students can also use the aerial image of the Grinnell Glacier to try and determine the position of the margin of the glacier. Using aerial images to determine the margin of

glaciers is very challenging because in summer the glacier collects a lot of dirt and debris and appears “dirty”, similar to the surrounding rock. In winter the glacier and the surrounding area are all white and make it extremely difficult to determine glacier boundaries.

Exchange

Students should compare their results with each other and discuss what occurred.

Evaluation-questions

1. Is there any correlation between the recession of the Grinnell Glacier and temperature change over the same time period?
2. How well can you estimate change in glacial area?
4. What additional data would be needed to calculate volume change of the glacier?
5. Why are receding glaciers of concern to scientists?
6. Explain why it would be important to do a similar investigation on other glaciers around the world?
7. What is a "trend line" in the temperature graph and how does represent the overall changing climate trend as opposed to the great variability in the year to year data?
8. In this activity, and most uses of temperature/climate data, why is use of the trend line fundamental to understanding the changing climate?
9. How does the variability compare to the trend line?

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Resources.

1. http://www.nrmsc.usgs.gov/research/glacier_retreat.htm

2. http://www.nrmsc.usgs.gov/staff/fagre.html

3. http://www.nrmsc.usgs.gov/research/glaciers.htm

4. http://www.nrmsc.usgs.gov/research/glaciers.htm

Glossary

Trend line- n : a line on a graph indicating a statistical trend

Glacier- A huge mass of ice slowly flowing over a land mass, formed from compacted snow in an area where snow accumulation exceeds melting and sublimation.