POLAR TREC

TEACHERS AND RESEARCHERS EXPLORING AND COLLABORATING

The Effect of Postglacial Rebound on Melt Estimates for the Greenland Ice Sheet

Overview

This lesson was created by 2017 PolarTREC teacher Steve Kirsche who took part in the Dynamic Observations of the Microstructural Evolution of Firn expedition. The lesson is intended to introduce students to the concepts of isostasy and postglacial rebound through a demonstration and related instruction. Students will then see how postglacial rebound is an important factor when assessing the extent of the ice melt on the Greenland ice sheet.

Objectives

At the completion of this lesson:

- Students will gain a greater understanding isostasy and postglacial rebound.
- Students will be able to see how complex systems in nature require analyzing a wide range of factors.

Lesson Preparation

Prior to the lesson

- Students should understand the layers of the Earth (crust, mantle, outer core, and inner core) as well as the layers of the mantle (lithosphere, asthenosphere, and mesosphere).
- Students should have a general knowledge of Greenland including the fact that most of it is covered with an ice sheet.
- The teacher will need to create the model used as a demonstration in the lesson.

Creating the model

- A clear glass container such as a glass baking pan or a small aquarium will be needed. This should be filled

Details

Lesson
Arctic
About 1 period
Download, Share, and Remix
High school and Up

Materials

Glass container with water (blue food coloring is optional)
Piece of 2 x 4 board to represent Greenland
Piece if 1 x 4 board to represent Greenland ice sheet
Copies of *ScienceDaily* news release

Standards

Florida Standards

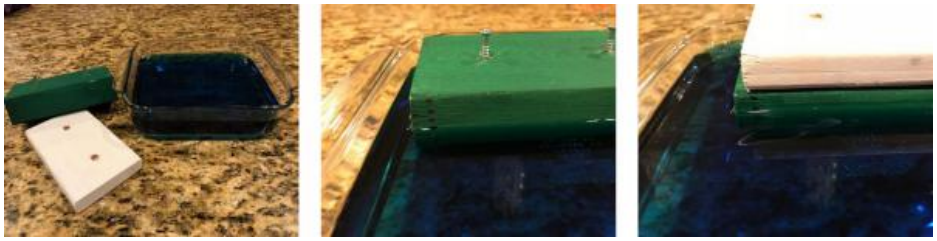
SC.912.E.6.1 - Describe and differentiate the layers of Earth and the interactions among them.
SC.912.E.6.2 - Connect surface features to surface processes that are responsible for their

about ¾ full with water. It is a good idea to add a few drops of blue food coloring to the water to make it more visible.
- A piece of a 2 x 4 board will be used to model the continental crust (Greenland). If you mark each centimeter on the side of the board, it will be easier to measure how much remains above the water.
- A piece of 1 x 4 board will be used to model the ice sheet. It can be left natural or painted white. The white will help students better see it as the ice sheet when it is placed on top of the 2 x 4.

formation.
SC.912.N.3.5 - Describe the function of models in science, and identify the wide range of models used in science.

National Standards

HS-ESS2-2. Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.
HS-ESS2-5. Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.



Materials and modeling of Greenland, the ice sheet and water.

Teaching the Lesson

- The teacher will review the prerequisite knowledge.
- The demonstration will be completed.
- Students will read/analyze the *ScienceDaily* release to see how postglacial rebound is important when estimating ice melt.
- Students will write a brief explanation of how the demonstration models the effect of postglacial rebound and its effect on estimating ice melt in Greenland.

Procedure

1. Begin by reviewing the layers of the Earth (crust, mantle, outer core, and inner core) and the layers of the mantle (lithosphere, asthenosphere, and mesosphere). It is important to emphasize the concept that the lithosphere "floats" on the asthenosphere, allowing for tectonic plate movement.
2. Conduct the demonstration.

- Show the students the clear container with the water in it and explain that this represents the asthenosphere.

- Take the piece of 2 x 4 board and explain that this represents the lithosphere. Ask what they expect to happen if the board is place in the water. Lead a discussion with the students to remind them that the lithosphere consists of the upper mantle and the crust and that it "floats" on top of the asthenosphere.
- Place the board in the water and let students see how it floats, but part of it sinks down into the water. Explain the concept of isostasy where pieces of the lithosphere, such as Greenland, push down into the asthenosphere a bit. You can use the example of a piece of memory foam to illustrate this. If you lay on a memory foam mattress you sink down in a bit. Measure how much of the board is above the water.
- Place the piece of 1 x 4 on top of the piece of 2 x 4 to model an ice sheet on top of the land. Students should note that the combined weight of the two boards causes the board to sink a bit more into the water. Explain that the ice sheet on top of Greenland causes it to sink down even more in the asthenosphere. Measure the amount of the board that is above the water.
- In the attached photos, the board with the attached ice sheet had 2.7 cm above the water. When the 1.8 cm board was removed, there was only 1.6 cm above the water line. Your measurements should be similar (or you can use the attached photos). Lead a discussion of how the "elevation" above the water changed by 1.1 cm when there was a loss of 1.8 cm of ice. In Greenland, a similar phenomenon is occurring and it is called postglacial rebound. It means that just looking at the change in elevation due to ice melt is not telling the whole story – there is actually more melting going on than what is measured this way.

  3. Provide students with a copy of the *ScienceDaily* news release (https://www.sciencedaily.com/releases/2016/09/160923123732.htm). They should read through this article, highlighting or underlining the important points. After the students have read it, discuss as a group how postglacial rebound can affect the accuracy of the measured ice loss on the Greenland ice sheet. Please note that, for Greenland, the postglacial rebound is slower than the ice melt. So, although it affects the accuracy of the ice melt readings, it could be worse.

  4. Conclude the lesson by having the students write 2-3 paragraphs to respond to the following writing prompt:
- Explain what postglacial rebound is and why it is happening as the Greenland ice sheet has shrunk.
- Explain how the demonstration we did in class models this phenomenon.
- What are the limitations of this as a model?

Extension

- The demonstration can be easily modified to make it into a lab/activity that the students can do themselves.
- For some students, the *ScienceDaily* release will provide enough information to understand the concepts being taught. For other students, they should use the full University of Buffalo paper (http://advances.sciencemag.org/content/2/9/e1600931.full).
- A component on the densities of ice and continental crust can be added. A small piece of granite can be used. Students can determine the volume using displacement in a graduated

cylinder and determine the mass using a triple beam balance. This can be compared to the average density of ice which is approximately .92 g/cm3. Using this information students can hypothesize the relative postglacial rebound compared to the thickness of ice loss.

Resources

- Site for the expedition to Summit Station (can also be reached at: polartrec2017.com): https://www.polartrec.com/expeditions/dynamic-observations-of-the-micros...
- *ScienceDaily* release which provides an overview of a 2016 University of Buffalo paper which helps examine the effect of postglacial rebound on ice melt estimates for the Greenland ice sheet: https://www.sciencedaily.com/releases/2016/09/160923123732.htm
- Full text of the University of Buffalo paper: “Geodetic measurements reveal similarities between post–Last Glacial Maximum and present-day mass loss from the Greenland ice sheet”: http://advances.sciencemag.org/content/2/9/e1600931.full

Assessment

Students will be assessed by evaluation of the paragraph(s) they write at the end.

Author/Credits

Steve Kirsche, 2017 PolarTREC Teacher, steve@redotter.com

ScienceDaily®
Your source for the latest research news

Science News

from research organizations

Greenland rising as ice melts

Date: September 23, 2016

Source: University at Buffalo

Summary: A new study on the Greenland Ice Sheet provides valuable insight on climate change, using unique research methods to establish new estimates of ice loss for both modern and ancient times, says geologists.

FULL STORY

Zachariae Isbræ, northeast Greenland.

Credit: Anders A Bjørk

A new study on the Greenland Ice Sheet provides valuable insight on climate change, using unique research methods to establish new estimates of ice loss for both modern and ancient times, says UB geologist Beata Csatho, one of more than a dozen team members on the international project.

The research was published today in *Science Advances*. It was led by Shfaqat A. Khan of the National Space Institute at the Technical University of Denmark (DTU Space).

The study improves estimates of past and present-day ice loss by going deep -- by exploring the Earth's activity beneath the Greenland Ice Sheet, says Csatho, professor of geology in the College of Arts and Sciences.

"This research is a great first step toward better understanding how geologic processes below the surface of the Earth influence ice loss and, ultimately, sea level rise," she says. "It opens up new opportunities for better understanding how the ice sheet is changing and interacting with the rocky layers of the Earth below it."

She explains that the ice sheet sits on the Earth's solid crust, which is in turn perched atop a softer layer of rock called the mantle. When the ice sheet loses ice, the crust underneath rises up -- similar to the way in which a compressed spring will bounce up when pressure is removed.

This uplift, called postglacial rebound, means that scientists can't measure how much an ice sheet is shrinking by simply tracking changes in its surface elevation. They also must figure out how much of that elevation change is caused by the bedrock rising.

The new research uses data from GPS stations fixed on bedrock to capture the uplift process in unprecedented detail, showing that earlier studies may have underestimated past and present-day mass loss, Csatho says.

The paper also hints that the mantle beneath Greenland is not uniform: The ice sheet's southeast region has experienced unexpectedly rapid uplift rates of about 12 millimeters per year, suggesting the mantle may be hotter and less viscous here, making it springier.

"It's a very exciting study," Csatho says. "It's a new and different way of understanding the ice sheet and this critical process of uplift."

Story Source:

Materials provided by **University at Buffalo**. Original written by Charlotte Hsu. *Note: Content may be edited for style and length.*

Journal Reference:

1. S. A. Khan, I. Sasgen, M. Bevis, T. van Dam, J. L. Bamber, J. Wahr, M. Willis, K. H. Kjaer, B. Wouters, V. Helm, B. Csatho, K. Fleming, A. A. Bjork, A. Aschwanden, P. Knudsen, P. K. Munneke. **Geodetic measurements reveal similarities between post-Last Glacial Maximum and present-day mass loss from the Greenland ice sheet**. *Science Advances*, 2016; 2 (9): e1600931 DOI: 10.1126/sciadv.1600931

RELATED STORIES

Figuring out How Fast Greenland Is Melting

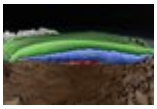
July 5, 2017 — A new analysis of Greenland's past temperatures will help determine how fast the island's vast ice sheet is melting. Other research shows the accelerated melting of Greenland's ice ... **read more** »

Greenland on Thin Ice?

Dec. 7, 2016 — First-of-their-kind studies provide new insight into the deep history of the Greenland Ice Sheet, looking back millions of years farther than previous techniques allowed. However, the two studies ... **read more** »

Huge Ancient River Basin Explains Location of the World's Fastest Flowing Glacier

June 14, 2016 — An ancient basin hidden beneath the Greenland ice sheet may help explain the location, size and velocity of Greenland's fastest flowing outlet glacier. The research also provides an insight into ... **read more** »



3-D View of Greenland Ice Sheet Opens Window on Ice History

Jan. 23, 2015 — Scientists using ice-penetrating radar have created 3-D maps of the age of the ice within the Greenland Ice Sheet. The new maps will aid future research to understand the impact of climate change on ... **read more** »

FROM AROUND THE WEB