On Thin Ice: The Melting of Ice on Land and Sea

Summary

Students will conduct a series of experiments to model the potential impact of melting sea ice and melting land ice on sea levels.

Materials

For each student team

- deep dish pie or cake pan
- toothpick
- modeling clay
- ice cubes
- water
- one piece of wood approximately 5 cm x 15 cm
- clear plastic wrap

Vocabulary

ice sheet, ice shelf, glacier, iceberg, sea ice

Background for Teachers

The melting of ice that sits on land (an *ice sheet*) or on the ocean (*sea ice*) has profoundly different consequences for global sea level and climate. This Activity introduces students to several different kinds of ice (including *glaciers* and *icebergs*) and invites them to simulate and measure the different effects of melting ice on the ocean and on land.

The Arctic consists of an ocean surrounded by the northern boundaries of several continents (North America, Europe, Asia) and Earth's largest island, Greenland. Between these land masses it connects with the other oceans of the world and thereby has an impact on global weather and climate. Much of the water is covered with *sea ice* which increases and decreases seasonally in both thickness and total surface area. While roughly half of the Arctic sea ice freezes and melts during this process, the remaining half remains frozen and grows in thickness over many years.

At the opposite end of the Earth near Antarctica, sea ice retreats to four million square kilometers during summer, but grows to cover 19 million square kilometers (7,334,000 square miles) during winter. As the air temperature begins dropping in March, the ocean temperature drops to --1.8 degrees C and starts freezing at the incredible rate of 5.75 square kilometers (2.2 square miles) per minute. This thin ice coating covers an area nearly twice the size of the United States. The ice grows to more than a meter thick as winter progresses. Satellite imagery is helpful in monitoring sea ice extent and temperature.

The freezing and melting of sea ice around Antarctica each year is the world's biggest seasonal climate event (Williams, 2003). *Ice sheets* form over land. Both Greenland and Antarctica are covered with thick *sheets* that represent nearly 90% of the world's ice. On the continent of Antarctica, the ice sheets can be over 1.2 miles (2 kilometers) thick. When these ice shets extend out over the ocean but are still attached, they're called ice shelves. A *glacier* is a mass of slow-moving thick ice that has built up over many years on land. When a large block of ice breaks off from a glacier, it becomes an *iceberg*. Perhaps history's most infamous iceberg was the one that contributed to the sinking of the Titanic in 1914.

The Beaufort Sea in the Arctic has experienced remarkable change in sea ice cover over the last 5 years. The recent summer minimum of sea ice extent has receded approximately 200km north compared to the 1979-2000 mean summer minimum ice extent. Climate models suggest that Arctic sea ice could decline dramatically this century. On April 30, 2007 a new study reported that Arctic sea ice was melting at an even faster rate than projected by computer models used in the recent IPCC report. (taken from PPZA website, HDvCC APLIS 2007)

Instructional Procedures

Have students check out the Lehrer NewsHour piece on Greenland and the field work of oceanographer, Dave Holland. Or link to Alberto Behar's work and the "Ice Expedition" video
Earth is the only planet in our solar system on which water exists in all three phases -- solid in the form of ice, liquid covering nearly two-thirds of the Earth's surface, and gas as water vapor in the atmosphere. Whether water exists as a solid, liquid, or gas depends on the average speed of the atoms and molecules that make it up. That average speed of the atoms and molecules is what we measure as temperature. When the temperature rises enough to cause ice to melt into liquid water, changes occur in both its state and its density. What effect does the melting of sea ice have on sea level? Could the melting of land ice, such as ice sheets and glaciers, increase sea level?
Procedure
Ice Investigation #1: If sea ice melts, will sea level rise?

- Give each team of students a pan and a lump of clay.
- Mold the shape of a continent, pressing the edges flat against the pan.
- Pour in water to partially cover the clay continent.
- Put several ice cubes in the water to represent sea ice.
- Trace the water level into the clay with a toothpick or pencil.
- Cover the pan with clear plastic wrap to prevent evaporation of the water.
- Observe the marked water line as the ice melts. Does the water level rise? Why or why not?

Ice Investigation #2: If glaciers and ice sheets melt, will sea level rise?

- Use the same pans and continents from investigation #1.
- Place the same number of ice cubes on top of the clay continent to represent glaciers or icecaps.
- Trace the water level into the clay with a toothpick or pencil.
- Cover the pan with clear plastic wrap to prevent evaporation of the water.
- Observe the marked water line as the ice melts. Does the water level rise? Why or why not

Ice Investigation #3: What impact will melting land ice have on the land itself

- On the surface of the wood, mark the points of the compass N, S, E, and W.
- From N to S across the surface draw E-W lines at 1 cm intervals.
- Along the N and S edge mark lines at 2 mm intervals.
- Fill the container with water and place the wood in the water.
- Put one or two ice cubes on the N edge of the floating wood.
- Watch and note the level of water in the container and the on the N and S edges. What happens to the water level in the container? What happens to the N and S edges of the block of wood as the ice melts?

Extensions

Water contracts as it cools until it reaches about 4°C. It then expands by up to 10% as it freezes, making it less dense than liquid water. (You can check this out by freezing a carefully measured volume of water in a plastic measuring cup, then checking the volume again.): Melting sea ice will not raise sea level because the volume contracts again when the ice melts. Melting ice sheets and glaciers raise sea level, however, by adding more water to the ocean from the land. Do you think melting glaciers and other land-based ice masses will make sea level rise? Will it submerge the continents on which the ice used to be? Most of the world's tide gauges are on the edge of continents that in recent geologic past had massive ice sheets on them. Can we get a good measure of trends in the world's sea levels from such gauges if we do not properly consider the vertical land movements? (Referenced source - Williams, Jack. The Complete Idiots Guide to the Arctic and Antarctic, 2003, Alpha Press

Teachers with access to stream tables or wall paper trays can experiment with blocks of ice to determine the minimal angle of elevation needed to cause the ice to slide down the stream table. They can also experiment with a slow stream of water flowing down the stream table to determine its effect on the movement of the block of ice (simulating the flow of water from a moulin under a glacier.)

Snow density can be determined by the students using quart (liter)- sized jars to collect snow, marking the jars from the bottom to the top from 1-100, and allowing the snow to melt, thereby determining the snow density as a percentage of water to original snow volume. Melting down to the 22 line would be read as a water/snow density of 22%.

Cryosphere Study - Plan an outdoor activity during the school year following a moderate snowfall -- if you live in parts of the USA which experience significant quantities of snow. The students would model the work of polar researchers by working outside the classroom (under teacher supervision and properly dressed for outdoor work), collecting data and images including snow crystal identification and study, snow pit analysis, calculating moisture content through a snow melt activity, measuring snow depth and underlying soil temperatures, measuring snow vs dry ground albedo with light meters/sensors, wildlife on the snow identification, atmospheric conditions, GPS work, etc.

Check out the "SnowSTAR 2007" podcast on the PPZA website to see Matthew Sturm and his team of snow and ice researchers doing similar activities during their 4,000km plus traverse from Fairbanks, AK, to Baker Lake, Canada.

Challenge your students to design a structure for construction atop two-mile thick sheet of moving ice like the new Amundsen-Scott South Pole Station. How would they meet the daily needs of shelter, food, water, medical assistance, entertainment, waste disposal, energy source, etc? This could be a physical model, poster, or done in HTML or as a Power Point Presentation.

"Monitoring the Weather: From Pole to Pole to Pole" - The International Polar Year can also apply to studying the North Pole of Mars. In May of 2008, NASA's Phoenix spacecraft will land near the northern polar cap of Mars to help scientists learn about the history of water on the Red Planet. The spacecraft will have a weather station, and data should be accessible on the Internet. The students can record and compare daily temperature readings in the Arctic, the Antarctic, from the Phoenix Mars lander, and from their own location.

Bibliography

Adapted from:

Passport to Knowledge -Live From Antarctica II Teacher's Guide p.18

"When Land Ice Melts", and "Climate Change and Sea Level, Curriculum Modules for the Pacific Schools" -- Edited by Aung, Kalumin and Lennon, p. 103-104

- NSTA IPY Symposium #1

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