Changing Planet: Rising Ocean Temperatures - Rising Sea Levels

Summary:

Students investigate how thermal expansion of water affects sea level

Source:

Adapted by NESTA/Windows to the Universe team members Missy Holzer, Jennifer Bergman, and Roberta Johnson from the Thermal Expansion and Sea Level Rise activity on Windows to the Universe

Grade level:

5-9, although it may be adapted to higher grade levels using the extensions below

Time:

Approximately one lab period

Student Learning Outcomes:

- Students will be able to describe the change in water level when the water is exposed to heat
- Differentiate between the effects of thermal expansion and melting land-based snow and ice fields as they relate to sea level rise
- Predict the impact of rising sea level on coastal areas

Lesson format:

Demonstration or hands-on inquiry investigation

National Standards Addressed:

- National Science Content Standards 5-12: Abilities necessary to do scientific inquiry
- National Science Content Standards 5-12: Understanding about scientific inquiry
- National Science Content Standard 5-8: Properties of Earth materials

Materials:

- Student worksheet (/teacher_resources/ocean_temperatures_student.pdf)
- Conical flask
- Two-hole cork for flask
- Thin, glass tube
- Long thermometer
- Portable lamp (a flexible desk lamp works well)
- 100 - 150 Watt incandescent light bulb
- Food coloring
- Water

- Salt
- Ethyl Alcohol
- Marker
- Small ruler
- Stopwatch

DIRECTIONS:

1. For background information on the consequences of warming oceans watch the *Changing Planet* episode *Ocean Temperatures (/earth/changing_planet/ocean_temperatures_intro.html).* Also, explore these topics on the Windows to the Universe website at the links listed below.
2. Gather materials and print out the worksheet. The materials listed above are for each student team if this lesson is done as a laboratory or for the teacher if this lesson is done as a demonstration. If all the materials are not available, consider modifying the lesson using similar materials making sure the container is tightly sealed as it would be if you were to use a cork on the and flask.
3. Discuss the concerns about rising ocean temperatures and the impacts on marine life and coastal properties. Probe their understanding of the causes of sea level rise. Ask them if melting ice sheets in the polar regions would impact rising sea levels in low latitudes, and if not, then what is causing sea level to rise? Note that students may hold the misconception that the melting of sea ice and land-based glaciers and ice both lead to sea level rise, whereas it is the melting of the land-based snow, ice and glaciers that lead to sea level rise.

   Follow these steps if this is a demonstration:

4. Completely fill the flask with very cold water (to improve visibility, a few drops of food coloring can be added).
5. Place the thermometer and glass tube into the cork as shown in the picture on the student worksheet.
6. Place the cork (with tube and thermometer) into the mouth of the flask. The water should rise a short way up the glass tube. There should not be a gap between the surface of the water and the bottom of the cork - as you put the cork on, the water should spill over slightly, so that the flask is completely full of water, and water rises slightly up the glass tube.
7. Have a student report the temperature of the water and mark the water level in the glass tube with marker.
8. Ask students to predict what will happen to the water level when exposed to heat. Form a hypothesis or multiple hypotheses.
9. Place the flask under the lamp. (Lamp should be aimed towards the water by positioning it a few inches from the side of the flask, not the top.)
10. Turn on the lamp and within 5-10 minutes the water level in the glass tube will have risen. The water level will continue to rise, and typically rises about 9 cm over a 50 minute period.
11. Discuss results, hypotheses, and how this example relates to the effect of global warming on sea level (pointing out the dissimilarity between the flask and ocean basins).

    Follow these steps if it is a student laboratory.

12. Distribute the student worksheet, and before students handle any equipment, have them create a hypothesis for the laboratory question.
13. Caution students to handle all materials with care, and to follow the procedure closely to ensure quality data is acquired.
14. To save time in the second half of the lab consider assigning half the class to explore the thermal expansion of alcohol, and the other half of the class explore the expansion of salt water.
    Use this last step in both cases.
15. Close the lesson by assigning the students the National Geographic article and the Pulse of the Planet podcast listed in the resources below. After the students have read and listened to the materials, have a class discussion referring to the results of the lab along with the content of the article and podcast. Be sure to discuss the strengths and limitations of their laboratory model of thermal expansion.

ASSESSMENT:

Students should be evaluated on their laboratory skills and analysis. Consider using the extensions above to assess

student understanding of the lesson concepts and their laboratory abilities. Students may also be given a writing assignment that focuses on the impacts of rising ocean temperatures by contextualizing the issue by writing a letter to the people of a small island facing rising sea levels, or by writing a letter to the local paper on how the impacts of rising sea levels will affect everyone.

LAB SAFETY:

Alcohol is a flammable substance. Handle with extra care around heat. Monitor student use of sharp and glass objects at all times. Glassware may break and create extremely sharp shards. Have clean-up materials handy if breakage should occur.

CLEAN-UP:

Wash and dry all lab equipment and properly store for future use.

EXTENSIONS:

- An effective way to get the point across about sea level rise is to have students map the changes in sea level. Mapping Ancient Coastlines (http://windows2universe.org/teacher_resources/teach_bathymetry.htm) is an excellent activity to start, and then students can map changes in sea level on coastal properties around the United States using USGS (http://www.usgs.gov) topographic maps.
- Satellite data from Topex Poseidon provides scientists with data to monitor changes in sea level. MY NASA DATA provides students with easy access to satellite data that can be easily correlated. For instance, sea level height may be correlated with sea surface temperature. Ocean Impacts of an El Nino Event (http://mynasadata.larc.nasa.gov/preview_lesson_nostds.php?&passid=68) uses both sea surface temperature and sea level height and can be adapted for this lesson.

BACKGROUND INFORMATION:

The Earth's ocean (/earth/Water/ocean.html) covers more than 70% of our planet's surface. Because of the ocean's size and depth, changes to the ocean will affect our planet greatly and that concerns all who share this planet.

Most of the solar radiation (/physical_science/physics/radiation.html) (light and heat) that hits the ocean is absorbed in the first few tens of meters of water. Waves and turbulence mix this heat downward quickly. The surface layer of the ocean is well mixed from the top to the bottom of that layer. The temperature (/earth/Water/temp.html) of the surface waters (/earth/Water/ocean_currents.html) (the mixed layer) varies mainly with latitude (/earth/Water/images/ocean_temp.html). The polar seas (/earth/polar/polar_oceans.html) (high latitude) can be as cold as -2 degrees Celsius (28.4 degrees Fahrenheit) while the Persian Gulf (low latitude) can be as warm as 36 degrees Celsius (96.8 degrees Fahrenheit). The average temperature of the ocean surface waters is about 17 degrees Celsius (62.6 degrees Fahrenheit).

There is a boundary between surface waters of the ocean and deeper layers (/earth/Water/deep_ocean.html) that are not well mixed. The boundary usually begins around 100-400 meters and extends several hundred of meters downward from there. This boundary region, where there is a rapid decrease of temperature, is called the thermocline (/earth/Water/temp.html). 90% of the total volume of ocean is found below the thermocline in the deep ocean. Here, temperatures approach 0 degrees Celsius. So even though surface waters can be a comfortable 20 degrees Celsius (good for swimming in!), the majority of our ocean water has a temperature between 0-3 degrees Celsius (32-37.5 degrees Fahrenheit).

At the surface of the ocean, thermometers placed on buoys can take temperature measurements. In the last decade, the Argo program (http://www.argo.ucsd.edu/) has taken on the task of monitoring the state of ocean surface waters across the globe. The Argo program deploys floats that measure salinity (/earth/Water/salinity.html) and temperature throughout the surface layer of the ocean. Over 3,000 free-drifting floats have been deployed all over the ocean and each float is programmed to sink 2,000 meters down, drifting at that depth for about 10 days. The float then makes its way to the surface measuring temperature and salinity the whole time. Data is transmitted to a satellite once the float reaches the surface, so that scientists and the public have access to the state of the ocean within hours of the data collection. At a greater depth in the water, in situ measurements are often made with a CTD instrument (CTD =

conductivity, temperature, depth) (/earth/Water/CTD.html), where the instrument is placed in the ocean water from a ship or a platform. These instruments are used by the Bermuda Institute of Ocean Sciences (http://www.bios.edu/research/index.html) (BIOS), where they have been tracking ocean measurements like temperature, salinity and oxygen concentrations for over 55 years.

The Argos and BIOS program have both published results that confirm that the ocean is warming (/earth/climate/cli_effects.html). Surface water temperatures obviously change from season (/the_universe/uts/seasons1.html) to season and year to year, but the whole ocean has warmed about 0.1 degree Fahrenheit (0.55 degree Celsius) in the past 30-50 years. This may not seem like much of a temperature change, but it is quite significant. Think about a pot of water heating on a stove. A small pot of water will heat quickly, while a large pot of water at the same heat setting will heat very slowly. This is due to a difference in heat capacity. The ocean has an enormous heat capacity because of its large size, thus, it is like an enormous pot of water, and it takes a great amount of heat to warm the ocean. The fact that the ocean has warmed significantly in 30 to 50 years is remarkable.

The rise in ocean temperature has scientists concerned for a number of reasons. The rising temperature of the ocean affects the global food web of the ocean. Also, because of ocean-atmosphere interactions, the warming of the ocean will change global weather (/earth/Atmosphere/weather.html) patterns. In fact, there is strong evidence that global warming has been increasing the intensity of hurricanes (/earth/climate/hurricane_climate.html) for over the past few decades. According to MIT scientist Kerry Emmanuel, hurricanes (/earth/Atmosphere/hurricane/hurricane.html) have become 70-80% more powerful over this timeframe. Hurricanes take heat energy from the oceans and convert it into the energy of the storm. Thus, warmer oceans offer more heat energy to hurricanes, allowing them to become stronger storms that last longer. The effect of global warming on hurricanes continues to be an area of active research.

Another main concern scientists have is that global warming is causing sea level (http://windows2universe.org/earth/Water/sea_level.html) rise. Currently, global sea level is rising about 3 mm per year (about 1/8 inch.) Scientists are still trying to pin down exactly how much sea level rise we can expect during the 21st Century. The Intergovernmental Panel on Climate Change (http://windows2universe.org/earth/climate/ipcc.html) estimates 18-59 centimeters (7-23 in) of sea level rise. How does global warming (/earth/climate/ipcc_feb2007.html) cause sea level to rise? There are two ways. First, when climate warms, water that is on land in glaciers and ice sheets (/earth/polar/cryosphere_glacier1.html) melts and makes its way down rivers (/earth/Water/river.html) to the ocean. Second, as seawater warms, the water molecules move further apart which makes the water take up more space. Scientists suspect that more than half of sea level rise today is due to warmed and expanded sea water.

Today, there are large human populations living in coastal areas worldwide that would be affected by rising sea level and the flooding and erosion that it causes. Freshwater supplies could become contaminated with salt water and farmland could become flooded. Many countries are looking for new technologies to protect people from rising seas.

RELATED SECTIONS OF THE WINDOWS TO THE UNIVERSE WEBSITE:

- Temperature of Ocean Water (http://windows2universe.org/earth/Water/temp.html)
- Effects of Climate Change (http://windows2universe.org/earth/climate/cli_effects.html)
- Rising Sea Level (http://windows2universe.org/earth/climate/cli_sea_level.html)
- Earth's Ocean (http://windows2universe.org/earth/Water/ocean.html)
- Thermohaline Circulation: The Global Ocean Conveyor (http://windows2universe.org/earth/Water/circulation1.html)
- Transfer and Storage of Heat in the Oceans (http://windows2universe.org/earth/Water/ocean_heat_storage_transfer.html)
- Are Hurricanes Becoming Stronger and More Frequent? (http://windows2universe.org/earth/climate/hurricane_climate.html)

OTHER RESOURCES:

- Living in the Greenhouse (http://www.eo.ucar.edu/kids/green/index.htm)
- Our Changing Climate (http://www2.ucar.edu/climate)

- Weather and Climate Basics (http://eo.ucar.edu/basics/index.html)
- Trinidad's Rising Seas: Effects of Global Warming (http://www.pulseplanet.com/dailyprogram/dailies.php?POP=1564) sponsored by National Science Foundation
- Warming to Cause Catastrophic Rise in Sea Level? (http://news.nationalgeographic.com/news/2004/04/0420_040420_earthday.html) by National Geographic
- Argo - Global monitoring of the surface oceans (http://www.argo.ucsd.edu)
- BIOS - Bermuda Institute of Ocean Sciences (http://www.bios.edu)

Last modified February 16, 2011 by Missy Holzer.