1.2 Rising Waters: The Ocean Is Getting Too Big for Its Beaches

AGE RANGE

9th—12th grade

TIME REQUIRED

90 minutes

ACTIVITY OVERVIEW

Engage: NASA SLR graph
Explore: Land & sea ice melt
Explain: Discussion
Elaborate: Thermal expansion
Evaluate: Discussion and graphs

MATERIALS

Probe thermometer
Heat lamp
Water
Food Coloring
Marker
Plastic bottle
Clear plastic straw
Scissors
Modeling clay
Two clear, plastic food-storage containers, approx. 6in by 6in
Clay (enough to fill about a quarter of each tub with 1-2 inches of clay)
Ice cubes
Ruler

BASED ON:

Lesson based on "What's Causing Sea-Level Rise? Land Ice Vs. Sea Ice" JPL, "Thermal Expansion Model" JPL, and "Thermal Expansion and Sea Level Rise" Centers for Ocean Science Education Excellence.

LESSON TOPIC: Thermal expansion and ice melt

ACTIVITY SUMMARY: Students will explore the two main causes of sea-level rise by recreating ocean water processes through a classroom lab.

OBJECTIVES:

Students will be able to explain that:

- Thermal expansion is the increase in volume of water as a result of increased water temperature.
- Melting land ice contributes to sea-level rise. Not melting sea ice.
- Global sea-level rise is due to warming atmospheric temperatures leading to
    - thermal expansion of ocean water, and
    - addition of water volume from melting land ice.
- Changes in sea-level affect living organisms including humans.

LESSON BACKGROUND: Global sea level has increased by 24 cm since 1880, with 8 cm of that rise occurring since 1993. The rate of sea-level rise since 1900 has been faster than during any other time period in the last 2800 years. The rate of sea-level rise is being driven by global climate change. Sea-level rise impacts coastal areas by increasing the vulnerability of communities to severe storms, erosion of land, inundation of low elevation, salt-water intrusion into aquifers, and increased flooding. Coasts are especially densely populated with about 40% of the world's population living within 100 km of a shoreline. A rise in sea-level of 0.9 meters would permanently inundate areas that 2 million Americans call home.

There are two main factors that drive sea-level rise are a result of a warming atmosphere and ocean. The first factor is thermal expansion of water. As water warms, the molecules vibrate more and take up more space, causing the overall volume of water to expand. The ocean absorbs heat from the atmosphere, and as the ocean warms the water level rises due to thermal expansion. The second factor is melting land ice. Warming atmosphere temperatures melt ice that is stored on land in glaciers and ice sheets and it flows into the ocean, further increasing the volume of water and causing the water level to rise.

Sea level is measured by monitoring stations on the shoreline and at sea. There are over 120 sea level monitoring stations in the U.S. and 240 additional stations worldwide. Sea level has been measured at some stations for more than a century, providing sea level data going back to 1880. In addition to the individual monitoring stations, satellites such as NASA's JASON-3 satellite collect data on sea level. By looking at data from these stations and satellites over periods of 25 years or more, trends can be identified at specific locations along the coast and compared with global trends. This gives scientists useful information about local conditions. Those data can also be used to calculate the global average sea level and study it over time, giving scientists a picture of what's happening to the ocean on a planetary scale.

Sea-level projections and scenarios from: Sweet, W.V., R.E. Kopp, C.P. Weaver, J. Obeysekera, R.M. Horton, E.R. Thieler, and C. Zervas, 2017: Global and Regional Sea Level Rise Scenarios for the United States. NOAA Technical Report NOS CO-OPS 083. NOAA/NOS Center for Operational Oceanographic Products and Services.

VOCABULARY:

Changes in Temperature	Fluctuations (increases or decreases) in temperature. Climate projections show increasing temperatures across the Gulf of Mexico as well as on average globally.
Land Ice	Land ice in the form of glaciers and ice sheets contains the majority of the world's fresh water and covers about 10 percent of the world's land area.
Sea Ice	Frozen ocean water (e.g., icebergs).
Sea Level	Base level for measuring elevation and water depth on Earth. Because the ocean is one continuous body of water, its surface tends to seek the same level throughout the world. However, winds, ocean currents, river discharges, and variations in gravity and temperature prevent "sea level" from being truly level.
Sea-Level Rise	Increase in sea level caused in part by melting land-based ice and expanding water. Exacerbates existing coastal hazards such as flooding, erosion, inundation, and extreme events. Often abbreviated to SLR.
Thermal Expansion	Increase in linear dimensions of a solid or in volume of a fluid because of a rise in temperature.
Global Sea-Level Rise	Average increase in sea level caused primarily by land-ice melt and water expansion across the entire world.
Relative Sea-Level Rise	Rate of sea-level rise at any given point on the coast. Affected by local processes that can reduce or exacerbate global sea-level rise (e.g., subsidence [ground sinking], tectonic plate movement, etc.).

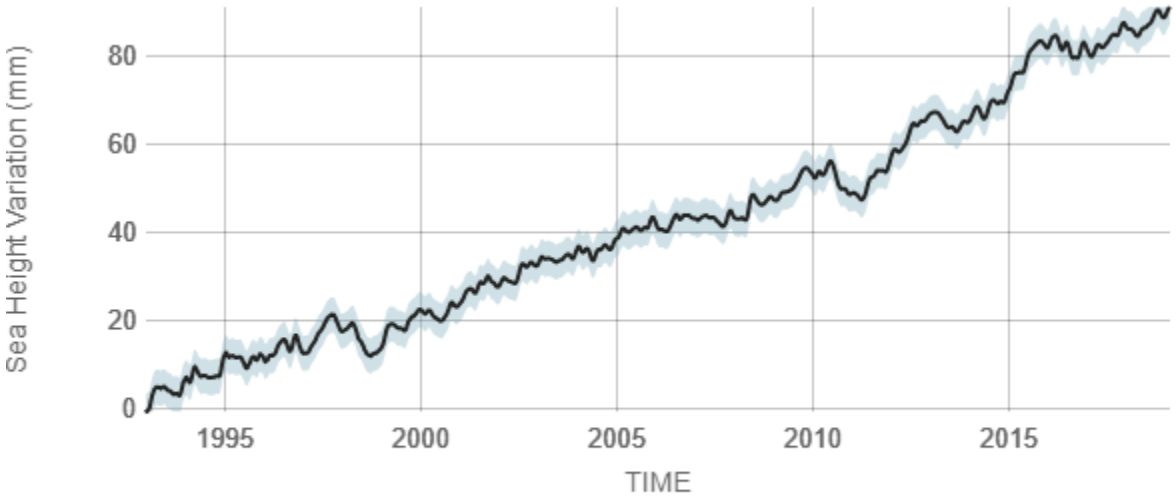
ENGAGE:

Show graph of global sea level from NASA: https://climate.nasa.gov/vital-signs/sea-level/

SATELLITE DATA: 1993-2019

Data source: Satellite sea level observations.

Credit: NASA Goddard Space Flight Center



Source: climate.nasa.gov

Ask students: What is the trend of the data? What would cause sea level to rise? What impact does an increase in temperature have on sea level? What human action contributes to sea-level rise?

EXPLORE:

Activity Overview: In this activity students will compare the added volume of ocean water from melting ice that is on land and melting ice that is in the sea. It can be set up in the classroom using a purchased land model or created using clay. Two trays will be set up with "land" and water. In one tray, ice cubes will be placed in the water and in the other tray the ice cubes will be placed on land. Students record and measure the water level of the tray as the ice melts. The water level will only increase in the tray with the ice on land.

Discuss climate change and sea-level rise with students.
Ask students to identify causes of sea-level rise.
Ask students: What impacts does temperature increase have on water? Target answer: Melting of ice.
Ask students: Where is ice located on Earth? A: Ice sheets on Greenland and Antarctica and glaciers are land ice. Frozen seawater ice and icebergs are sea ice.
Direct students to record their hypothesis for which ice will contribute more to sea-level rise.

Materials

Two clear, plastic food-storage containers, approx. 6 inches by 6 inches
Clay (enough to fill about a quarter of each tub with 1-2 inches of clay)
Tray of ice cubes
Ruler
Water
Permanent marker or tape

Procedure

1. Press clay into one side of the plastic tub, making a ledge. Repeat exactly on other container.
    a. Consider adding push pins along the edge of the clay to represent cities or landmarks.
2. In one container place as many ice cubes as can fit on the clay ledge to represent land ice.
3. In the other container place the same number of ice cubes on the bottom of the container not on the clay to represent sea ice.
4. Pour water in the sea-ice container until the ice floats. The clay ledge should remain out of the water.
5. Pour an equal amount of water into the land-ice container without touching the ice cubes.
6. Use the rule to measure the water level in millimeters in each tub. Mark the water level on the outside of the containers with the marker or tape.
7. At regular intervals measure the water and record the water level. Allow the ice in both containers to melt completely. Using a heat lamp will speed this up.
8. Allow the ice to melt while you move onto the other activity.

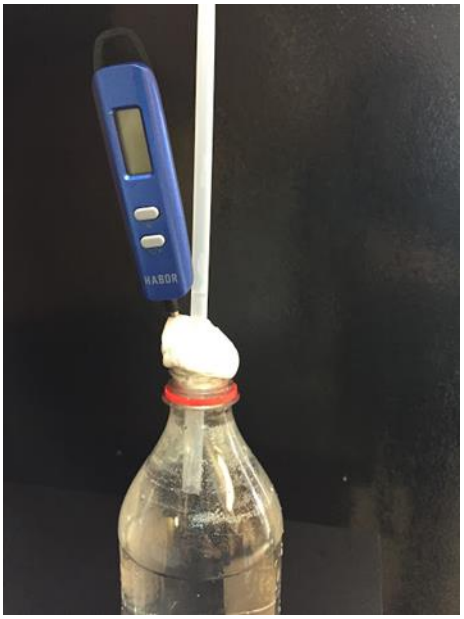
EXTENSION: Follow the same procedure as above but in step 1 switch out the clay for another material, like sand. This will allow for a conversation about different types of land and how the ice will still add to volume of water.

EXPLAIN:

Again, **discuss** climate change and sea-level rise with students. If students did not mention thermal expansion before, explain that in addition to ice melt, there is another phenomenon that contributes to sea-level rise. The following activity will demonstrate that phenomenon.

ELABORATE:

Activity Overview: In this activity students will observe thermal expansion of water. This activity can be set up in a classroom using either science lab equipment (flask and clear glass tube) or using everyday items (water bottle and straw). As the water is heated under a lamp the level in the straw rises, demonstrating thermal expansion.



Materials

Probe thermometer
Heat lamp
Water
Food Coloring
Marker
Plastic bottle
Clear plastic straw
Scissors
Modeling clay

Procedure

1. Completely fill the plastic bottle with water and food coloring to improve visibility.
2. Surround the thermometer and straw with modeling clay a few inches from the bottom of the straw. Do not block the straw with clay.
3. Place the clay into the bottle and press to seal to edges. The water should rise up the straw.
4. Mark the water level using the marker on the straw. Record the temperature of the water.
5. Place a heat lamp approximately 5 inches away from the bottle. Direct the light towards the middle of the water, not at the top.
6. Have students make hypothesis for how the water level will change when the lamp is turned on.
7. Turn on the lamp. Record the temperature and mark the water level after 5-10 minutes.

Ask students: What happened to the water level? What was the impact of the lamp?
A: The water level rose. The lamp added heat energy and increased the temperature of the water.
Ask students: Why did the water level rise as the temperature increased?
A: The lamp adding heat energy to the water resulted in the water molecules moving around more and taking up more space. Each molecule taking up more space increased the volume of water in the bottle and the only place to move was up the tube/straw. This is thermal expansion.

EVALUATE:

Record the measurements from the ice-melt activity to create a line graph representing water level in each tub.
Ask students: Under which ice conditions did the water level rise more? A: The container with the land-ice.
Ask students: Why did this happen? A: The sea-ice was already adding its volume to the water, but the land-ice was adding new water so it increased the total volume as more melted.
Ask students: What does this mean on a global scale? A: Ice melting from land-ice increases global sea-level.

MELTING LAND AND SEA ICE

Which type of ice (land or sea) will contribute more to sea-level rise?

Hypothesis:

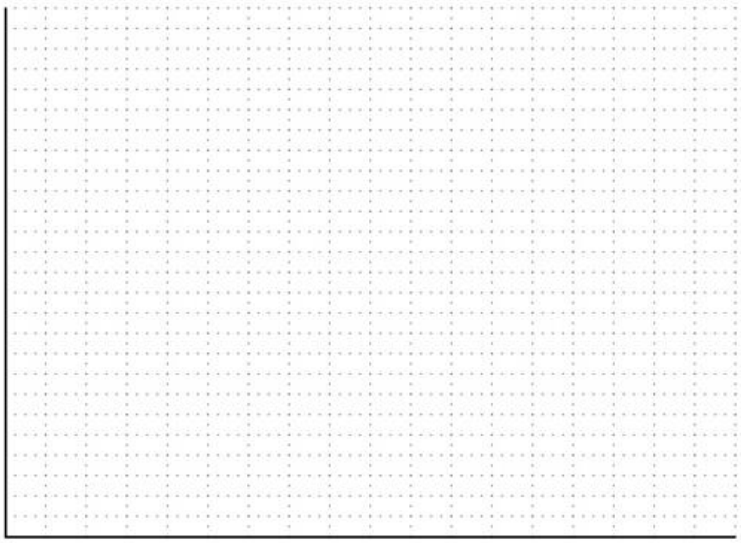
Record the water level in millimeters at the indicated time increments in the chart below:

Time	Land Ice Water Level (mm)	Sea Ice Water Level (mm)
0 min		
10 min		
20 min		
30 min		

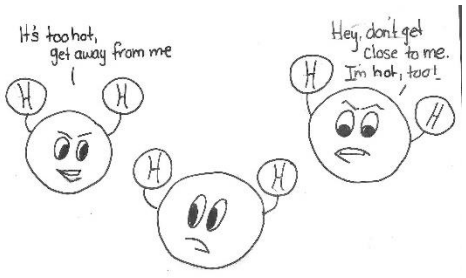
Describe the results from the melting ice lab:

Explain whether or not your hypothesis was supported by the data:

Graph: Create a line graph with time in minutes on the x-axis, water level in millimeters on the y-axis, and the land and sea ice containers represented by different lines.



THERMAL EXPANSION OF WATER



Credit: Kate Tagai, Island Institute

What impact will the heat lamp have on the water in the bottle?

Hypothesis:

Record the water temperature at the indicated time increments in the chart below:

Time	0 min	5 min	10 min	15 min
Water Temperature (°C)				

Describe the results from the thermal expansion lab:

Explain whether or not your hypothesis was supported by the data:

STUDENT PAGE | Reading - Sea Level and Sea Level Change

Global sea level is an average level of the surface of the global ocean. Sea level varies from place to place due to shifting surface winds, the expansion of warming ocean water, and the addition of melting land ice. The sea level measurement of specific locations is called local or relative sea level. A local change can be caused by an increase in sea surface height, or by a decrease in land height. Over relatively short time spans (hours to years), the influence of tides, storms, and decadal oscillations (e.g., El Niño and La Niña) dominates sea level variations. Over longer time spans (decades to centuries), the influence of climate change is the main contributor to sea level change in most regions.

Sea level is measured using tide gauges and satellites. Tide gauges measure relative sea level, so they include changes resulting from vertical motion of both the land and the sea surface. Before computers were used to record water levels, special "tide houses" sheltered permanent tide gauges. The instrumentation—including a well and a mechanical pen-and-ink recorder—was housed inside and a tide staff was attached outside. Essentially a giant measuring stick, the tide staff allowed scientists to manually observe tidal levels and then compare them to readings taken every six minutes by the recorder. The computer age led to tide gauges that used microprocessor-based technologies to collect sea-level data. Today's recorders are more sophisticated. Some send an audio signal down a narrow "sounding tube" and measure the time it takes for the reflected signal to travel back from the water's surface. Others are on the sea floor and measure the pressure and density of the water to account for the depth of the water. Since the late 20th century, satellite measurements of the height of the ocean surface relative to the center of the Earth (known as geocentric sea level) show differing rates of geocentric sea level change around the world.

Over many coastal regions, vertical land motion is small. However, in some regions, vertical land motion has had an important influence. For example, the steady fall in sea level recorded in Stockholm is caused by uplift of this region after the melting of a large (>1 km thick) continental ice sheet at the end of the last Ice Age, between ~20,000 and ~9000 years ago. Land subsidence, the gradual settling or sinking of land, is common in many coastal regions, particularly in large river

deltas like Louisiana. Subsidence can occur because of natural processes, such as the compaction of soil, or due to human processes, such as the extraction of groundwater or oil/natural gas from underground.

Melting ice from glaciers or the Greenland and Antarctic ice sheets lead to sea level rise, but it is not uniform throughout the world. Melting results in regional differences in sea level due to processes like changes in ocean currents, winds, the Earth's gravity field, and land height. Large ice sheets are so massive that they have gravitational pull on the surrounding water. When the ice sheets melt, the gravitational attraction between the ice sheets and ocean water is reduced. As the ocean water relaxes away from the ice sheets, it moves to new areas in the ocean and causes sea level to rise in greater amounts compared to the global average value.

In summary, a variety of processes drive height changes of the ocean surface and land elevation, resulting in different patterns of sea level change at local to regional scales. The combination of these processes produces a complex pattern of total sea level change, which varies through time as the relative contribution of each process changes. The global average of sea level change reflects climatic processes and represents a good estimate of sea level change across many coastal locations, but the rate and amount of sea-level rise will differ among regions.

Adapted from: Church, J.A., P.U. Clark, A. Cazenave, J.M. Gregory, S. Jevrejeva, A. Levermann, M.A. Merrifield, G.A. Milne, R.S. Nerem, P.D. Nunn, A.J. Payne, W.T. Pfeffer, D. Stammer and A.S. Unnikrishnan, 2013: Sea Level Change. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

NOAA. What is a tide gauge? National Ocean Service website, https://oceanservice.noaa.gov/facts/tide-gauge.html, 06/25/18.

STUDENT PAGE | Rising Waters

DO NOW:

What is one impact of increased carbon dioxide in the atmosphere?

EXIT TICKET:

Why does melting sea ice not contribute to sea-level rise?