

## Thermal Expansion and Sea Level Rise

A demonstration or group activity directed at grade levels 5 – 9

### **Activity Summary:**

This activity provides an opportunity for students to investigate how thermal expansion of water affects sea level rise. The suggested lab activity allows students to observe and describe the change in water level in a container when the water is exposed to heat.

*Original Source - Windows to the Universe, University Corporation for Atmospheric Research*

[http://www.windows.ucar.edu/tour/link=/teacher\\_resources/teach\\_thermalexpand.html](http://www.windows.ucar.edu/tour/link=/teacher_resources/teach_thermalexpand.html)

**Major Concepts Addressed:** Water Properties, Sea Level Rise

### ☉ **Big Idea:**

Increases in the atmospheric concentrations of the greenhouse gases (carbon dioxide, methane, nitrous oxide and chlorofluorocarbons) are expected to result in substantial global-scale warming in the future. In response to this warming, global mean sea level will change in part due to thermal expansion of the oceans. In this activity, global warming is not being shown, rather thermal expansion of water is used as a valid and simple activity to demonstrate that an increase in temperature can cause sea level rise.

### ☉ **Key Concepts**

- In the context of oceans, thermal expansion is the increase in volume (or decrease in density) of ocean water as a result of increased temperature of the water.
- A rise in global sea level due to the warming caused by the greenhouse effect could probably be caused by only two effects:
  1. thermal expansion of the water column (due to a decrease in water density caused by its warming); and
  2. the addition of water volume due to the melting of glaciers and ice sheets.
- Changes in sea level affect habitats and the flora and fauna they support.
- Changes in sea level impacts humans.

### ☉ **Essential Questions**

- What might cause sea level to rise?
- What kinds of problems would you expect sea level rise to cause?
- What information would we need to know to plan for rising sea levels on Earth?
- Does water expand in response to temperature change?
- How are humans contributing to sea level rise?
- What actions can we take now to counteract our impacts on climate variability and change?

## 🌀 Knowledge and Skills

Students will be able to:

- Describe the change in water level when the water is exposed to heat.
- Predict the impact of rising sea level on coastal areas.
- Explain the role of global warming on sea level rise.

## 🌀 Prior Knowledge (according to AAAS Atlas for Science Literacy & National Science Education Standards)

- K-2 : Things can be done to materials to change some of their properties, but not all materials respond the same way to what is done to them.
- 3-5 : Heating and cooling cause changes in the properties of materials.
- 6-8 : Increased temperature means greater average energy of motion, so most substances expand when heated.

## 🌀 Common Preconceptions

- *The melting of sea ice will increase sea level.* Actually this contributes very little to sea level rise. This is a consequence of Archimedes' principle of buoyancy. The mass of floating ice (above and below water both) is identical to the mass of the water displaced. If the ice melts into water, its density decreases but its mass is the same, and water level is unchanged. Thermal expansion and glacial melt will have a greater contribution and lasting effect on sea level.
- *Coastal erosion is an unusual process.* Erosion is an integral part of natural coastal processes which have formed beaches and shorelines and which maintain them in a condition we can all enjoy. However, an increase in sea level will exacerbate coastal erosion, particularly during large storm events, by increasing the vulnerability of coastal areas.

## 🌀 Background (from the [Water Encyclopedia](http://www.waterencyclopedia.com) <http://www.waterencyclopedia.com> )

**Sea level** is the level of the sea after averaging out the short-term variations due to wind waves. Regional, short-term sea level is constantly fluctuating due to tidal and wind-driven effects on the ocean. Global sea level has fluctuated throughout Earth's history. These long-term, widespread changes in the mean sea level are known as **eustatic** sea level changes.

Over the twentieth century, global sea level has risen on the average of 2.0 millimeters (0.08 inches) per year for a total of 10 to 25 centimeters (3.9 to 9.8 inches). According to a recent Environmental Protection Agency study, it is expected to rise at least another 20 centimeters (7.8 inches) by 2100. Most experts agree that human-induced global warming is the force behind the current global sea-level rise.

### *Causes of Eustatic Variations*

Eustatic variations in sea level are the effects of external forces. There are three eustatic factors that contribute to sea level rise:

1. Regional subsidence and land movements including, tectonic displacements;
2. Thermal expansion of the water in the ocean; and
3. Exchange of water stored on land by glaciers and ice sheets.

As the global climate warms, the average level of the ocean is gradually increasing, because warmer water occupies a greater volume. The warmer climate also is causing the melting of mountain and nonpolar glaciers, which adds volume to the oceans.

### *Impacts of Rising Sea Level*

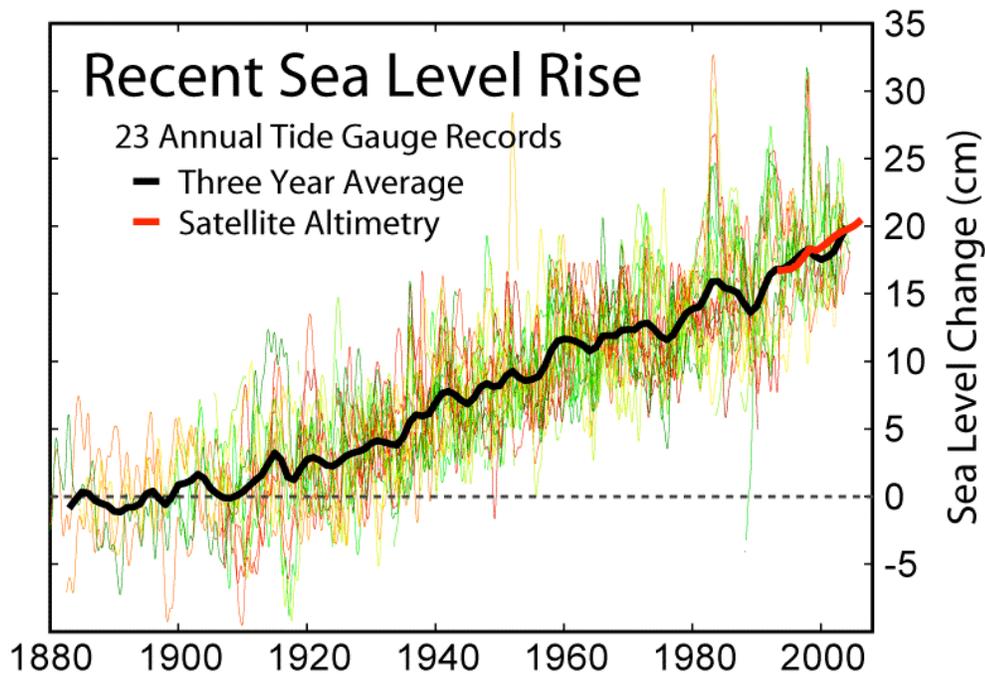
Rising sea level has many impacts on coastal areas. Although an increase in sea level will not necessarily affect the intensity of storms, such as hurricanes, it does increase the vulnerability of coastal areas to severe storms. Coasts are especially densely populated. More than 100 million people are estimated to live within 1 meter (approximately 3 feet) of the present-day sea level.

A rise in sea level causes five primary physical effects:

- erosion of beaches and bluffs;
- increased flooding and storm damage;
- inundation of low-lying areas;
- salt-water intrusion into aquifers and surface waters; and
- higher water tables.

#### *Post-Glacial Rebound*

The primary reason for inconsistencies in relative sea level is regional **subsidence** and emergence of land due to post-glacial rebound. During the last glacial period, approximately 18,000 years ago, enormous glaciers covered continental areas. The land beneath these glaciers subsided due to the added weight. When the ice melted at the end of this period, the land began to emerge again, and continues to do so today. Other factors that can cause changes in relative sea level are either uplift or subsidence related to tectonic processes, fluid withdrawal, and sediment deposition and compaction.



*Temperature changes during a similar period and possibly responsible for causing the observed sea level rise. From [Wikipedia.com](http://en.wikipedia.org/wiki/Sea_level_rise) [http://en.wikipedia.org/wiki/Sea\\_level\\_rise](http://en.wikipedia.org/wiki/Sea_level_rise)*

During a period of glaciation, the average global temperature drops considerably and the volume of the ocean decreases greatly. The water that would otherwise be in the ocean is frozen as ice in continental glaciers, or as sea ice in the oceans. During the peak of the last glacial period, global sea level was approximately 100 meters (328 feet) lower than it is today. Only when the temperature began to warm did the glaciers melt and flow back into the ocean. This is just one example of how the global climate can have a substantial effect on sea level.

It is estimated that most of the increase in sea level will be from as the result of global warming, which will cause **thermal expansion** of the oceans. Thermal expansion is caused when seawater expands because of the higher temperature of the water. Since the oceans absorb heat from the atmosphere, when the atmosphere becomes warmer so will the oceans. Warm seawater has a greater volume than cold seawater. As the temperature of the ocean increases so will the total ocean volume. The increased volume will cause the level of the water in the oceans to rise.

Two factors will contribute to this accelerated rise in sea level. First, although the oceans have an enormous heat storage capacity, if global atmospheric temperatures rise, the oceans will absorb heat and expand. A greater volume of ocean water due to thermal expansion will lead to a rise in sea level. Second, rising temperatures will cause the ice and snowfields to melt, thereby increasing the amount of water in the oceans. It should be noted that only the melting of land-based ice and snow increases sea level. The melting of floating ice will not affect sea level. This can be demonstrated to your students by partially filling a glass container with ice and water and marking the water level on the glass. When the ice cubes melt, note that the water level has not changed.

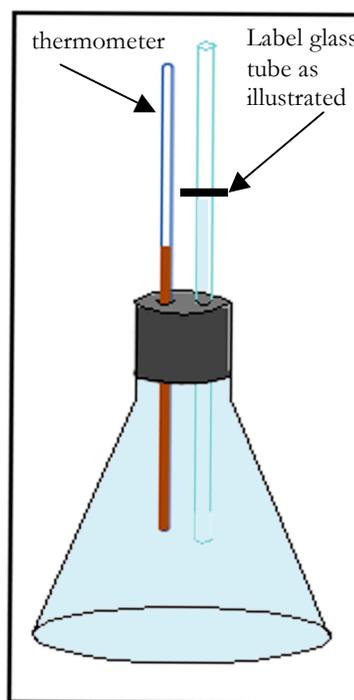
### Materials

- Conical flask
- Two-hole cork for flask
- Thin, glass tube
- Long thermometer
- Portable, clamp-on reflector lamp
- 150 Watt floodlight
- Food coloring
- Water
- Marker

Many of these materials are commonly found in a school chemistry lab. If you are a middle school teacher without a science lab, consider asking your district's high school lab science teachers for use of materials.

### Activity Directions:

1. Completely fill the flask with very cold water (to improve visibility, food coloring can be added).
2. Place the thermometer and glass tube into the cork as shown in the picture at the right.
3. Place the cork (with tube and thermometer) into the mouth of the flask. The water should rise a short way up the glass tube.
4. Have a student report the temperature of the water and mark the water level in the glass tube with marker or piece of tape.
5. Ask students to predict what will happen to the water level when exposed to heat. Form a hypothesis or multiple hypotheses.
6. Place the flask under the lamp. (Lamp should be aimed towards the water, not the neck or top of flask.)
7. Turn on the lamp and within 5-10 minutes the water level in the glass tube will have risen.



*Image courtesy of Windows to the Universe*

### Assessment / Discussion Questions

Discuss results, hypotheses, and how this example relates to the effect of global warming on sea level (pointing out the distinction between the flask and ocean basins).

## 🌀 **Vocabulary**

eustatic: long-term, widespread changes in the mean sea level

sea level: average height of the ocean

subsidence: lowering or sinking of land caused by compaction

thermal expansion: the tendency of matter to increase in volume or pressure when heated

## 🌀 **Additional resources**

### **Related sites with further classroom applications**

Digital Library for Earth Science Education – Teaching Boxes

<http://www.teachingboxes.org/seaLevel/index.jsp>

Atmospheric Radiation Measurement Program – Teacher’s Lounge

<http://education.arm.gov/teacherslounge/lessons/thermal.stm>

Texas A&M University Ocean Drilling Distance Learning Program

[http://oceandrilling.coe.tamu.edu/curriculum/Sea\\_Level/Ice\\_Volume/index.html](http://oceandrilling.coe.tamu.edu/curriculum/Sea_Level/Ice_Volume/index.html)

### **News / Press**

Warming to Cause Catastrophic Rise in Sea Level?

[http://news.nationalgeographic.com/news/2004/04/0420\\_040420\\_earthday.html](http://news.nationalgeographic.com/news/2004/04/0420_040420_earthday.html)

Scientists Get a Real "Rise" Out of Breakthroughs in How We Understand Changes in Sea Level

[http://www.nasa.gov/vision/earth/environment/sealevel\\_feature.html](http://www.nasa.gov/vision/earth/environment/sealevel_feature.html)

### **Agency reports with reputable graphics and background information**

Environmental Protection Agency Climate Change – Science

<http://www.epa.gov/climatechange/science/recentstlc.html>

NASA Science Update: Breakthrough Discoveries in Sea Level Change Research

[http://www.nasa.gov/vision/earth/environment/sealevel\\_papers.html](http://www.nasa.gov/vision/earth/environment/sealevel_papers.html)

NOAA Sea Levels Online

<http://tidesandcurrents.noaa.gov/sltrends/sltrends.html>

## 🌀 **Notes on Pedagogy:**

Activity seems best suited as a demonstration for younger students (grades 5-6) and could be used as a group / lab activity with (grades 8-9).

Use the simulations from the Texas A&M Ocean Drilling website (see resources above for URL) to supplement the activity and provide a visualization of the differences between the effects of melting ice that is floating and “land” based ice, on sea level. This site also has a pre- and post-test for knowledge and understanding, along with activity worksheets.