Causes and Effects of Our Rising Seas

Educator Lesson Plan

Original lesson by E.V. Bell and Brittney Marshall, COSEE–SE, 2009

Updated by E.V. Bell, 2020

About This Activity

Target Grade Levels: 5 – 12

South Carolina State Science Standards: 5.E.3; 6.E.2; 7.P.2; 8.E.5; H.E.6

Ocean Literacy Essential Principles

#2: The ocean and life in the ocean shape the features of Earth.
#3: The ocean is a major influence on weather and climate.
#4: The ocean and humans are inextricably interconnected.

Focus Questions

- What are the main differences between sea ice and glacial ice?
- How does melting sea ice and/or glacial ice impact currents? Sea level?
- What is thermohaline circulation? How does it affect climate?

Objectives

- Describe impacts of melting sea ice and melting glaciers on sea level.
- Demonstrate an understanding of specific gravity, refraction, and current technologies to measure salinity.

- Distinguish between salt and fresh water by exploring density-driven currents.
- Explain the concept of thermohaline circulation and its impact on climate.
- Locate sources of sea ice and glaciers across the globe.

Preparation

Group Size: 3 - 4 people per group

Time: Two 45-minute class periods (excluding set up)

Recommended Prerequisite Activity: Hot, Cold, Fresh, and Salty (oceanservice.noaa.gov/education/lessons/hot_cold_lesson.html)

Materials

For Pre-Procedure Set Up

- One sealable sandwich-sized plastic bag/student group
- One 14-cube ice tray/student group
- Blue or green food coloring
- Access to water (e.g., faucet and tap water)
- Access to freezer

For Procedure

- Clear container (one/student group) (suggested size 25.5 cm x 15 cm x 17.5 cm)
- Masking tape
- Modeling clay (3 – 4 different colors, if possible)
- Heat lamp (one/student group)
- Salt (¼ cup/student group)
- Refractometer (one/student group)
- Hydrometer (one/student group)
- Permanent marker (one/student group)
- Ruler (one/student group)
- 1 L beaker (one/student group)

- Small scale (triple beam balance recommended)
- Access to warm water
- Optional: Vernier Lab Quest© and salinity probe or YSI Instrumentation

Pre-Procedure Set Up

Note: this should be completed with enough time for water to freeze. Students can participate in this step or the instructor can complete.

- Fill ice cube tray with regular tap water. Add two or three drops of food coloring to each cube. Freeze overnight. Freeze one ice cube tray per group.
- Fill sandwich bag nearly full of tap water (about three cups) and add 10 drops of green or blue food coloring (recommended that you use the same color used for the ice cubes). Lay bag flat in freezer, ensuring no leaks. Freeze one plastic bag per group.

Procedure

Intro (Class Period 1)

Have your students read the Introduction provided to them in their student handout. Review with the class the scientific concepts found in the introduction (density, currents, sea level rise, etc.), define the vocabulary, and answer questions 1 and 2 on the worksheet. For an online animation that illustrates thermohaline circulation, go to:

www.windows.ucar.edu/tour/link=/earth/Water/thermohaline_ocean_circulation.html

Part 1 (Class Period 1): Create Your Ocean

- Use clay to build a centrally located "land mass" inside the clear container. This land mass should have a minimum height of 8 cm, with a flat surface (recommended shapes: cylindrical or hour-glass, see diagram below for guidance).
- Fill beaker with 1 Liter of warm tap water.
- Measure out 35 grams of salt per 1 Liter of water. This should create a 35 part per thousand saline solution close to that of sea water.
- Use the hydrometer to measure the salinity, record your results on your salinity chart.

- Repeat step 4 using the refractometer and probes, record your results.
- Answer questions 3 – 5 on the worksheet.

Part 2: Melting Sea Ice

- Pour your “sea water” into your clear container. Make sure that your “land mass” is at least 4 cm above the water level.
- Place the heat lamp over your plastic container.
- Put all fourteen colored ice cubes into your plastic container. Using masking tape and a marker, label the new water level (sea level) as Pre-Melt Sea Level 1 (PMSL1) on your plastic container as soon as the ice cubes are added. Record your new sea level in the sea level chart of your worksheet. The ice cubes are representative of sea ice.
- Allow the ice cubes to melt completely and DO NOT MIX. Re-measure the sea level and label it as New Sea Level 1 (NSL1) on your plastic container. Record your new sea level on your chart.
- Observe the layer of colored water in the container after the ice melts. Is the color on the top or bottom of your container? Why?
- Gently use the hydrometer to measure salinity; record your results on salinity chart.
- Repeat step 4 using the refractometer and probes, record your results on salinity chart.
- Answer question 6 on your worksheet.

Part 3 (Class Period 2): Melting Glacier

- Take the frozen bag of colored ice out of the freezer. Remove the bag from around the ice. This ice sheet is representative of glacial ice or land ice.
- Place the heat lamp over your plastic container.
- Place the ice sheet on your clay land mass; be sure that it is not making contact with your ocean water.
- Using masking tape and a marker, record your current sea level as PMSL2 immediately after placing the glacier on your land mass.
- After the glacier has melted completely, mark the new sea level as NSL2 on your container and record your new sea level on your sea level chart.
- Again, observe the color layers of the water. How has the level of color changed?
- Use the hydrometer to measure salinity, record your results on salinity chart.

- Repeat step 4 using the refractometer and probes, record your results on salinity chart.
- Answer question 7 on the worksheet.

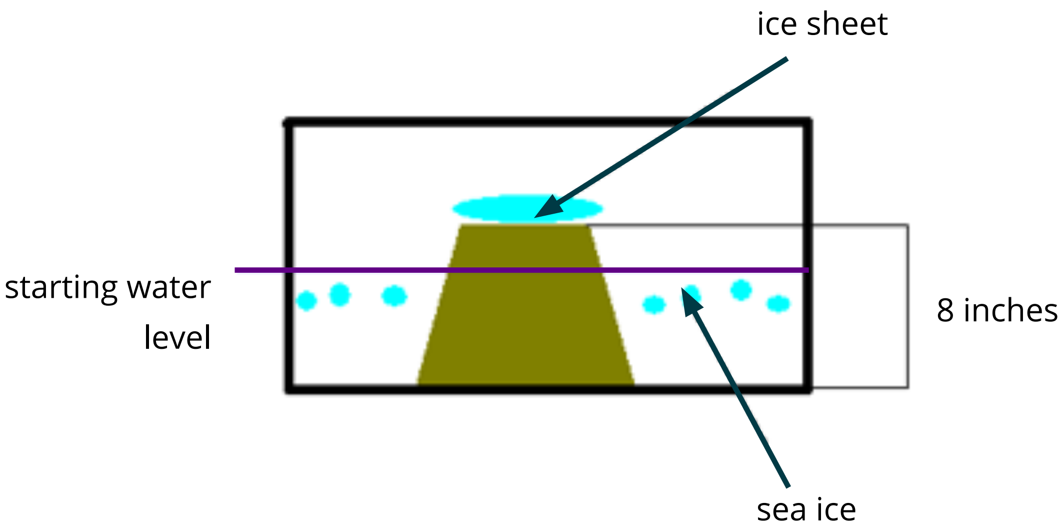

Diagram of the experiment setup.

Causes and Effects of Our Rising Seas

Student Handout

Introduction

The Cryosphere

The **cryosphere**, which is composed of freshwater **glaciers, sea ice, and continental ice sheets and caps**, is one of five major "spheres" that regulate our climate. Glaciers are masses of *land ice* that flow downhill under gravity and form by the accumulation of snow at high altitudes (International Panel on Climate Change, IPCC). Sea ice is any major ice mass found at sea that has originated from the freezing of sea water (IPCC) and is therefore already part of the ocean's total volume. Ice sheets are defined as large masses of *land ice* that cover most of the underlying bedrock of the continents which they are found on; ice caps are defined similarly, but are considerably smaller (IPCC). There are only three large continental ice sheets found in the modern world: two in Antarctica and one in Greenland (IPCC). The interactions between the cryosphere, hydrosphere, atmosphere, lithosphere (the earth's solid surface), and the biosphere (the living organisms on land and in the ocean) all determine climatic factors such as global temperatures, sea level rise, and even smaller-scale weather patterns.

Sea Level Rise

One of the major concerns linked with a global warming scenario of 1.5-4.5°C over the next 100 years is the potential for sea level (the level of the ocean surface midway between high and low tide) to increase by an average of 65 cm (approximately 6 cm per decade) (Information Unit on Climate Change, IUCC). More extreme predictions for rising sea levels range from

2-12 ft (0.6-3.6 meters) by the year 2100 (IUCC). Two major environmental factors can lead to accelerated sea level rise: (1) the oceans absorbing heat from the atmosphere which causes them to expand, and (2) the melting of glaciers and the Greenland and Antarctic ice sheets (IUCC). The first factor mentioned, **thermal expansion**, occurs when heated substances increase their volume due to vibration in their molecular components (IUCC). The effects of sea level rise would vary for each geographical location based on several factors including tidal range, land elevation, and topography (the shape and features of the land).

Ocean Currents and the Effects of Melting Land Ice

The world's oceans exhibit two types of **currents** (a horizontal movement of water or air): *surface currents* which are wind-driven, and *subsurface currents* or *deep water currents* which are density-driven. Density is the ratio of mass to a unit volume denoted as grams per cubic centimeter. In order to better understand density-driven currents, remember that colder substances (like the cold ocean water located at the higher latitudes) are denser than warmer substances. As a result, a denser substance will sink below a less dense substance due to gravity.

The subsurface currents are collectively referred to as **thermohaline circulation** (figure 1), which arises from variances in ocean water density due to temperature and salinity differences. **Salinity** is a measure of the total concentration of dissolved solids (namely salt or NaCl) in seawater, usually expressed as parts per thousand (ppt). Thermohaline circulation is responsible for the formation and perpetuation of the North Atlantic Deep Water (NADW) which originates in the north near Greenland, sinks due to its moderately salty and cold nature, and runs along the bottom of the Atlantic Ocean. This current helps to maintain what scientists refer to as "conveyor belt circulation," illustrated to you in figure 1, which plays a key role in our global climate. This circulation provides warm surface waters and also warm air masses to reach the upper latitude countries like those of Europe.

The maintenance of thermohaline and conveyor belt circulation is vital to maintaining the modern climate, particularly the upper latitude regions. What do you suppose would happen if the chemistry of the main driver of thermohaline circulation, the NADW, were to change? Suppose one of the major ice sheets, the one located in Greenland, were to melt enough due to global warming that the salinity of the NADW would change. Remember that ice sheets and sea ice are composed of freshwater and the melting of them would cause a decline in ocean salinity. The following activity will assist you in answering the above question and in understanding the basic scientific concepts that have been discussed in this introduction. Before you begin your experiment, define the terms on your student handout and answer questions 1 and 2.

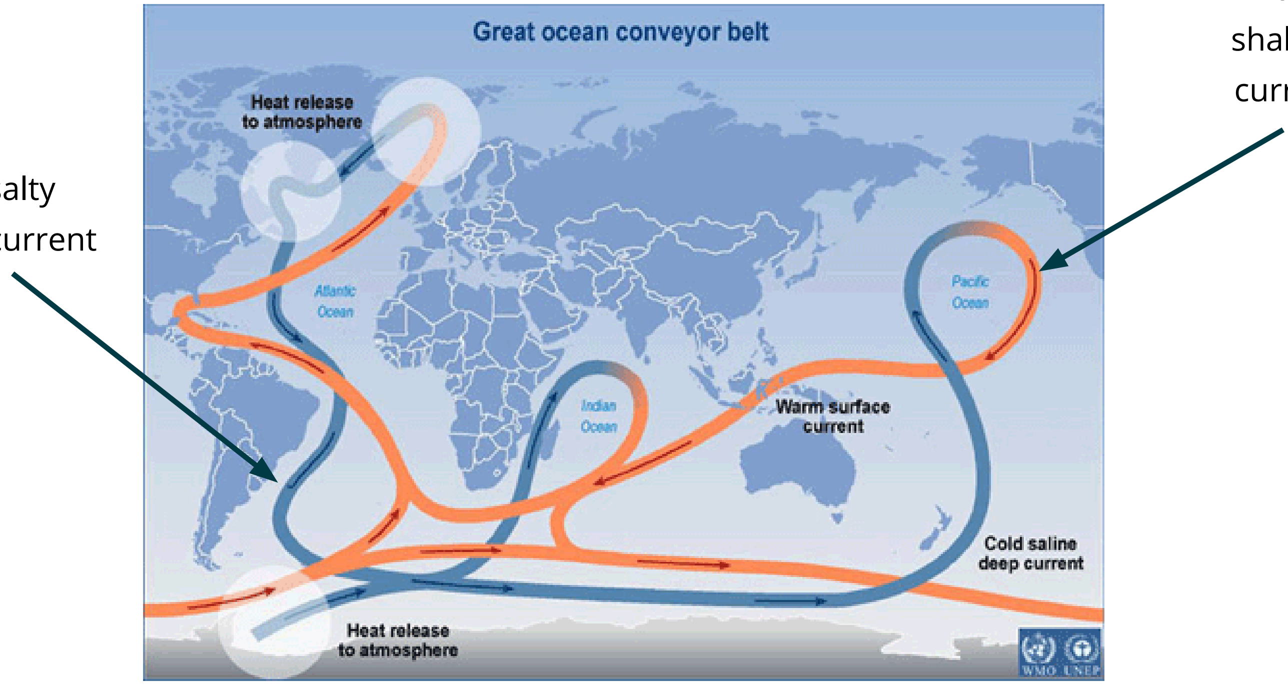

Figure 1. Image showing thermohaline and conveyor belt circulation. Credit: NOAA.

Procedure

Read the Introduction provided above, define your vocabulary, and answer questions 1 and 2 on your worksheet prior to beginning your experiment.

Part 1: Create Your Ocean

1) Use molding clay to build a centrally located “land mass” inside the plastic container, this land mass should have a minimum height of 8 cm, with a flat surface (recommended shapes: cylindrical or hour-glass, see diagram below for guidance).
2) Fill beaker with 1 Liter of warm tap water.
3) Measure out 35 grams of salt per 1 Liter of water. This should create a 35 part per thousand saline solution close to that of sea water.
4) Use the hydrometer to measure the salinity, record your results on your salinity chart.
5) Repeat step 4 using the refractometer and probes, record your results.
6) Answer questions 3 through 5 on your worksheet.

Part 2: Melting Sea Ice

1) Pour your 1 Liter of sea water into your plastic container. Make sure that your “land mass” is at least 4 cm above the water level.
2) Place the heat lamp over your plastic container.
3) Put all fourteen colored ice cubes into your plastic container. Using masking tape and a marker, mark the new water level (sea level) as Pre-Melt Sea Level 1 (PMSL1) on your plastic container as soon as the ice cubes are added. Record your new sea level in the sea level chart of your worksheet. The ice cubes are representative of sea ice.
4) Allow the ice cubes to melt completely. Re-measure the sea level and label it as New Sea Level 1 (NSL1) on your plastic container. Record your new sea level on your chart.
5) Use the hydrometer to measure salinity, record your results on your salinity chart.
6) Repeat step 5 using the refractometer and probes, record your results on your salinity chart.
7) Answer Question 6 on your worksheet.

Part 3: Melting Glacier

1) Unwrap the sheet of colored ice from the plastic bag. This ice sheet is representative of glacial ice or land ice.
2) Place the heat lamp over your plastic container.
3) Place the ice sheet on your land mass, be sure that it is not making contact with your ocean water.
4) Record your current sea level as PMSL2 immediately after placing the glacier on your land mass.
5) After the glacier has melted completely, mark the new sea level as NSL2 on your container and record your new sea level on your sea level chart.
6) Use the hydrometer to measure salinity, record your results on your salinity chart.
7) Repeat step 6 using the refractometer and probes, record you results on your salinity chart.
8) Answer Question 7 on your worksheet.

Part 4: Making Connections

You have now completed your experiment! Answer the questions in the Making Connections portion of your student worksheet (below).

Name ____________________

Date _____________________

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Student Worksheet

Vocabulary

Read the introduction on your student handout and define the following terms prior to beginning your experiment.

Sea ice:

Glacier:

Ice sheets:

Cryosphere:

Sea level:

Thermal expansion:

Salinity:

Density:

Thermohaline circulation:

Questions

Before beginning your experiment, answer the following questions.

1) Which do you think has a greater impact on sea level rise, melting glaciers or melting sea ice? Why?

2) Is a glacier made of salt or freshwater? Is sea ice made of salt or freshwater? What do you think happens to the salinity of ocean water when glaciers and sea ice melt?

Salinity Chart

	Hydrometer	**Refractometer**	**Probe**
Starting ocean salinity (ppt)			
Salinity after sea ice melts (ppt)			
Salinity after glacier melts (ppt)			

3) What does a refractometer use to measure salinity?

4) How does a hydrometer measure salinity?

5) In your opinion, which of the three methods that you used to measure salinity is the most accurate?

Sea Level Chart

PMSL1	
NSL1	
PMSL2	
NSL2	

6) What happened to the sea level after the sea ice completely melted? Why do you think you saw this effect?

7) What happened to the sea level after the glacier melted? Why do you think you saw this effect?

Making Connections

1) After having completed the experiment, which do you think has a greater impact on sea level rise, melting glaciers or melting sea ice? Why?

2) What happened to the salinity of your ocean after the glacier and sea ice melted? Knowing now what you know about ocean currents and density-driven thermohaline circulation, what kind of impact on ocean circulation do you think melting glaciers and sea ice will have?

3) What region do you think will be most impacted by melting sea ice and glaciers? What do you think the major impacts will be on this region?

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Methods of Measuring Salinity

What is Salinity?

Salinity is the amount of salt found in a solution. The open ocean (i.e., full strength seawater) is estimated at 35 parts per thousand (ppt). Closer to the coast in estuarine/brackish water systems, this amount may decrease depending on the influx of freshwater rivers and tidal cycles. During this lab, three different methods will be used for measuring salinity levels. All instruments are commonly used for measuring salinity, but each captures the amount of salt through a different process: refractometer, hydrometer, and Vernier© probe and LabQuest instruments (optional).

Refractometers

The refractometer uses the process of refraction to measure salinity. Refractometers measure the speed of light through a medium (such as a prism) and use optical glass to slow and bend light as it passes from one medium to another with a difference in refractive index. The amount of salt crystals dissolved in a solution will dictate the salinity reading. The higher the concentration of salt crystals = the increased bending of light = higher salinity reading. As light travels through the refractometer, it passes through lenses and lands on a scale. The bending of the light at the liquid/prism interface sends the light higher or lower in the scale's grid. The dividing line between light and dark is the place to obtain a reading.

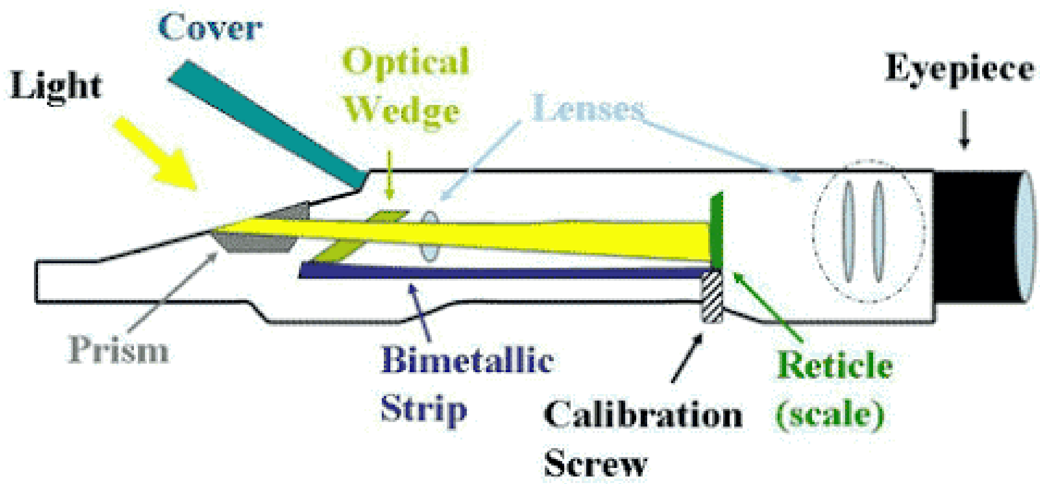

Image: schematic drawing of a refractometer.

Hydrometers

Another instrument that is commonly used to measure salinity is a hydrometer which uses specific gravity to measure the amount of salt in a solution. Specific gravity indicates density while salinity indicates the actual weight of the salt. Hydrometers are based on the assumption that a solid body displaces its own weight of the liquid in which it floats. Therefore, readings will rise based on the density (or amount of salt) in the water. Density is also dependent upon temperature – the hotter the water the higher the density (warmer water expands). Therefore, the temperature and the amount of salt come into play when getting an accurate salinity reading. Hydrometers are calibrated to 60 degrees F in which the density of distilled water equals 1.000.