Ocean Currents in a Cup

A Classroom Activity

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Adapted from Lawrence Hall of Science GEMS "Ocean Currents: Marine Science Activities for Grades 5-8"

Grade level: Grades 5-9

Concepts: In this demonstration, students will model the formation of deep water masses in the Iceland and Labrador Seas and investigate the role of salinity in stratification.

Background information: The oceans are the major surface feature of Earth, covering about two thirds of the planet. Because water gains and loses heat much more slowly than air or land, oceans are the most important factor influencing global and regional climates. One way oceans affect climate is by transporting heat from equatorial towards polar regions and giving off heat in latitudes that receive less direct sunlight. Oceans also affect climate by absorbing and releasing huge amounts of carbon dioxide, one of the most important heat-trapping gases in the atmosphere.

This activity models how cold surface temperatures in the Iceland and Labrador seas can increase water density, causing it to sink. In these far northern regions, sinking or "downwelling" water is replaced at the surface by water from warmer regions, a process which pulls relatively warm water at the surface in the North Atlantic Ocean toward the cold high latitudes. As the warm water moves toward these areas, much of its heat is lost and is carried to northern Europe by the atmosphere, warming the climate there. (see diagram by Ruth Curry at http://www.whoi.edu/science/PO/people/rcurry/powerpoint.htm)

An important factor influencing sinking is the salinity, or saltiness, of the water. Salt increases the density, or mass per unit volume, of water. The warm water transported to high latitudes in the North Atlantic is very salty since it comes from the warm regions near the equator where evaporation removes much water vapor. The very cold, salty water sinks and flows slowly (over the course of about 1000 years) at depth around the globe as part of what is called the "ocean conveyor" (see image from the international panel on climate change at http://www.ipcc.ch/present/graphics/2001syr/large/04.18.jpg or the diagram in Kevin Trenberth's article in this issue). The density-driven circulation of ocean water caused by differences in temperature and salinity is called thermohaline circulation.

Surface water will only sink if its density is greater than that of water below it. If the salinity of high latitude North Atlantic water is reduced by increased freshwater from ice melting in the Arctic Ocean and from the Greenland Ice Sheet, the formation of deep water may be decreased or halted, and the warm North Atlantic currents may not reach high latitudes. There is evidence that this has happened in the past and that the change in ocean circulation was accompanied by significant changes in regional climates (*Abrupt Climate Change: Inevitable Surprises,* US National Academy of Sciences, National Research Council Committee on Abrupt Climate Change, National Academy Press, 2002).

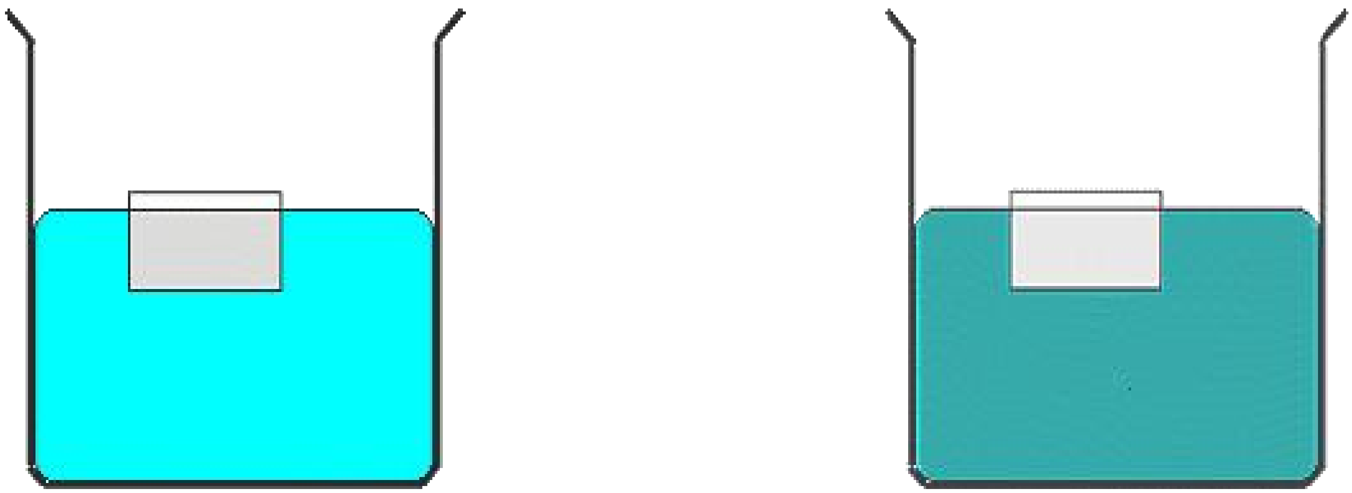
In this activity, students compare the melt time of an ice cube in fresh vs. salt water and try to explain the results. In fresh water, the cold water melting from the ice cube is denser than the room temperature fresh water and sinks to the bottom. In salt water, although the water melted from the ice cube is cold, it is fresh, so it is less dense than the salt water and does not sink. The fresh water forms a layer on top of the salt water, inhibiting mixing, and the ice cube takes longer to melt. Water masses that form layers of different densities are said to be stratified.

Vocabulary: density, salinity, downwelling, stratification, thermohaline circulation

Materials:
- clear plastic cups or beakers, at least 250 ml. or 8 oz.
- pipettes
- salt
- food coloring
- room temperature fresh water
- room temperature water with about 200 grams (about half a cup) of salt per liter (about a quart) dissolved in it
- ice cubes made from fresh water, as similar as possible in shape and volume

Activity:

1. Discuss with students how ocean water might differ in different parts of the globe. Introduce the ideas of temperature, depth, saltiness, and whether ocean water stays in the same place or moves.
2. Show students a diagram of North Atlantic circulation illustrating the transport of warm water from low to high latitudes. A diagram by Ruth Curry of WHOI is available at http://www.whoi.edu/science/PO/people/rcurry/powerpoint.htm
3. Ask students to predict whether an ice cube might melt faster in salt or fresh water, and have them explain the basis for their predictions.
4. Have students work in pairs. Give each pair of students two clear cups or beakers and have them carefully measure 250 ml (or one cup) of fresh water into one and the same amount of salt water into the other. You can tell them the difference in the two water samples or have them suggest differences to explain their observations during the discussion after the activity.



5. Distribute paper for students to record their observations.
6. Distribute two ice cubes to each pair of students and have them immediately put one in each cup.
7. Ask students to observe what happens and record their observations.
8. After all the ice cubes have melted, discuss with the students what they observed and ask for explanations. Students may wish to design other experiments to test their explanations.
9. Relate the students’ observations to the recent research results that the surface waterin the North Atlantic is freshening. Discuss with students how changes in surface circulation around the North Atlantic might affect climates in North America and Europe.

Extension:

1. A more realistic downwelling system can be modeled using salty water. Repeat the “ice cube melt” activity using ice cubes made with water saturated with salt. Students will observe the cold, salty water from the ice cube sinking in both the salt water and fresh water cups. This represents the very salty water that sinks when it becomes very cold and very dense in the high latitudes of the North Atlantic.
2. Ask students to extend the connections to the earth’s climate system by asking the following: How might the “ocean Impacts” be linked to the global climate system? Students can brainstorm and come up with a list and one line to explain each item on the list.

Notes: You may want students to observe downwelling prior to this activity. Have them follow these instructions:

1. Fill a clear plastic cup or beaker with about 250 ml of room-temperature fresh water.
2. In a different cup, add a drop or two of food coloring to about 10 ml of very cold water.
3. Use a pipette to slowly and gently add some of the cold, colored water to the cup at the edge where the water meets the side of the cup.
4. Observe what happens to the cold water.

5. Explain your observations.
6. Try the experiment in other ways, varying the temperature or salinity of the water in the cup or the water added to the cup.
7. If time allows, have students observe changes over time, as long as they do not shake their cups
8. This activity may also be done with cold salty water (color it green) and with warm water (color it red). The colder the water, the bettwe this will work/

Massachusetts Science, Technology, and Engineering Standards
Earth and Space Science
Grades 3–5

- Describe how global patterns such as the jet stream and water currents influence local weather in measurable terms such as temperature, wind direction and speed, and precipitation.
- Give examples of how the cycling of water and its change of state, both in and out of the atmosphere, has an effect on climate.

Grades 6-8
Heat Transfer in the Earth System

- Explain the relationship among the energy provided by the sun, the global patterns of atmospheric movement, and the temperature differences among water, land, and atmosphere.

Grade 9 or 10
Matter and Energy in the Earth System

- Provide examples of how the unequal heating of the earth and the Coriolis Effect influence global circulation patterns, and show their impact on Massachusetts weather and climate.
- Oceans redistribute matter and energy around the earth, through surface and deepwater currents, tides, waves, and interaction with other earth spheres.
    - Explain the dynamics of oceanic currents, including upwelling, density, and deep water currents, the local Labrador Current and the Gulf Stream, and their relationship to global circulation within the marine environment and climate.

Sources of additional information
Gagosian, Robert. Abrupt Climate Change: should we be worried? 2003. Prepared for a panel on abrupt climate change at the World Economic Forum, Davos, Switzerland
http://www.whoi.edu/institutes/occi/viewArticle.do?id=9986

NASA Facts. The Roles of the Ocean in Climate Change The Earth Observing System Terra Series FS-1999-06-026-GSFC

US National Academy of Sciences. *Abrupt Climate Change: Inevitable Surprises,* National Research Council Committee on Abrupt Climate Change, National Academy Press, 2002

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