Arctic Sea Ice Impacts on Salinity, Temperature, and Density of Sea Water

Overview
This lesson investigates the impact of melting and freezing arctic sea ice on the properties of salinity, temperature and density that contribute to the stratification of ocean waters. This lesson combines several learning approaches including a hands-on lab, a web-quest and collaboration with other students.

Grade Level: Middle School and Up

Objectives
Students will be able to:
- Explain and demonstrate how Arctic sea ice melting and freezing can impact the ocean properties of salinity, temperature and density.
- Explain and demonstrate how these properties contribute to vertical stratification of the deep ocean and the currents of the ocean conveyor belt system.

Standards
This lesson plan was developed prior to finalization of the Next Generation Science Standards and alignment of the Alaska Science Standards to them. When those standards are available, these activities will be re-aligned.

National Science Education Standards

<u>Grade 5-8</u>
Content Standard A: Science As Inquiry:
a. Abilities necessary to do scientific inquiry
b. Understandings about scientific inquiry
Content Standard B: Physical Science:
a. Properties and changes of properties in matter
Content Standard D: Earth and Space Science:
a. Structure of the earth system
Content Standard E: Science and Technology:
a. Abilities of technological design
b. Understandings about science and technology

<u>Grades 9-12</u>
Content Standard A: Science As Inquiry:
a. Abilities necessary to do scientific inquiry
b. Understandings about scientific inquiry
Content Standard B: Physical Science:

b. Structure and properties of matter
Content Standard D: Earth ad Space Science:
b. Geochemical cycles
Content Standard E: Science and Technology:
a. Abilities of technological design
b. Understandings about science and technology

Materials

- Plastic soft drink/water bottles with top portion cut off
- Insulated cup holder or enough bubble wrap to wrap around the sides and bottle base
- 500 mL local seawater or 33 –34 g salt dissolved in1000 g fresh water
- Salinity probe
- Temperature probe or thermometer and stand
- Hydrometer or multi-meter
- Freezer
- Hot plates
- Tea bag (Lipton or something similar)
- Stirring rod
- 2-500 ml glass beakers
- Student journal to collect data and write up Experimental Design according to rubric

Preparation

Students should be able to explain what density signifies, how different materials with different densities interact and what effect changes in temperature and pressure have on the density of materials. Students should also have a thorough understanding of density concepts prior to completing this lab. Density labs can be found at: https://sites.google.com/site/springs8thgradescience/word-of-the-week/ge... Select the folder labeled Density Labs.

Procedure

Part 1. Introductory Mini-Lesson: teacher presentation (5-10 minutes)

Use a diagram of the Global Conveyor Belt (see below) and a video (see below) to introduce the following information: The currents of the Ocean Conveyor Belt System contribute to weather and climate and influence the movement of heat, organisms, nutrients and gases throughout the ocean system. The main cause of ocean currents and vertical stratification involve differences in water temperature due to the uneven heating of the Earth. Another contributing factor is the difference in salinity that results from differential evaporation from the sea surface and uneven freshwater inputs to the ocean. Colder water temperatures and higher salinity both contribute to higher density seawater, which will tend to sink. In this lesson you will be exploring how the formation of Arctic sea ice increases salinity and the density of ocean water and contributes to the process of deep-water formation. By contrast, when sea ice melts, the resulting liquid water is fresher and less dense and contributes to vertical stratification. The use of tea (a form of dissolved organic carbon) will help students understand how materials in seawater (including salt) are excluded from ice when it forms.

1. Illustration of the Global Conveyor Belt in the Arctic and Atlantic: http://www.dfo-mpo.gc.ca/science/Publications/article/2006/02-04-2006-en...
2. Great Ocean Conveyor Belt: http://nsidc.org/news/press/day_after/q5_ocean_belt.html

Part 2. Lab Activity

To begin the lab activities, students will enter the title "How Sea-Ice Formation and Sea-Ice Melt Influence Sea Water Salinity and Density" at the top of a lab report or in a student science notebook. Provide them with the Experimental Design rubric (attached) which they will follow throughout the activity, beginning by stating the problem and making a hypothesis based on that problem. They will follow Part B of the rubric (B-only) as they write-up and conduct the experiment below, including data tables, graphs, photographs and/or diagrams where appropriate.

Lab activity procedure:

1. Fill a cut-off soda bottle to approximately 1 centimeter below the cut-off point, with local or classroom made seawater. Label this bottle, 'seawater'. Fill the other bottle in the same manner with your freshwater and label the bottle 'freshwater'. Measure and record the temperature and salinity of the seawater. Record data collected onto a data table. If equipment is available students can also test for the density of the water with a hydrometer or multi-meter throughout the experiment.

2. Pour the seawater into a beaker and place on a hot plate or burner stand. Add a tea bag and heat the seawater to approximately 60 degrees Celsius or just hot enough to allow the tea to leach easily into the water. Stir and gently put pressure on the tea bag occasionally during this process to increase tea leaching.

3. When the water has darkened with the tea, remove the beaker from the hot plate and let the saltwater tea solution cool approximately to room temperature.

4. Pour the seawater tea back into the cut-off seawater soda bottle.

5. Measure and record the temperature and salinity of the seawater onto the student data sheet.

6. Place the bottle with the seawater tea in the insulated cup holder, or wrap with 2 layers of bubble wrap. Make sure to include 2 bubble wrap cut outs to insulate the bottom of the bottle as well if you're using bubble wrap.

7. Place the bottle with the seawater tea in the freezer and mark the time on the student data sheet. Alternatively, for less time in the freezer, students can set the bottle in an ice bath making sure that none of the ice bath enters the bottle.

8. Leave the bottle in the freezer until about 2-6 centimeters of ice has formed on the top of the water. Freezing time will vary but should take between 2.5-6 hours depending on the starting temperatures. The teacher should test out approximate freezing time well in advance of doing the actual lab with students as freezing times vary greatly depending upon the bottle shape, freezer configuration, etc. Using the ice bath ahead of freezing greatly reduces freezing time. If due to timing students are not available when the correct top layer of ice forms, the teacher may need to conduct this portion of the lab.

9. Remove the bottle from the freezer. Place a thermometer through the ice and into the middle of the water. Determine the temperature of the water and record temperature in the data table.

10. Squeeze the bottle slightly and remove the ice layer. Mark one beaker 'sea ice' and place the ice into the beaker. Mark the second beaker 'seawater' and pour the remaining seawater tea into this beaker.

11. Allow both samples of water to warm to room temperature. (If samples are to be left overnight cover with plastic wrap to decrease evaporation)

12. Measure/record temperature and salinity. Record in the students' data table.

13. Observe the color of each water sample. Students should include drawings of each sample and write a description of what is observed based on the color of the liquids.

To complete the Experimental Design write-up using the rubric, the students will first collaborate and compare data to reach a conclusion that relates directly to their original hypothesis and then self-edit and peer-edit each other.

Part 3. Web Quest and Collaboration

Students will use the following web-based articles and videos to answer the discussion questions with their lab partner(s).

Articles

- Density of Ocean Water: Windows To The Universe http://www.windows2universe.org/earth/Water/density.html&edu=highThis links with a high reading level. This reading level can be changed with all of the Windows To the Universe readings. Please note the tabs at the top of each web page where you can change to beginner, intermediate or a translated version in Spanish.
- Thermohaline Circulation: The Global Ocean Conveyor-Windows To The Universehttp://www.windows2universe.org/earth/Water/circulation1.html&edu=high
- The Arctic Ocean Currents-Windows To The Universehttp://www.windows2universe.org/earth/polar/arctic_currents.html&edu=high
- Melting Arctic Sea Ice and the Global Ocean Conveyor-Windows To The Universehttp://www.windows2universe.org/earth/polar/icemelt_oceancirc.html&edu=high
- CTD Instrument-Windows To The Universe http://www.windows2universe.org/earth/Water/CTD.html

Videos

- Sea ice melt: YouTube: http://www.youtube.com/watch?v=dMgDOSTTXJs&feature=fvwrel
- Sea ice melt: NASA: http://www.nasa.gov/topics/earth/features/thick-melt.html
- Dive Discover-Woods Hole Oceanographic Institute: Ocean conveyor belt:http://www.divediscover.whoi.edu/arctic/circulation.html#

- NOAA Science On A Sphere: Ocean Circulation http://sos.noaa.gov

Assessment

- Part II: Students will be assessed based on the Experimental Design rubric and scores from self, peer and teacher review.
- Part III: Students will be assessed based on their responses to the web-quest survey.

Resources

- Experimental Design Rubric-National Science Olympiad: http://soinc.org/exper_design_b.
- Experimental Design Summary-North Carolina Science Olympiad Coaches Workshop October 2007, Michael Huberty Mounds View High School Arden Hills Minnesota: http://www.sciencenc.com/event-help/experimentaldesign.php

Assessment

- "Module 7:Double Diffusion Salt Fingers". The Salmon Project The Sea-Air-Land Modeling and Observing Network (SALMON) Project is located at the University of Alaska in Fairbanks, Alaska:http://www.ims.uaf.edu/salmon/education/lesson%20plans/mod7.html
- "Par 5" a Windows2Universe.org salt water vs. fresh water density lab:http://www.windows2universe.org/teacher_resources/par5_edu.html

Credits: Matt Conforti, Barrow High School, Barrow, Alaska), Lisa Seff, Springs School, East Hampton, NY; in cooperation with research scientists: Dr. Lee W. Cooper, University of Maryland Center for Environmental Sciences; Dr. Matthew Druckenmiller, National Snow and Ice Data Center at University of Colorado at Boulder and Rachel Potter, University of Alaska at Fairbanks.

This lesson included adaptations from the following lesson plans:

1. Sea Ice and Salinity: Antarctic Climate & Ecosystems CRC. Lab governed by Australian & International copyright laws. © 2007 ACE CRC.
2. Salinity Experiment: Created by CJ Mundy (University of Manitoba & Shannon Delawsky, Central Middle School, Dawson Creek, BC) 2005 Schools on Board Field Program.
3. Learning through Experimentation: Ice Cubes, Density, Currents. Adapted from Lawrence Hall of Science GEMS "Ocean Currents: Marine Science Activities for Grades 5-8". Activity 5: Ice Cube Demonstration, p. 85.

This lesson plan was developed as part of the Arctic Ocean Ecosystem Workshop, held in Barrow, Alaska, on May 18-23, 2012. The Alaska Center for Ocean Sciences Education Excellence (COSEE) and its partners Alaska Sea Grant, the University of Alaska Fairbanks (UAF) School of Fisheries and Ocean Sciences, the Alaska SeaLife center, Alaska Ocean Observing System (AOOS) and the UAF Center for Cross-cultural Studies collaborated with the North Slope Borough School District, the North Pacific Research Board (NPRB), and the Arctic Research Consortium of the US (ARCUS) to engage scientists and teachers in lesson plan development. Major support was provided by the National Science Foundation.

Teacher Background

Dr. Lee Cooper presents his research at on Arctic ocean processes and how these relate to oceans around the world at http://www.polartrec.com/resources/presentation/arctic-ocean-processes-in-the-context-of-the-global-ocean (Arctic Ocean teacher-scientist workshop, Barrow, Alaska, May, 2012)

Sea Ice Impact: An Investigation in Arctic Thermohaline Circulation

A Web-Quest Student Survey

After you have finished Parts I, II and III, of the Sea Ice Impact Lesson Plan, complete the following survey questions in your Science Notebook. Responses should cite specific details from your lab data as well as information obtained through your web-quest articles and videos. All responses should be written with complete sentences, in your own words.

1. How does temperature influence ocean water density?

2. How does salinity influence ocean water density?

3. What is a CTD instrument and what 3 important variables does it measure in the ocean?

4. Which variable, salinity or temperature has a greater effect on the density of ocean water?

5. Surface ocean currents are driven by winds. What are deep-water ocean currents driven by?

6. Explain thermohaline circulation, also known as the Global Ocean Conveyor Belt system.

7. Based on your lab results, peer discussions and web-quest materials, explain how an increase in Arctic Sea Ice melt, and resulting changes in water density could change the Global Ocean Conveyor Belt system. Make sure to cite specific examples from your lab results and web-quest materials to support your conclusions.