Ocean Layering: Density, Temperature, Salinity, and Circulation

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Summary

We developed a 3-4 day unit on the vertical structure of the ocean that gives students the opportunity to work with actual data, learn about the global circulation, and learn about some of the smaller scale features that stir and mix the ocean. The unit uses ship-based observations on a global scale and observations north of Hawaii from an ocean robot, the autonomous underwater glider Spray, as application activities.

Science Standards

We focus on teaching California science standard 5d: "Students know the properties of ocean water, such as temperature and salinity, can be used to explain the layered structure of the ocean, the generation of horizontal and vertical ocean currents, and the geographic distribution of marine organisms."

Learning Goals

• Students will be able to describe vertical currents and currents near the bottom of the ocean on a global scale.

• Students will be able to explain vertical layers of the ocean in temperature, salinity, and density.

• Students will be able to explain why temperature and salinity change more near the surface than at depth.

Misconceptions

• All ocean currents are caused by tides

• The deep ocean never changes and doesn't move

• The ocean has the same salinity everywhere

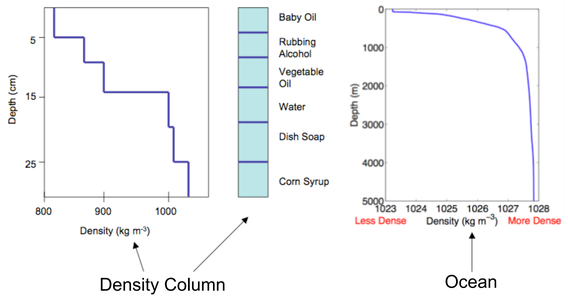
Context for Use

This activity was designed for a 9th grade earth science class, and would also be appropriate for middle school students. There are three 55-minute lessons and one 20-minute quiz. This unit was taught after an atmospheric section and a short unit on the surface circulation of the ocean. Students were familiar with the concepts of density, energy, waves, and the atmospheric circulation as well as the surface circulation of the ocean and what the ocean transports.

Lesson 1: Density and the Ocean

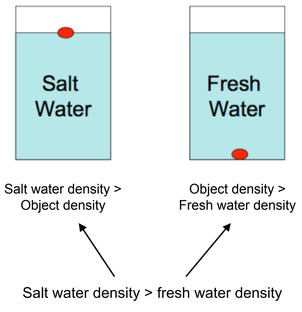
Liquids can sink and float

A density column demonstration introduces students to the idea that liquids can have different densities and can sink and float on top of each other. The ocean is like a density column with the lightest water on top and the heaviest water on the bottom.



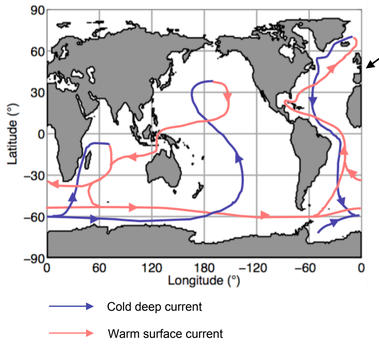
Density & Salinity

Students investigate how salinity effects density through a hands on lab activity. The sink / float lab includes one object that will float in salt water and sink in fresh water. Students conclude that salt water is denser than fresh water.



So What?

Dense water sinks to the bottom of the ocean, slowly spreads out, and slowly rises back to the surface. This circulation is sometimes referred to as the global conveyor-belt circulation.



Schematic of the global conveyor-belt circulation after the popular one by W. S. Broecker*. Water sinks in a few spots near the poles, spread out horizontally, and rises up slowly everywhere else.

*Broecker, W S, 1987. The biggest chill. Natural History Magazine, Vol. 97, pp. 74-82.

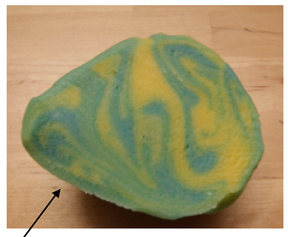
Lesson 2: Deep Currents, Stirring, and Mixing

Stirring and Mixing

Students use clay to create a model of the ocean. Different colors represent different types of water:

- Warm and cold water
- Fresh and salty water
- Polluted and unpolluted water
- Water full of organisms and water none
- Water with nutrients and water without

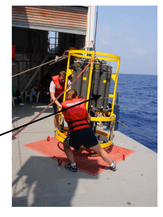
A slice through the clay gives information about what happened to the clay. Similarly, a slice through the ocean gives information about what has happened to the ocean.



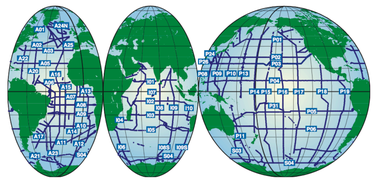
Blue and yellow colors have been stirred around, and green colors have been mixed together.

Sampling the global ocean

One way oceanographers sample the ocean is to take slices through it with a ship, stopping every 50 km and dropping instruments down to the bottom. The R/V Melville, pictured at right, is one of the ships used to sample the ocean.



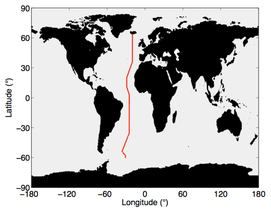
Water is collected in bottles and brought back to the surface for analysis.

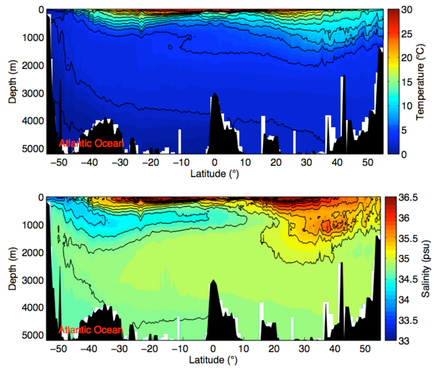


From 1990-1998, several slices through the ocean were taken as part of an international effort to observe the global ocean. Some of these sections have been observed prior to and after as well.

Atlantic Sections

Students complete a short activity using sections of temperature and salinity in the Atlantic. Students see that not all of the water on the bottom is the same, and can trace where water has come from using salinity.



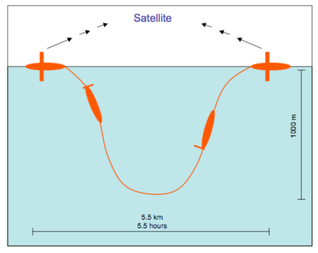


Above: sections of temperature and salinity in the Atlantic. Left: The red line shows where this section is located.

Lesson 3: Glider Observations

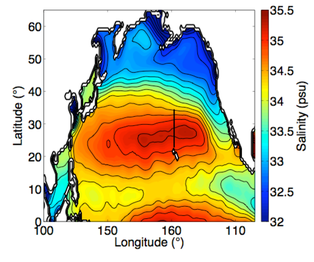
Spray Gliders: autonomous ocean robots

Gliders have no propulsion mechanism and use buoyancy to control their depth in the water by pumping oil into and out of an external bladder. The glider moves forward in the water as it dives up and down because of the wings. It is ~6 ft long and weighs ~100 lbs.



Gliders have a satellite antenna in their wings, which allows data to be sent back to the scientists and instructions to be sent to the glider. The glider travels 5.5 km horizontally in 5.5 hours for each 1000 m dive. The small horizontal spacing of dives allows smaller-scale features to be studied.

North Pacific Sections



16 sections of temperature and salinity were obtained from July 2007 - December 2009 along a line north of Hawaii. It crosses through the center of the surface gyre.

Students use six of the sections from different seasons and years to look at ocean layering and some of the smaller scale features.