Ocean Layering: Density, Temperature, Salinity, and Circulation

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Summary

This is 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 consists of four lessons and concludes with a short review and 20-minute quiz. Topics covered include an introduction to density, the ocean's global scale vertical structure and circulation, and how ocean properties are stirred around and mixed together. 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.

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.

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.

Description and Teaching Materials

The first lesson is on density and density's role in the ocean. A density column demonstration, 01t.activity.densitycolumn (http://earthref.org/cgi-bin/erda.cgi?n=1001), introduces students to the idea that liquids can have different densities and can sink and float on top of each other. A density lab, 01t.activity.densitylab (http://earthref.org/cgi-bin/erda.cgi?n=1002), allows students to determine the relationship between salinity and density. The day concludes with notes on density's role in the ocean. Students are introduced to the global circulation of sinking, spreading, and rising water sometimes referred to as the global conveyor-belt circulation. Students learn that both temperature and salinity affect density, that dense water sinks, and that

changes in the ocean's density cause currents near the bottom of the ocean. A handout to guide note taking, 01c.handout.notes (http://earthref.org/cgi-bin/erda.cgi?n=999), and accompanying slides, 01c.slides.density (http://earthref.org/cgi-bin/erda.cgi?n=1000), are also provided.
Also available:
Handout for the density lab:
01c.handout.densitylab (http://earthref.org/cgi-bin/erda.cgi?n=998)
Sample answers to the density lab handout:
01t.handout.densitylab.answers (http://earthref.org/cgi-bin/erda.cgi?n=1003)
Sample answers to the guided notes handout:
01t.handout.notes.answers (http://earthref.org/cgi-bin/erda.cgi?n=1004) page 1
Annotated instructor version of the slides on density's role in the ocean:
01t.slides.density (http://earthref.org/cgi-bin/erda.cgi?n=1006)
Tips for linking the day's segments together:
01t.overview (http://earthref.org/cgi-bin/erda.cgi?n=1005)

The second lesson on the ocean's vertical structure reinforces the idea of the global conveyor-belt circulation introduced in the first lesson. An activity using clay, 02t.activity.stirmix (http://earthref.org/cgi-bin/erda.cgi?n=1011), introduces students to how water with different properties can be stirred around and mixed together. Students then take notes on one way oceanographers sample the ocean on a global scale and a section of temperature and salinity through the Pacific Ocean. Salinity shows how the ocean is stirred and mixed on a global scale, and where some of the water is moving. A handout to guide note taking, 01c.handout.notes (http://earthref.org/cgi-bin/erda.cgi?n=999), and accompanying slides, 02c.slides.globallayers (http://earthref.org/cgi-bin/erda.cgi?n=1009), are provided. The lesson concludes with a short activity, 02t.activity.globallayers (http://earthref.org/cgi-bin/erda.cgi?n=1010), using a section through the Atlantic to look at the vertical structure of temperature and salinity and the relationship to vertical and horizontal currents.
Also available:
Handout for the global layers activity in color and black & white:
02c.handout.altsections.color (http://earthref.org/cgi-bin/erda.cgi?n=1008)
or 02c.handout.altsections.gray (http://earthref.org/cgi-bin/erda.cgi?n=1007)
Sample answers to the global layers activity handout:
02t.handout.atlsections.answers (http://earthref.org/cgi-bin/erda.cgi?n=1012)
Sample answers to the guided notes handout:
01t.handout.notes.answers (http://earthref.org/cgi-bin/erda.cgi?n=1004) page 2
Annotated instructor version on the slides on global ocean sections:
02t.slides.globallayers (http://earthref.org/cgi-bin/erda.cgi?n=1014)
Tips for linking the day's segments together:
02t.overview (http://earthref.org/cgi-bin/erda.cgi?n=1013)

The third lesson is on the vertical structure and seasonal changes of a small section through the North Pacific. Students are introduced to an autonomous underwater vehicle called a Spray Glider that collected the observations using a few slides, 03c.slides.gliders (http://earthref.org/cgi-bin/erda.cgi?n=1018). An activity using these observations, 03t.activity.nplayers (http://earthref.org/cgi-bin/erda.cgi?n=1019), teaches students about the vertical structure and circulation of the ocean on smaller scales as well as seasonal changes in the

ocean. Students answer questions individually, and in groups comparing observations from different seasons.
Also available:
Handouts for the North Pacific layers activity in color and black & white:
03c.handout.nplayers.figs.color (http://earthref.org/cgi-bin/erda.cgi?n=1016)
or 03c.handout.nplayers.figs.gray (http://earthref.org/cgi-bin/erda.cgi?n=1015)
and 03c.handout.nplayers.ques (http://earthref.org/cgi-bin/erda.cgi?n=1017)
Sample answers for the North Pacific layers activity handouts:
03t.handout.nplayers.answers (http://earthref.org/cgi-bin/erda.cgi?n=1020)
Annotated instructor version on the slides on ocean gliders:
03t.slides.gliders (http://earthref.org/cgi-bin/erda.cgi?n=1022)
Tips for linking the day's segments together:
03t.overview (http://earthref.org/cgi-bin/erda.cgi?n=1021)

The fourth lesson is a short review and 20-minute quiz on the ocean's vertical structure. The quiz, 04c.handout.quiz.color (http://earthref.org/cgi-bin/erda.cgi?n=1024), consists of multiple choice and application questions. There are an extra 25 minutes for a more extensive review or additional activities at the instructors discretion.
Also available:
Handout for the quiz with black & white figures:
04c.handout.quiz.gray (http://earthref.org/cgi-bin/erda.cgi?n=1023)
Answers to the quiz:
04t.handout.quiz.answers (http://earthref.org/cgi-bin/erda.cgi?n=1025)
Tips for a short review before the quiz:
04t.overview (http://earthref.org/cgi-bin/erda.cgi?n=1026)

No homework assignments are included with this unit. We assigned appropriate readings and questions from their textbook to reinforce the concepts discussed in class that day. Deciding on an appropriate homework assignment, if any, is left up to the instructor.

Some activities in this unit have questions with no right or wrong answer. They are designed to get the students thinking, observing, and applying concepts.

Common misconceptions include:
- All ocean currents are caused by tides
- The deep ocean never changes and doesn't move
- The ocean has the same salinity everywhere

Each file in the unit is titled so that the first two digits "01-04" refer to the day with "00" referring to material for the overall unit, "c" refers to material for the students, and "t" refers to material for the teacher.
Material for the overall unit is here:
A glossary of useful terms:
00t.glossary (http://earthref.org/cgi-bin/erda.cgi?n=996)
A supply list for the unit:
00t.supplylist (http://earthref.org/cgi-bin/erda.cgi?n=997)

A list of files and brief descriptions:

00t.filelist (http://earthref.org/cgi-bin/erda.cgi?n=995)