**Ocean Layering: Density, Salinity, Temperature, and Circulation**
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**Activity: North Pacific vertical layers**
See '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)
See '03c.handout.nplayers.questions' (http://earthref.org/cgi-bin/erda.cgi?n=1017)
See '03t.handout.nplayers.answers' (http://earthref.org/cgi-bin/erda.cgi?n=1020)

**Goal:**
Students interact with observations and see some of the smaller-scale features and seasonal changes in the ocean.

**Instructor Prep:**
- Print out copies of the figures and questions for each student. Different students will have different figures.

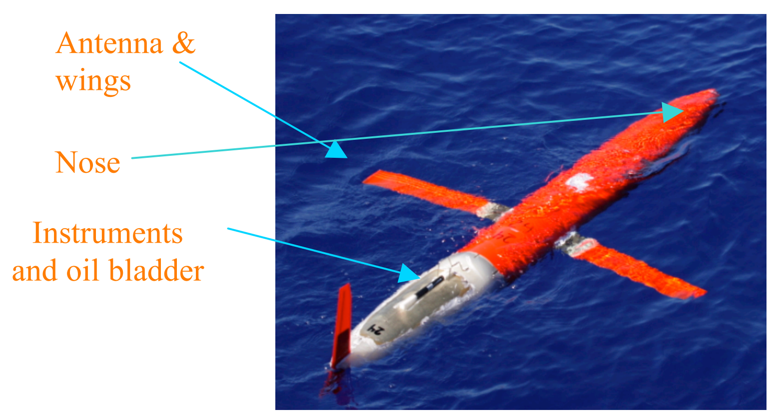
**Implementation:**
- Neighboring students should have different sections. The sections are labeled A-F on the bottom left. Not all sections need to be used.
- Lead the students through question 2 first. An example is included in '03c.slides.gliders' (http://earthref.org/cgi-bin/erda.cgi?n=1018).
- Give students time to complete the remaining three questions on their own.
- Instruct students to work in pairs or small groups to finish the remaining questions.

**Conclude:**
Discuss similarities and differences between the sections and the seasonal changes that occur. The last two slides in '03c.slides.gliders' (http://earthref.org/cgi-bin/erda.cgi?n=1018) are sections from winter, spring, summer, and fall. See notes in the instructor version, '03t.slides.gliders' (http://earthref.org/cgi-bin/erda.cgi?n=1022).

**More information:**
Temperature, salinity, and density were observed along a north-south section north of Hawaii taken with autonomous underwater Spray gliders.

*How does a Spray glider work:*
The Spray glider was developed by Scripps Institution of Oceanography and is routinely deployed around the world.

The Spray glider does NOT have a propulsion mechanism, and sinks and rises in the ocean




Spray glider

by changing its buoyancy. Buoyancy is controlled by pumping oil into and out of an external bladder. Wings on the sides provide forward movement as the glider sinks and rises so that the glider moves horizontally through the water as well. Just by pumping oil out of an external bladder, the density of the glider increases, the glider sinks, and the wings push it forward through the water.

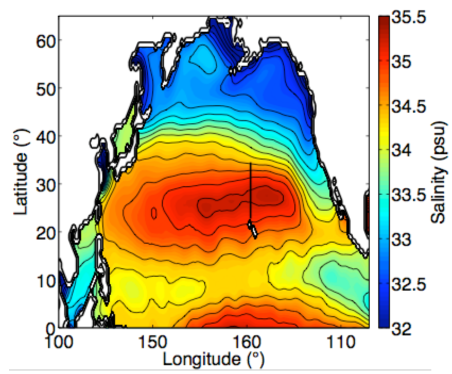
The glider is steered by moving battery packs inside it forward and backward to control the pitch and side to side to control the roll. This is the same way a person steers a hang glider by moving their weight around. Gliders must continuously dive and surface, with dive depths between 100 m and 1000 m. Horizontal speed is approximately 0.25 m/s, which is faster than most average currents in the upper 1000 m.

Gliders have a satellite antenna that allows them to send data back and receive instructions in near-real time. The data can be checked, the glider can be told to head in a different direction, and the position is reported so we know where to pick up the glider at the end of its mission.

Gliders are deployed and recovered at minimal cost from small boats. The lifetime of a glider is limited by its battery life, which is 3-4 months. Two gliders can be used to continuously observe the ocean for a longer time period. For the Hawaii observations, a second glider was deployed when the first one was recovered. The recovered glider was then shipped to San Diego, batteries changed, sensors checked, and shipped back to Hawaii for another deployment.

*Hawaii Observations:*
The gliders were deployed from Hawaii because that is a convenient island in the middle of the subtropical gyre. Gliders occupied the section almost continuously from July 2007 to December 2009.

This activity uses six of the sections collected over the 2.5 years of observations. The section code is in the lower left of the page in '03c.handout.nplayers.figs.color' (http://earthref.org/cgi-bin/erda.cgi?n=1016). These six were chosen because they cover the entire section and are from different seasons and years.



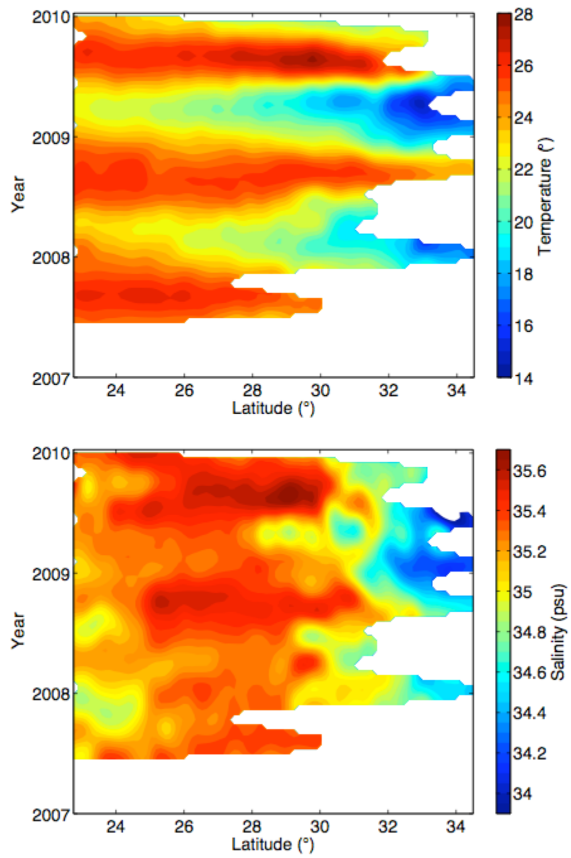
The map shows mean surface salinity from the World Ocean Atlas (see glossary) with the glider track in black slicing through the center of the gyre.

| Section Code | Date at south end | Date at north end | Season |
|---|---|---|---|
| A | 20 Nov 2007 | 12 Jan 2008 | Winter |
| B | 04 Aug 2008 | 25 Sept 2008 | Summer |
| C | 16 Nov 2008 | 25 Sept 2008 | Fall |
| D | 30 Mar 2009 | 31 Jan 2009 | Winter |
| E | 14 Apr 2009 | 09 Jun 2009 | Spring |
| F | 09 Aug 2009 | 09 Jun 2009 | Summer |

*FAQ's*

- How big is the seasonal change?

The figure to the right shows how temperature and salinity at 10 m depth evolved over the 2.5 years of the experiment. Temperature changed seasonally by 5-10°C. Salinity changed seasonally by less than 1 psu. The picture of temperature is something that oceanographers can observe with satellites, but the picture of salinity requires instruments in the ocean.




Temperature (top) and salinity (bottom) at 10 m depth mapped with a 50 km lengthscale and 80 day timescale. Not all of the sections went to 34.5°N.

- Why does salinity change abruptly in some places?

Just like there are fronts in the atmosphere that separate cold and warm air, there are fronts in the ocean that separate warm and cold water, or fresh and salty water, or polluted and unpolluted water, or almost any other property. In this case, the abrupt change in salinty near 30-32°N is called the subtropical front.

- What are all the little wiggles? Why aren't temperature, salinity or density flat?

In the vertical sections, the smallest wiggles are called internal waves. Just like throwing a pebble in a pond produces waves on the surface between the water and air that spread out horizontally, there are waves in the middle of the ocean that wrinkle the density surfaces. The "pebble" that generates these waves can be wind blowing on the surface or the flow of tidal currents over ridges and mountains in the ocean.

- How do the gliders know when to turn around?

We tell them. Each glider gets a set of points to head for in a certain order. When the glider gets close enough to one of those points, usually within 1 km, it heads for the next one. We can also change what point it is heading for by sending a message it will get when it surfaces.

- Do you ever loose them?

Yes. Like all instruments that are put in the ocean, there is a chance that something will happen and you will not get the instrument back. While the chances are small that we won't find a glider again, gliders can have mechanical problems and get stuck below the surface, can have problems communicating, can be caught in fishing nets, or run over by boats.

- How much do they cost?

With a basic set of sensors, the instruments cost around $80,000 each. Compared to many oceanographic instruments this is cheap. One day of ship time costs $10,000-$30,000. Moorings (a string of instruments at different depths in one location) can cost anywhere from $50,000-1,000,000. The expense of a ship means that gliders are very cheap if they can be deployed close to land.

- Can I access the data?

Data for some of the spray gliders including the Hawaii sections can be found at http://spray.ucsd.edu/ under the 'data' tab. The Hawaii sections have 'HOTS_Hawaii' as their location. Maps and sections for each deployment can be found by clicking on the glider number.