Print

# 2008 Annual Report: Physical Oceanography

On a calm day, ocean waters may look featureless and smooth at the surface. Beneath, currents and variations in the water's temperature, salinity, density and other features create structure within the ocean that affects sea, land, and atmosphere. Researchers in the Physical Oceanography (PO) Department seek to describe and understand the physical structure and variability of the ocean and the processes that create that structure and variability.

They investigate physical properties of the ocean using laboratory experiments, analytical and numerical modeling (creating mathematical descriptions and computer simulations of the ocean to test against real-world observations), analysis and synthesis of existing data, and new observations at sea. A strong heritage and expertise in observing the ocean and in developing new observational methods plays a defining role in work done by members of the PO Department, in 2008 as in other years.

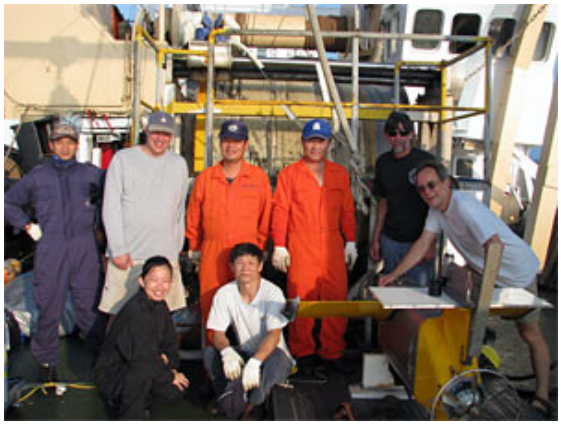
Here, we highlight some of the year's accomplishments.

- Glen Gawarkiewicz, Frank Bahr, and Craig Marquette participated in an international experiment to study oceanographic processes that contribute to uncertainty in predictions of ocean currents and how sound travels in the East China Sea. In September 2008, these scientists conducted a pilot experiment for this project, jointly with scientists from National Central University, National Taiwan University, and National Taiwan Ocean University.
- In this pilot project northeast of Taiwan, WHOI and National Taiwan University team members used a "SeaSoar"—a towed vehicle that undulates up and down through the water, measuring water properties as it moves forward— to identify water from the strong Kuroshio Current forcefully intruding over the continental shelf. The Kuroshio is the northward-flowing current that is the Pacific counterpart to the Gulf Stream in the western north Atlantic. The main fieldwork for this international project will take place in August and September 2009, with four different ships measuring ocean currents, temperature, salt content, and density, as well as how sound propagates in an oceanographically complex region.

- Closer to home Richard Limeburner, Bob Beardsley, and Will Ostrom deployed an array of three moorings from the *R/V Tioga* to measure and record temperature, salinity, and currents at the three main openings to Nantucket Sound – between Woods Hole and Martha's Vineyard, between Martha's Vineyard and Nantucket, and between Nantucket and Monomoy Island on Cape Cod. The moorings were recovered in November 2008, refurbished and re-deployed December, and their final recovery will be in June 2009.

- The moorings'– collected measurements will be used to improve computer models of ocean circulation for the waters around Cape Cod and the larger-scale coastal ocean in this region. One of these is the Northeast Coastal Ocean Forecast System (NECOFS) – a coupled atmosphere/ocean model for the New England and Gulf of Maine region, recently developed by PO's Bob Beardsley and Changsheng Chen of the University of Massachusetts Dartmouth.

- Work at high latitudes continues as a research focus. In August-September 2008, a WHOI PO Department team led by Richard Krishfield (see www.whoi.edu/beaufortgyre for details) returned to the Beaufort Gyre in the Canadian Arctic Ocean, to make field observations, re-deploy moorings, and install instrument systems including Ice-Tethered Profilers (ITPs), Ice Mass Balance Buoys (IMBs)) and Autonomous Ocean Flux Buoys (AOSBs) – all designed to measure properties of the ice-covered ocean. Scientists will observe variability over years to decades, observe changes in



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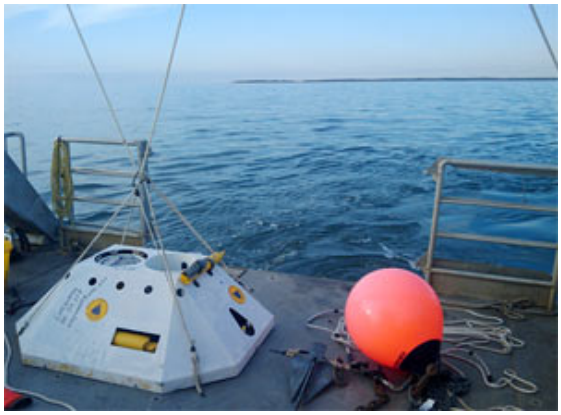
The Taiwanese/U.S. "Sea Soar" team on the fantail of the research vessel *Ocean Researcher #1*. The team used the towed vehicle to measure ocean properties and identify water from the Kuroshio Current over the continental shelf.



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A bottom-mounted instrument package is being deployed from the R/V *Tioga* on a calm day in December 2008. Wasque nature reserve, on the southeast corner of Martha's Vineyard, is visible in the background. (Photo by Richard Limeburner, Woods Hole Oceanographic Institution)

Enlarge Image

Due to the ice conditions, Will Ostrom brings the recovered top float of a BGOS (Beaufort Gyre Observing System) mooring onboard upside down, with the "upward looking sonar" that measures ice thickness, now pointed down! Four BGOS moorings were recovered for the 5th straight year and three were redeployed to obtain another year of oceanic data beneath the Arctic ice pack. (Photo by Gerty

fresh water and heat content, and aim to understand processes involved in Arctic climate change. Since 2004, 31 of these systems—developed and constructed at WHOI, placed by WHOI and by international teams of scientists—have operated throughout the Arctic Ocean in all seasons, recording conditions from the seafloor to just below the ice cover (approximately 7 to 760 meters.)

- Fiamma Straneo continued fieldwork in Canada's Hudson Strait, to quantify the transport of freshwater southward through the strait, part of the overall export of freshwater from the polar region, a process that markedly affects ocean circulation. Straneo also began doing innovative measurements from a small local vessel in a glacial fjord in East Greenland, that showed a thick layer of warm, salty subtropical waters rapidly intruding deep into the fjord, which may contribute to the acceleration of Greenland's outlet glaciers (and loss of ice) that researchers observe.

- PO Department members continue to do research in the Red Sea under a research partnership with KAUST (King Abdullah University of Science and Technology) highlighted elsewhere in this annual report. Planning for the National Science Foundation's Ocean Observatory Initiative (OOI) advanced this year as well.

- Terry Joyce and many in the Department have been studying the formation of a persistent layer of constant-temperature seawater in the north Atlantic [link here] called "18 $^{o}$C mode water" that may influence climate – part of a project called CLIMODE ("CLIVAR Mode Water Dynamics Experiment.") Shipboard research for this project finished in 2007, and scientists are following up this year with data analysis and publication.

- Members of the Department continue making long-term observations of the ocean – both with long-term "Ocean Reference Station" moorings (off northern Chile, north of Hawaii, and in the North Atlantic trade winds region) and with ongoing deployments of ARGO profiling floats that drift throughout the global ocean automatically measuring temperature and salinity from the surface to great depth.

- Claudia Cenedese is interested in improving our understanding of how buoyant (less-dense) waters in the ocean transport pollution and sediments along coastlines, particularly when multiple buoyant sources are present. Using a combination of analytical calculations and laboratory simulations, she is studying the interaction and stability of two buoyant coastal currents having different densities. Using calculations, she predicted different scenarios for where the currents would be, along the coastline. Then, doing laboratory experiments with a rotating tank designed to mimic Earth's rotation, she confirmed her analytical predictions. Furthermore, she discovered that the two current fronts (edges) became unstable, as shown in the accompanying image. This result – the two currents' coupled frontal instability – is different from previous results on the instability of a single current, a difference that is unexpected and interesting, and could yield insight into real-ocean situations.

- Members of the PO Department also continued numerical and analytical modeling and theoretical studies through 2008. Joe Pedlosky's contributions were acknowledged when he was invited to deliver the Haurwitz Lecture at the January 2009 American Meteorological Society annual meeting, presenting a talk entitled "Kelvin's Theorem, the Tunneling of Rossby Waves and the Circulation around Planetary Islands." And Senior Scientist Ray Schmitt participated in a large study on climate change by the National Academy of Sciences, serving on a panel on the science of climate change.

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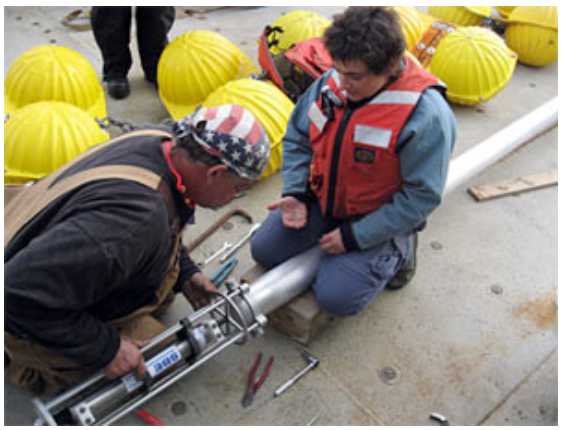
After deploying an Ice-Tethered Profiler, Canadian Coast Guard crew member Gary Morgan attaches the helicopter sing to a winch for transport back to the icebreaker. The surface buoy will drift with the sea ice in all seasons and broadcast data from the subsurface instruments in real time to WHOI, which will make the data available on the ITP Web site within hours of acquisition. (Photo by Rick Krishfield, Woods Hole Oceanographic Institution)



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Scientist Fiamma Straneo and Kyle Covert, Boatswain of the R/V *Knorr*, put together the upper part of a mooring designed to measure the transport of fresh water through the Hudson Strait. The long tube containing a CTD recorder resides in the upper part of the water column, where collisions with icebergs and sea ice could occur. (Photo by Dave Sutherland, Woods Hole Oceanographic Institution)

—*Robert Weller, Department Chair*

*Last updated: August 10, 2009*

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Joe Pedlosky, delivering the Haurwitz Lecture at the January 2009 meeting of the American Meteorological Society. (Woods Hole Oceanographic Institution)

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Mail: Woods Hole Oceanographic Institution, 266 Woods Hole Road, Woods Hole, MA 02543, USA.
E-Contact: info@whoi.edu; press relations: media@whoi.edu, tel. (508) 457-2000
Problems or questions about the site, please contact webdev@whoi.edu