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Using Dye to Study Lateral Mixing in the Ocean: 100 m to 1 km

Murray D. Levine
Oregon State University
104 COAS Admin Bldg
Corvallis, OR 97331
phone: (541) 737-3047 fax: (541) 737-2064 email: Levine@coas.oregonstate.edu

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LONG-TERM GOALS

The long-term goals of this research are to understand submesoscale processes causing horizontal dispersion of momentum and scalar quantities. We are interested in these processes in the open ocean as well as their role in mixing the coastal ocean.

OBJECTIVES

The specific objectives of the proposed research are to:

- Continue participation with Lateral Mixing DRI investigators in planning a coordinated multi-year observational program,
- Conduct dye release experiments in conjunction with the other observations planned by the other investigators to address DRI hypotheses, and
- Analyze experimental data and report results in Lateral Mixing workshops, national scientific meetings and publications.

APPROACH

The approach for each of the three specific objectives is given below.

Planning for coordinated multi-year observational program. The most recent planning meeting for the Lateral Mixing DRI took place in Seattle in December 2009. In June 2010 a virtual experiment was conducted by phone to attempt to simulate the decision making issues that would occur in a real field experiment. The next meeting is scheduled for January 2011 in Los Angeles; the Lateral Mixing investigators will assemble for the purposes of developing and refining the experimental plans for the first major field experiment scheduled for June 2011.

Conduct dye release experiments. We have purchased a new vertical profiling system for use from a moving ship, called a Moving Vessel Profiler (MVP) (manufactured by ODIM Brooke Ocean, Canada). As part of the purchasing agreement, we conducted a 3-day test cruise with an ODIM engineer off Newport, Oregon, in April 2010. Several fluoroscein dye releases were made at the surface to provide practice in using the MVP to track a dye patch.

We participated in the integrated 7-day test cruise known as the East Coast Pilot experiment along with groups led by J. Ledwell, M. Sundermeyer and K. Shearman. Several dye releases were conducted as well as a number of exercises testing our capability to acquire, process and use real-time data streams.

The major field experiments are being planned for 2011 and 2012. In 2011 there will be 3 ships. Currently we expect to be on the vessel which injects and tracks dye, similar in operation to the East Coast Pilot cruise.

Analyze experimental data. Data analysis will follow each of the field efforts. The objectives of the test cruises are to assess the performance of the sensor system as well as evaluate the software tools developed to assist in tracking the dye. Adjustments and improvements will be made where necessary.

Following the major experiment in 2011, we will participate in a collaborative analysis with the other Lateral Mixing investigators. We envision that part of the analysis effort will include workshops leading to presentations at national meetings and publication in refereed journals.

WORK COMPLETED

We attended the Lateral Mixing workshop in Seattle in December 2009. Progress was made on planning for the first major field experiment in Spring 2011. Preparations were also made for the East Coast Pilot experiment which took place out of Beaufort, NC, in August 2010. We also participated in the virtual experiment which was conducted by phone in June 2010. The goal was to use near real-time products to guide an observational program. This provided practice for making decisions that will be necessary during the real field program. The exercise revealed the usefulness of certain remote sensing and model products and highlighted the challenges that will be faced during a real field experiment.

We conducted a 3-day cruise on the R/V Wecoma in April 2010 to test the newly-acquired Moving Vessel Profiler (MVP). This first deployment of this system was done with the aid of an MVP engineer. We learned much about running the instrument through a series of profiling exercises involving two surface dye releases. It was also a first opportunity to test our software system for analyzing real-time profile data from the MVP in conjunction with the ship's underway ADCP velocity profiles. The software is designed to provide a prediction of the dye patch advection which helps in deciding how to modify the ship's course.

The East Coast Pilot cruise occurred over 7 days in August 2010 on the R/V Cape Hatteras. Our objective for participating in this pilot cruise was to gain experience running the underway MVP and to learn how to work efficiently with the team of other investigators on board. The MVP group was nominally on watch from midnight to noon with the objective of running the MVP for significant blocks of time during these watchs. Computers in the main lab (Figure 1) controlled and monitored the operations of the automated MVP winch system (Figure 2). Different computers were also used to track the real-time ship track and the predicted location of the dye patch.

RESULTS

During the East Coast Pilot cruise we made over 2000 vertical profiles of temperature, conductivity, and fluoroscein fluorescence, to a depth of at least 50 m (Figure 3). We found artificial inversions in the salinity calculation due to the relatively slower response of the temperature sensor compared to the

conductivity cell. We are working on a processing scheme to compensate for the different sensor responses.

We gained experience in dye tracking which involved using the real-time data processing and prediction software to make informed decisions about making changes in ship heading and speed.

Figure 1. MVP control and analysis computers being monitored in main lab on R/V Cape Hatteras

Figure 2. MVP automated winch system on deck of R/V Cape Hatteras.

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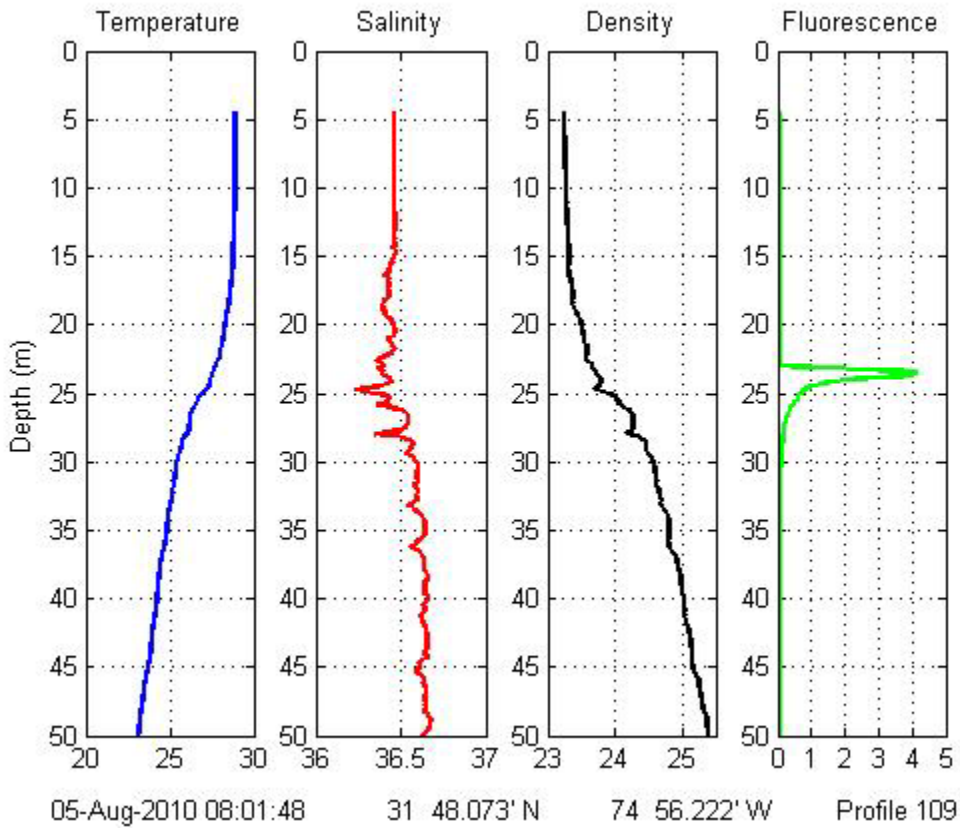

Figure 3. Profile of temperature, salinity, density and fluorescence (units of 0.1 ug/liter) made during a dye tracking survey.

We also experimented with following a pre-defined sampling grid pattern as a strategy for looking for dye while at the same time providing the larger ocean context.

Some preliminary results from the 6-day test cruise in 2009 off the Oregon coast were presented at the February 2010 Ocean Sciences meeting in Portland, Oregon. The dye was released in the surface layer near a significant horizontal density front. A fundamental objective of this analysis is to understand how the dye mixed and dispersed through this frontal region. A manuscript of this result is in preparation.

IMPACT/APPLICATIONS

During the 3-day Wecoma test cruise we had the opportunity to take 6 oceanography graduate students. Although it was only a test cruise, it provided a chance for them to experience sea-going operations without having to make a large time commitment. Some exposure to this type of field work could be valuable to these students as they continue their career.

RELATED PROJECTS

The observation and modeling of the coastal ocean off Oregon continues to be of great interest at OSU. Ultimately, improving understanding of the lateral mixing process will help in our ability to model coastal circulation.

Relating to the coastal ocean, I am currently involved in making continuous observations from a mooring at a site 10 miles off Newport (NH-10). Near-real time data are being collected and distributed on the web. This effort is funded by NOAA as part of the ocean observatory system, through the Northwest Association of Networked Ocean Observing Systems (www.nanoos.org) and www.orcoos.org), and by NSF, through the Center for Coastal Margin Observation & Prediction (CMOP) (www.stccmop.org).

I am also involved in CMOP (as Co-Director) with a major goal of improving our understanding of the river to ocean system. Submesoscale processes are important in trying to understand horizontal dispersion and mixing of the river plume with the coastal ocean. We have had the opportunity to conduct several short a dye release experiment in the Columbia River plume, learning much about tracking dye in a very energetic environment.