

# **Rapid Surveys of Frontal and Inner Shelf Features of Wind-Driven Upwelling**

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Grant #: N00014-0310406

## **LONG-TERM GOALS**

The long term goal of this project is to further understanding of the frontal and inner shelf dynamics of an upwelling system, particularly with respect to the evolution of frontal gradients, secondary frontal circulation and the formation of interleaving layers of differing hydrographic/optical properties (such as the commonly observed, but poorly understood, temperature maximum and high turbidity layers).

## **OBJECTIVES**

We aim to:

- Investigate the structure and dynamics of the upwelling front off Oregon in response to varying wind stress
- Investigate the three-dimensional extent of interleaving features, and their relation to alongshore gradients.
- Produce rapid hydrographic and current profiler (ADCP) sections which will guide, and provide context for, collaborative Autonomous Underwater Vehicle (AUV) and vertical profiling observations.

## **APPROACH**

Our primary observational tools are a Minibot undulating CTD and shipboard ADCP. The Minibot carries a payload of a Seabird 25 CTD, instrumented with a transmissometer and chlorophyll fluorometer in addition to regular CTD sensors. At a survey speed of 6-7 knots, we can make rapid transects of shelf and frontal hydrographic structure, including repeated passes through the frontal region in order to document the evolution of frontal features and gradients. The 2003 phase of the fieldwork has been conducted from a small vessel, the 54 ft *R/V Elakha*, although we plan to use a larger UNOLS vessel in 2004, allowing simultaneous operation of several sampling platforms. The

# Report Documentation Page

*Form Approved  
OMB No. 0704-0188*

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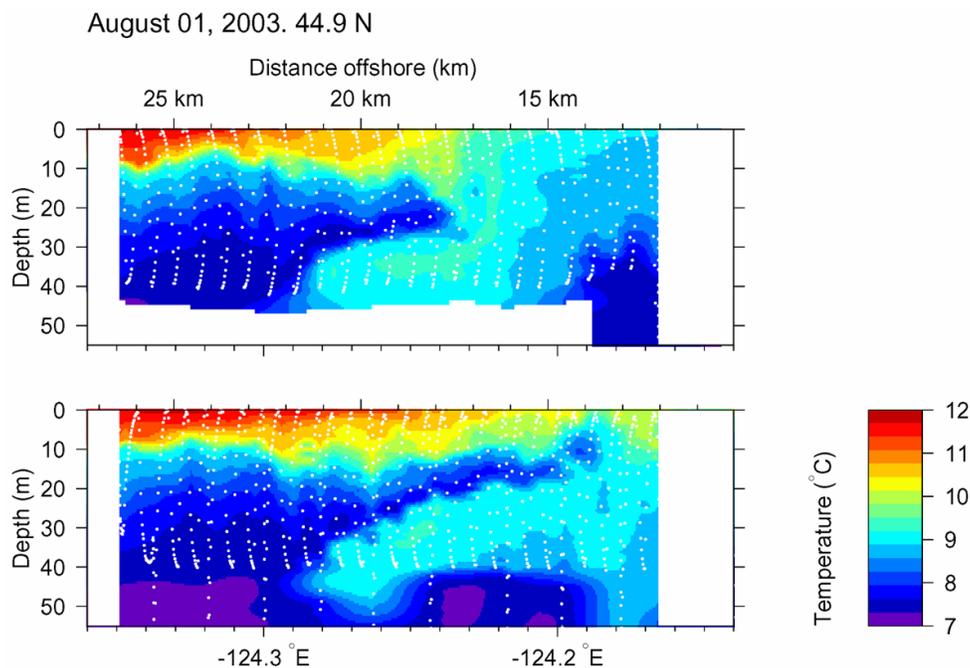
1. REPORT DATE <b>30 SEP 2003</b>	2. REPORT TYPE	3. DATES COVERED <b>00-00-2003 to 00-00-2003</b>			
4. TITLE AND SUBTITLE <b>Rapid Surveys of Frontal and Inner Shelf Features of Wind-Driven Upwelling</b>		5a. CONTRACT NUMBER			
		5b. GRANT NUMBER			
		5c. PROGRAM ELEMENT NUMBER			
6. AUTHOR(S)		5d. PROJECT NUMBER			
		5e. TASK NUMBER			
		5f. WORK UNIT NUMBER			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>College of Oceanic and Atmospheric Sciences,,Oregon State University,104 Ocean Admin. Bldg,,Corvallis,,OR,97331</b>		8. PERFORMING ORGANIZATION REPORT NUMBER			
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)			
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)			
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release; distribution unlimited</b>					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT <b>The long term goal of this project is to further understanding of the frontal and inner shelf dynamics of an upwelling system, particularly with respect to the evolution of frontal gradients, secondary frontal circulation and the formation of interleaving layers of differing hydrographic/optical properties (such as the commonly observed, but poorly understood, temperature maximum and high turbidity layers).</b>					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT <b>Same as Report (SAR)</b>	18. NUMBER OF PAGES <b>4</b>	19a. NAME OF RESPONSIBLE PERSON
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>			

field program has been led by Dr Dale, with technical assistance from Dennis Root. Dr Barth has also contributed to the field effort and his involvement will continue to the analysis phase.

## WORK COMPLETED

At the time of writing we have completed two of three planned 4-5 day collaborative field experiments scheduled for summer/fall 2003 (July 28-August 1 and August 26-29), and are embarking on the third (September 30-October 4). The Minibat undulating CTD, has been performing excellently, providing high quality data with good spatial coverage, from inshore of the 20 m isobath to up to 35 km offshore, and from near the surface to within 5 m of the bed. Minibat observations have been made on days adjoining AUV and profiler observations, yielding valuable contextual information. In addition to supporting collaborative observations in this way, we have also been able to pursue our own scientific goals by making back-to-back transects on August 1, August 26 and September 30, providing vivid pictures of evolving frontal structure and gradients on the timescale of 2-6 hours (see results below).

Detailed analysis of frontal gradients and potential vorticity structure will begin when the final phase of the 2003 observational program is complete.



***Figure 1. Evolution of an anomalously warm, turbid, chlorophyll-rich layer on the Oregon shelf. August 1, 2003. Two Minibat sections of temperature are shown, with the lower panel following the upper by approximately 1.5 hours and showing an elongation of the warm layer.***

## RESULTS

The observations of greatest interest from the early phases of fieldwork are two sets of back-to-back transects through the upwelling front made on August 1 and August 26. On August 1 (figure 1) we observed what appeared to be the initial stages of the formation of a temperature inversion layer. On

the first pass through the frontal region, a pooling of warm, turbid, chlorophyll-rich water, apparently of near-surface origin, extended to more than 40 m deep beneath the front. 1.5 hours later, this pooled water had smeared out horizontally, associated with an onshore motion of the relatively cool layer above it. This was a particularly intense feature, although whether it was primarily a result of alongshelf or cross-shelf processes will be a focus for investigation.

On August 26, a steep upwelling front was present 5 km offshore. Following 6 hours of downwelling-favorable winds, this front had apparently been driven toward the coast then offshore along the bed to the 25 m isobath. The distributions of hydrographic and optical properties in these two cases show clearly the evolution of the inner shelf and frontal structure during this period.

## **IMPACT/APPLICATIONS**

The datasets so far collected, in combination with collaborative AUV and profiler observations, are valuable contributions to the understanding of the dynamics of upwelling fronts, particularly with respect to evolution on short time scales (several hours), and the formation of interleaving features.

## **RELATED PROJECTS**

This project is part of a collaborative effort by Oregon State University researchers to address inter-related scientific questions concerning the dynamics, optical properties, and biology of the Oregon coastal ocean through the coordinated use of novel and complementary sampling platforms and methods. Lead investigators of other components of this work are Wijesekera/Boyd (AUV and microstructure), Pegau (AUV-measured optical properties) and Cowles (bio-optical profiler).

Drs. Dale and Barth, in conjunction with Murray Levine (also OSU) and Jay Austin (Old Dominion University), are also currently funded by NSF (2002-2004) for a series of dye tracer studies investigating the Lagrangian dynamics of the Oregon upwelling system. This work is highly complimentary to the objectives of this ONR project.