AUV-Based Measurements of the Oregon Coastal Ocean

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LONG-TERM GOALS

Our long-term goals are to understand the mechanisms of turbulence and mixing in the coastal ocean environment sufficiently well to be able to incorporate mixing processes in coastal circulation models as sub-grid scale parameterizations. We specifically target turbulent mixing in heretofore difficult to sample areas related to significant features of the coastal circulation. Our investigation includes processes affecting the surface boundary, upwelling front, buoyant plumes, and biological thin layers. We plan to address this objective by conducting measurements to concurrently resolve microscale, finescale, and mesoscale variability of various oceanic variables from sensors mounted on an autonomous underwater vehicle (AUV) along with other available and appropriate shipboard technology.

SPECIFIC OBJECTIVES

The specific objectives addressed in this study are:

1. Examined the structure and dynamics of vertical mixing over the continental shelf, including the surface wave boundary layer, upwelling front and coastal jet, using AUV-based concurrent measurements of temperature, salinity, horizontal velocity, and conductivity microstructure. These measurements have been placed within a mesoscale context provided through hydrographic measurements conducted by Andrew Dale and Jack Barth.

2. Examined spatial correlations among physical, optical, and biological variables, especially in regions of biologically active thin layers, using AUV-based concurrent measurements of physical, biological, and optical variables together with high-resolution vertical profiling, in collaboration with Scott Pegau and Tim Cowles.

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14. ABSTRACT

Our long-term goals are to understand the mechanisms of turbulence and mixing in the coastal ocean environment sufficiently well to be able to incorporate mixing processes in coastal circulation models as sub-grid scale parameterizations. We specifically target turbulent mixing in heretofore difficult to sample areas related to significant features of the coastal circulation. Our investigation includes processes affecting the surface boundary, upwelling front, buoyant plumes, and biological thin layers. We plan to address this objective by conducting measurements to concurrently resolve microscale, finescale, and mesoscale variability of various oceanic variables from sensors mounted on an autonomous underwater vehicle (AUV) along with other available and appropriate shipboard technology.

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APPROACH

Our collaborative approach included measurements with an AUV in order to resolve horizontal variability of physical, biological, and optical properties at a variety of scales (microscale, finescale, and mesoscale). Our AUV-based horizontal surveys have been in conjunction with high-resolution vertical measurements obtained by a slow free-falling profiler (conducted by Timothy Cowles), and with mesoscale CTD survey by an undulating CTD platform, MiniBat (conducted by Dale/Barth).

WORK COMPLETED

We planned three 4-day experiments (a total of 12 days) using OSU's small boat R/V Elakha during the summer of 2003. So far we have completed two collaborative experiments, one during July and the other during August, and 3rd experiment is planned to begin on 30 September, 2003. We adapted the following strategy during our two 4-day cruises conducted summer of 2003. (i) First carried out a mesoscale CTD survey from Dale/Barth's undulating towed platform, MiniBat, and (ii) then map the area of interest by flying the AUV in an undulating or lawn-mower pattern, while concurrently making a series of high-resolution vertical profiles along the programmed path of the AUV. We also performed several constant depth flights, which provided a data stream with O(1 m) horizontal resolution.

The following variables were measured during those cruises.

Hydrography: Temperature, salinity, pressure, and potential density
Velocity: Horizontal velocities (with high vertical resolution upward-looking 1200 kHz ADCP, and 300 kHz downward looking DVL)
Microstructure: Temperature and conductivity microstructure
Optics: AC9+, spectral backscattering and irradiance
Surface Meteorology: Meteorological measurements, using a custom built meteorological package for use on R/V Elakha.

Apart from those cruises we also conducted two 2-day test cruises (May and June, 2003) off the coast of Oregon before our collaborative studies. During those test cruises we familiarized ourselves with AUV navigation, operation, and testing of our payloads.

RESULTS

The preliminary scientific results of our summer 2003 cruises are summarized below.

Mixing near a frontal boundary: We measured temperature variance dissipation rate (χ_T) in the inner to midshelf region off the coast of Oregon along with finescale hydrographic and velocity fields on July 29, 2003, during which surface winds were upwelling favorable with magnitude of about 5 m/s (Figure 1). The background meteorological record shows upwelling favorable winds events of about 10 m/s had occurred prior to our collaborative study. The measoscale CTD survey conducted by Dale and Barth on July 28, 2003 showed a well developed upwelling front located near 44.9N, 124.7W. The AUV data sets shows elevated turbulent mixing rates (for example see eddy diffusivity in Figure 1) at the frontal boundary closer to the surface. The inshore side of the upwelling front was weakly stratified and has relatively high mixing rates compared to the offshore side of the front. The characteristic turbulent scale, $L_t = (K_H/N)^{1/2}$ was largest at the frontal boundary (Figure 1, bottom panel), where L_t was estimated by assuming the time scale associated with turbulent temperature fluctuations was on the order of [buoyancy frequency]$^{-1}$, N^{-1}.

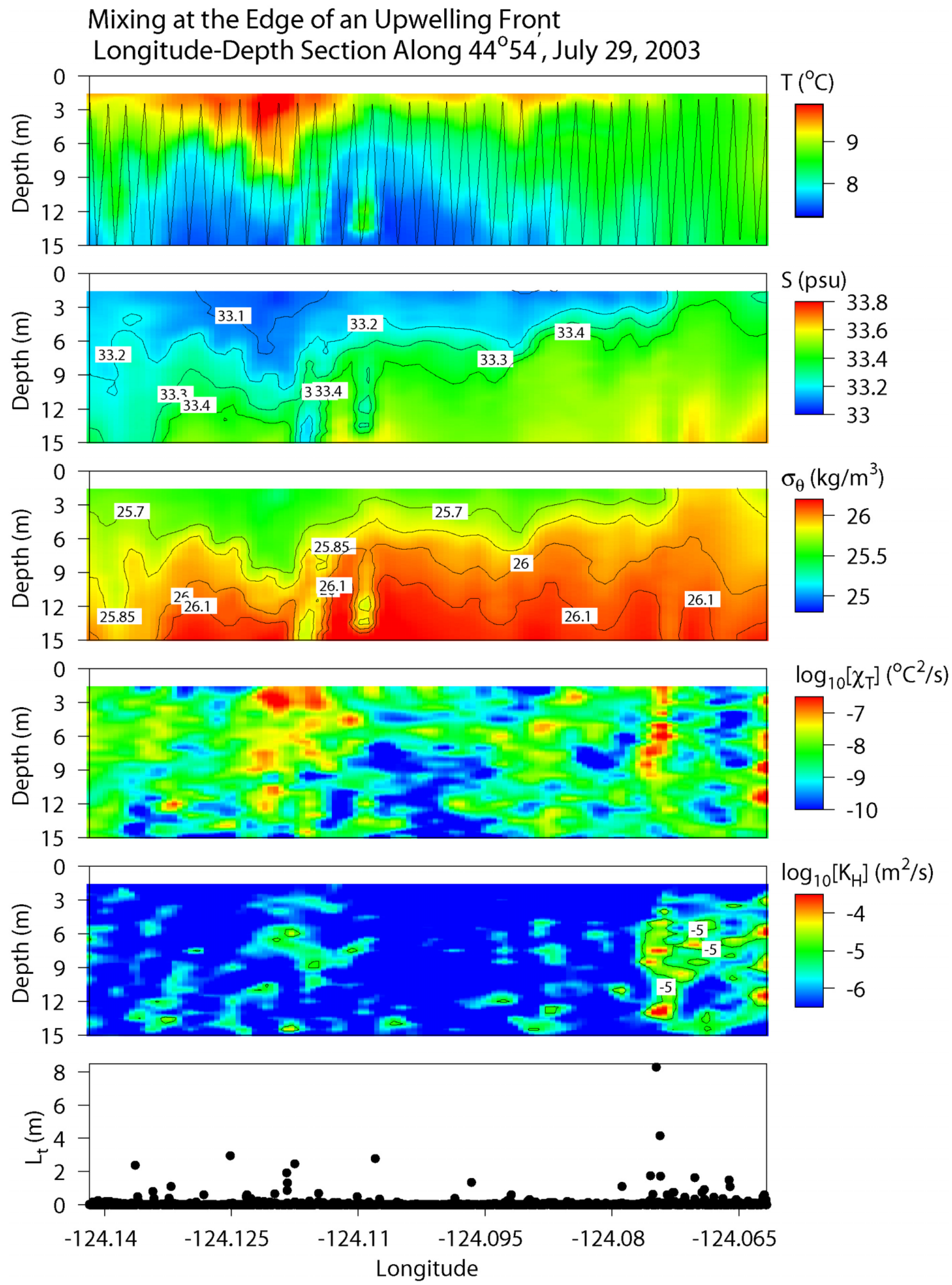

Figure 1: Hydrographic and microstructure observations in the upper 15 m. Top panel shows color image of temperature distribution along with AUV flight pattern (thin black lines). Distance between up and down casts was about 125 m. Salinity (2nd panel). Potential density (3rd panel). The selected three salinity and density contours are marked to show the location of the inshore side of the front. Logarithmic values of χ_T (4th panel). Logarithmic values of turbulent eddy diffusivity $K_H = \chi_T/\{2(\partial T/\partial z)^2\}$ and a characteristic turbulent length scale L_t (5th panel).

Mixing in a temperature inversion: The AUV survey conducted during July 30, 2003 off the coast Oregon (44.9N, 124.12W) shows a near surface temperature intrusion (Figure 2, left panel) similar to the intrusions reported by Austin and Barth (2000) and Pak et al. (1970) under similar surface wind conditions. What is new in the present observations is that we measured turbulent mixing and velocity/shear within the intrusion. As shown in the T-S diagram (Figure 2, right panel), the salinity field controls the density field. The physics of the formation of this type of structures is not well understood, but it has been suggested that upwelled water that is heated at the coastal boundary and subsequently subducted as it moves offshore. Within the inversion, there is a high spatial-correlation between observed temperature and the turbidity signal (which was measured from AC+9 and made available by Scott Pegau). Also there is an elevated turbulent mixing within the inversion compared to the outside of it (Figure 2). The characteristic turbulent scale estimated using $L_t = (K_H/N)^{1/2}$ is also comparable with the width of the temperature intrusion. The apparent spatial correlations among scalar fields (temperature and turbidity) and turbulent mixing suggest that turbulent mixing play an important role in the evolution these subductive features.

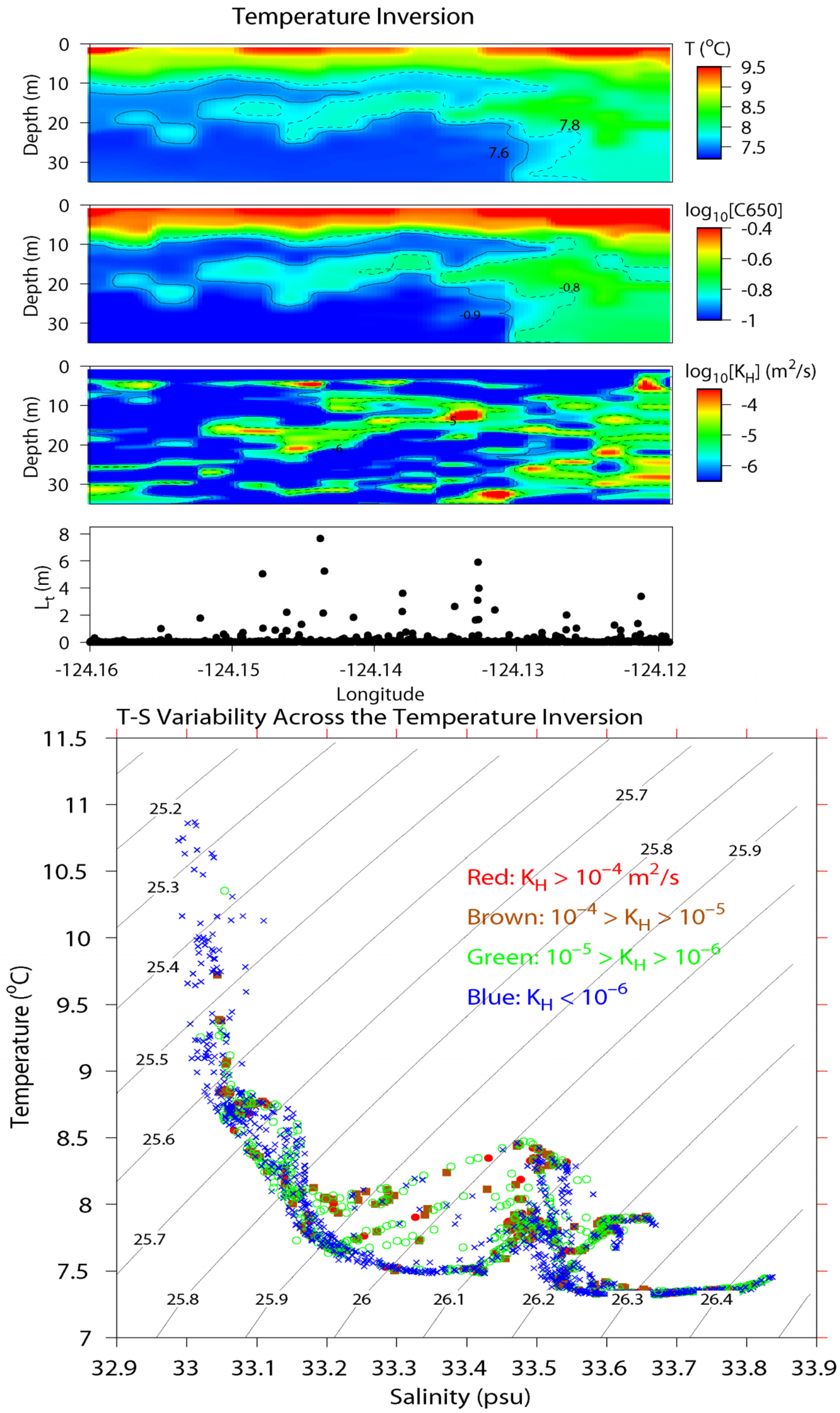

Figure 2: Temperature inversion observed on 30 July 2003. Left panels: temperature (T), turbidity corresponding to 650 nm wavelength (provided by Scott Pegau from AC9+ data sets); eddy diffusivity, and turbulent length scale. Right panel shows T-S structure plotted in eddy diffusivity bins; colors denote magnitudes of turbulent eddy diffusivity bins used. High values of eddy diffusivity can be found within the temperature inversion ($25.8 < \sigma_\theta < 26.1$ kg/m^3).

RELATED PROJECTS

AUV based optical measurements by Dr. Pegau at COAS/OSU.
Horizontal MiniBat survey off the coast of Oregon by Drs. Dale and Barth at COAS/OSU.
Vertical profiles of bio-optical properties by Dr. Cowles at COAS/OSU.

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Pak, H., G. F. Beardsley, Jr., and R. L. Smith, An optical and hydrographic study of a temperature inversion off Oregon during upwelling. J. Geophys. Res., 75, 629-636, 1970.

PUBLICATIONS

T. Boyd, H. Wijesekera, S. Pegau, and I. McCAllum. AUV-based measurements of the Oregon Coastal Ocean. Poster presented at EPOC Meeting, August, 2003.

Wijesekera, H. W., and T. J. Boyd, Measuring scalar microstructure in the coastal ocean using AUV as a platform (in preparation).