Consequences Of Persistent Small-Scale Biological Structure On Upper Ocean Trophic Processes

Timothy J. Cowles
College of Oceanic and Atmospheric Sciences
104 Oceanography Admin Bldg
Oregon State University
Corvallis, OR 97331-5503
Office: (541) 737-3966 FAX: (541) 737-2064 email: cowles@oce.orst.edu
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LONG-TERM GOALS

Our long-term goal is to quantify the interactions between small-scale biological and physical processes in the upper ocean. This project addresses that goal by examining the coherence in the distribution and variability of small-scale bio-optical properties with coincident spatial and temporal scales of physical properties and processes.

OBJECTIVES

Our scientific objective is to resolve temporal and spatial patterns in bio-optical and physical processes on those scales most relevant to planktonic organisms. Given the small size of planktonic organisms and the range of time intervals over which these organisms grow and reproduce, our objective requires observations that span centimeters to tens of meters in the vertical dimension, over time intervals of minutes to days. Integration of physical measurements with the biological measurements, on the same time and space scales, provides the opportunity to evaluate the trophic consequences of particular patterns of distribution and variability. Only by virtue of technical advances within the past few years, however, are we able to obtain the necessary high-resolution observations to address these questions.

APPROACH

We address the objectives and questions outlined above through time-series deployments of a free-fall profiling system. The instrumentation package has an adjustable fall speed so that we can resolve vertical patterns on scales less than 10 cm. Typically, we adjust the buoyancy on the profiling package to provide 2-3 cm resolution of physical and bio-optical properties during each profile. Repeated profiles (approximately 6 per hour) provide the time series necessary to define the temporal patterns of persistence of small-scale features. The profiling package is designed so that the instrumentation configuration can be modified easily. The deployment configuration used in these field experiments has consisted of a Sea-Bird 911 CTD, dual multi-wavelength absorption and attenuation meters (ac-9), a multi-wavelength spectrofluorometer which measures dissolved colored organic matter (SAFIRE), a data acquisition system (MODAPS), an Acoustic Doppler Velocimeter (ADV), and a rosette system for obtaining discrete samples during profiling. In addition, we deploy a thermistor chain to record temperature flucuations due to the passage of internal waves and record the vertical structure of horizontal currents with the shipboard Acoustic Doppler Current Profiler (ADCP).

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The combined data set obtained with the profiler, thermistor chain, and shipboard ADCP gives us the opportunity to address several important questions about bio/physical interactions on the small-scale. For example, what are the dominant time scales of persistence of small-scale planktonic structure? Are all bio-optical properties correlated within persistent small-scale features? To what extent can persistent planktonic features be predicted from physical processes? What are the consequences of intense small-scale planktonic structure on optical signal attenuation?

WORK COMPLETED

Our analysis in 1998 and 1999 includes data obtained during a 14-day cruise in September 1997 and a 21-day cruise in September 1998. During each of these field operations, we conducted time-series observations at three locations off the coast of Oregon. We focussed on a mid-shelf station (16 km from shore), a shelf-break station (50 km from shore), and an offshore station (200 km from shore). At each of these stations, we deployed a thermistor chain to record internal wave activity while recording the vertical pattern of horizontal currents with the shipboard Acoustic Doppler Current Profiler. We obtained several hundred high-resolution profiles of the upper water column with our free-fall profiler, and were able to obtain discrete samples with our mini-rosette system during free-fall profiling. Data analysis and sample processing from the 1997 and 1998 cruises is now complete and we are preparing manuscripts for submission.

RESULTS

Internal Waves

We have observed a wide range of internal wave activity at all locations, resulting in vertical displacements of 5-10m within 10min intervals (Figure 1). These rapid displacements altered the small-scale vertical patterns of phytoplankton distribution but rarely lead to mixing over these small vertical scales.

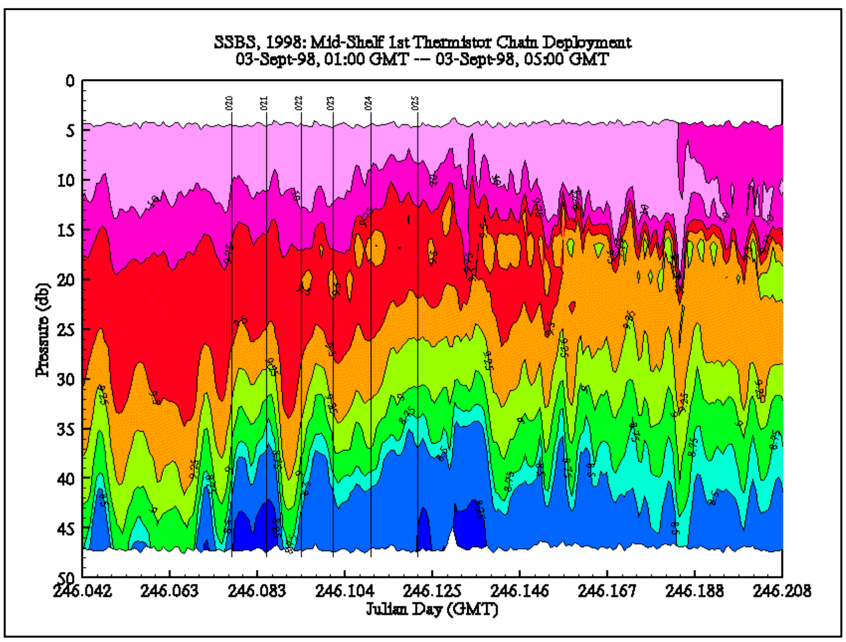

Figure 1. Contour plot of isotherm displacement during a four-hour interval on 3 September 1998. The contour interval between different colors and isolines is 0.25^o C. These data were collected with a thermistor chain suspended from from the ship while the ship maintained its position at mid-shelf, over the 80m isobath. Thermistors were spaced every 3m between 4 and 47m, and recorded temperature every 20s.

Thermistor chain data summaries for the 1997 and 1998 cruises can be found at: http://argon.oce.orst.edu/web/biooptics/projects/ssbs/results/tchain/tchain.htm

Relationship of small-scale horizontal velocity and vertical phytoplankton distribution

As mentioned above, our unique profiling system can detect vertical differences in horizontal velocity (relative to the profiler, using the Sontek Acoustic Doppler Velocimeter) while simultaneously measuring temperature, salinity, and optical properties. We have found a remarkable coherence between the small-scale velocity gradients and the vertical structure of density and phytoplankton (Figure 2).

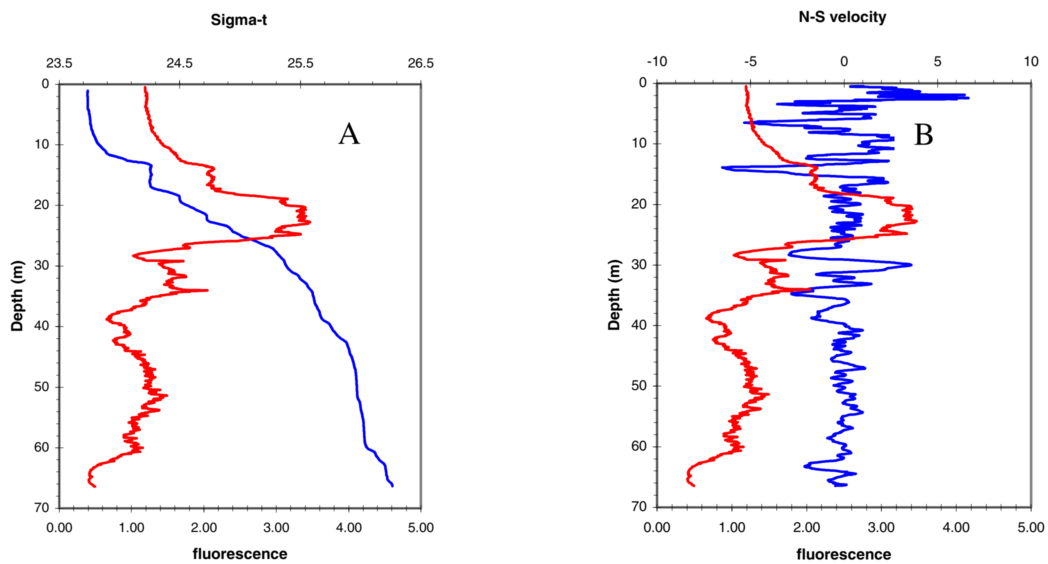

Figure 2. (A) Vertical profiles of sigma-t and fluorescence obtained on 20 September 1998 at the mid-shelf location off Oregon. Note the successive steps in density structure between 14m and 40m, and the corresponding structure in the vertical profile of fluorescence. (B) The vertical structure in the N-S component of horizontal velocity, relative to the profiler, as determined from the ADV. Note the steep velocity gradients near steep gradients in phytoplankton fluorescence, particularly at 14m and 28m. The three narrow maxima in fluorescence at 29, 32, 35m are also associated with small-scale vertical gradients in horizontal velocity.

These results suggest that care must be taken in the interpretation of vertical structure in the absence of coincident data on horizontal velocity on small scales. We are now analyzing the 4m vertical binned velocity data from shipboard ADCP and moored ADCP (at the mid-shelf 80m isobath) and establishing the mean field context for interpretation of the small-scale gradients in velocity obtained with the free-fall profiler.

Small-scale plankton distributions

We consistently observe persistent patterns of plankton distribution, with extremely steep gradients in properties over vertical intervals of 10-40 cm. Discrete samples across these confirm the observations obtained with our in situ bio-optical instrumentation.

Additional information about these cruises and the data sets can be found at :
http://argon.oce.orst.edu/web/biooptics/projects/ssbs/ssbs.htm

IMPACT/APPLICATION

Our instrumentation suite and observational approach provide the opportunity to extend our understanding of the response of planktonic assemblages to physical forcing across a range of time and space scales. We find persistent planktonic distributions within thin bands less than 1m thick, even when surface wind forcing is substantial. We can now address the trophic consequences of small-scale planktonic distributions that maintain their structure long enough to have a significant influence on growth and production.

TRANSITIONS

The two open ocean cruises with this instrumentation suite has prepared us for more extensive observations of horizontal scales of persistent small-scale structure. We will be using the free-fall profiling system during cruises off the Northern California and Oregon coasts in 2000 and 2001 as part of the CoOP and GLOBEC programs.

RELATED PROJECTS

This project is jointly supported by the Office of Naval Research and the National Science Foundation, Division of Ocean Sciences. Drs. Evelyn and Barry Sherr are co-investigators on the NSF portion of this work.

This ongoing work is also related to the Thin Layer experimental work in East Sound, WA, where we have direct field collaborations with the following ONR Principal Investigators:

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