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

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passage of internal waves and record the vertical structure of horizontal currents with the shipboard Acoustic Doppler Current Profiler (ADCP).

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

We have completed 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 cruise is now complete and initial manuscripts are in preparation. We are proceeding with data analysis and sample processing for the 1998 cruise.

RESULTS

We have observed a wide range of internal wave activity at all locations, resulting in vertical displacements of 5-10m within 10min intervals. While these displacements are rapid, in most cases the displacements do not appear to alter the small-scale vertical patterns of phytoplankton distribution via mixing. Our observations of small-scale vertical shear with the ADV will help us address this aspect of vertical mixing.

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.

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 begin to 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 use the free-fall profiling system with other ONR investigators off the Oregon coast during the summer of 1999.

RELATED PROJECTS

This project is jointly supported by the National Science Foundation, Division of Ocean Sciences. 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:

Dr. Percy Donaghay, University of Rhode Island
Dr. Jan Rines, University of Rhode Island
Dr. Dian Gifford, University of Rhode Island
Dr. J.V. R. Zaneveld, Oregon State University
Dr. Alice Alldredge, UC Santa Barbara
Dr. Sally MacIntyre, UC Santa Barbara
Dr. Mary Jane Perry, University of Washington
Dr. Van Holliday, Tracor Systems