THIN LAYERS: OBSERVATIONS OF SMALL-SCALE PATTERNS AND PROCESSES IN THE UPPER OCEAN

FOR DECADES, marine scientists have been asking questions about the response of planktonic distributions and processes to physical forcing across a range of temporal and spatial scales. The mismatch in measurement capabilities in physical, chemical, and biological oceanography, however, often frustrated attempts to link planktonic responses to physical forcing over equivalent time and space scales. The compelling nature of these questions about linkages and scale, coupled with technological advances in optical and acoustical methods, has resulted in the development of new instrumentation packages and sampling approaches that permit us to quantify and evaluate small-scale planktonic processes and physical processes on coincident temporal and spatial scales. The technical advances in optics and acoustics have included improved sensitivity and accuracy as well as greatly improved spatial and spectral resolution. The sensors resulting from these technical advances now have been deployed on a wide variety of platforms, including moorings, bottom-mounted inverted echo sounders, remotely operated vehicles (ROVs), autonomous underwater vehicles (AUVs), towed vehicles, and free-falling or bouyancy-controlled packages that decouple the instruments from the "smearing" effects of ship motion.

We now have the ability to resolve the vertical structure of biological, chemical, and physical properties on spatial scales of a few centimeters. As illustrated by the papers in this issue of *Oceanography*, many of the observations with these new optical and acoustical systems have revealed previously unresolved "thin layers" of phytoplankton and zooplankton <1 m in vertical extent. These submeter vertical structures often have local concentrations many times larger than found just above or below the layer. Some of these small-scale structures have been observed to persist for days over horizontal scales of kilometers.

These observations of small structure raise questions about the impact of such structure on planktonic processes, including those of nutrient flux, phytoplankton growth, feeding by zooplankton, reproductive behavior, and predation by animals at higher trophic levels. What physical mechanisms are involved in the formation, maintenance, and dissipation of small-scale planktonic structure? To what extent do small-scale planktonic structures in the upper ocean influence, or bias, observations obtained from satellite-based, ocean color sensors? The papers in this volume address some of these questions, while providing examples of the rich structure that, just a few years ago, was invisible to us.

This issue of *Oceanography* attempts to focus attention on "critical scale" phenomena that involve physics, chemistry, and biology. It is our contention that the sampling approaches described in these papers provide the means for new insights into upper ocean processes. It is likely that further observations of these "critical scale" phenomena may force us to reassess some of our existing ideas about planktonic processes, trophic dynamics, and physical-chemical-biological coupling. We hope that this collection of papers illustrates the need for that reassessment and stimulates readers to explore the role of small-scale distributions and the processes that occur within them. A sound understanding of these structures and processes is essential as we address questions ranging from how an individual organism finds sufficient food for growth and reproduction, to how ocean physics is linked to the amount of life the sea can sustain.

—*Tim Cowles and Percy Donaghay*