THE OFFICIAL MAGAZINE OF THE OCEANOGRAPHY SOCIETY

Oceanography

DOI

http://dx.doi.org/10.5670/oceanog.2006.58

significant conclusions about Hydro as a national strategic and policy asset. As it is, we see only the particulars.

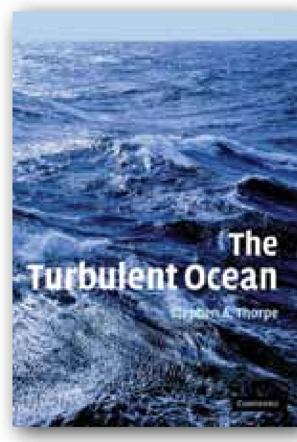
Addressing Hydro's history in the particular also misses the opportunity to appreciate essential relationships with other services, other countries, and with the academic community. In the case of Operation Cabot in 1950, the author's treatment leaves the impression of an American operation executed as part of the AMOS (acoustic, meteorological, oceanographic survey) series surveys. In reality, Cabot did not fit into the AMOS mold. It employed assets from Hydro, Canada's Defense Research Board, the Woods Hole Oceanographic Institution, and the U.S. Fish and Wildlife Service. The very lean account of this synoptic study of the Gulf Stream showed that a more informed perspective would have permitted further comment on both Hydro and Richard Fleming in a leadership role early in the Cold War. Only the larger picture can give the particulars proper significance and meaning.

In spite of the valuable information it contains, the layout of this book and its editing provided constant and unwelcome distraction. Printed by a private press, the pages are too crowded with text, spelling errors remain, bold black subheadings dominate too many pages, and the black and white photos seem like photocopies.

Dr. Bates' work will provide scholars and those interested in the history of the Hydrographic Office with valuable basic detail and selective personal insight. However, readers will have to consult other works currently available and studies yet to come to understand the evolution of Hydro and its national significance.

Gary Weir *(gary.weir@navy.mil) is Head, Contemporary History Branch, U.S. Naval Historical Center, Washington Navy Yard, DC, USA, and Guest Investigator, Woods Hole Oceanographic Institution, Woods Hole, MA, USA.*

The Turbulent Ocean



By Stephen A. Thorpe, Cambridge University Press, 2005, 439 pages, ISBN 0521835437, Hardcover, $75 US

REVIEWED BY WILLIAM D. SMYTH

Ocean circulation is often described in terms of relatively simple, quasi-steady current structures, the largest-scale example being the global "conveyer belt." In most measurements, however, such quasi-steady circulations are all but overwhelmed by motions that vary chaotically over a broad range of spatial and temporal scales. Besides complicating attempts to measure the conveyer belt, these chaotic motions transport heat, salt, chemicals, pollutants, and biota, and provide both propulsion and braking for larger-scale flows, including the conveyer belt itself. This chaotic aspect of ocean circulation is the subject of S.A. Thorpe's new monograph, *The Turbulent Ocean*.

Though of moderate length (and cost!), *The Turbulent Ocean* gives a very comprehensive overview of our present knowledge of ocean turbulence. This is possible because the author skips quickly over the simple theoretical models that form the foundation of our understanding, leaving room for discussion of advanced topics, including many from the cutting edge of current research. In addition to up-to-the-minute results, the author draws upon his long experience to provide historical perspectives that are both fascinating and enlightening.

The opening chapter is a nice overview of vertical diffusivity, introducing Munk's classic estimate ($K=10^{-4}$ m^2 s^{-1}) and then expanding on it; the chapter also familiarizes the reader with the problem of the "missing mixing" that ensued when *in situ* measurements gave values an order of magnitude smaller. The remainder of the book covers small-scale processes in the ocean interior (Chapters 2–7) and near boundaries (Chapters 8–12), and finally large-scale turbulence (Chapter 13).

Chapter 2 begins with a historical introduction to the study of internal waves, thought to be the main driver of turbulence in the ocean's interior. In contrast to the usual "textbook" approach, interfacial waves are discussed first. Waves in continuous stratification are discussed next. Rotation effects are included from the outset, a benefit of the author's non-rigorous approach. Also included at the outset are upper and lower boundaries and the resulting normal modes. The chapter includes several advanced topics that would not be found in most texts: parametric instability and other wave-wave interactions, wave-generation mechanisms, and vortical modes.

Before the internal-wave-breaking processes that lead to turbulence can be discussed, shear-driven and convective turbulence must be understood. Chapter 3 gives an excellent and detailed account of the transition to turbulence in shear flows. The main focus is on transition via Kelvin-Helmholtz instability. The author draws extensively on his own classic laboratory experiments, but also includes a historical account going back to the little-known tilted-tube experiments of Osborne Reynolds. Also included are Holmboe instability and the larger-scale barotropic and baroclinic instabilities.

A corresponding account of turbulence due to convective instability is given in Chapter 4. After briefly discussing the standard Benard problem, the author goes on to describe three convective phenomena of current interest to oceanographers: hydrothermal vents, deep convection, and double-diffusive convection. I was amazed to learn that hydrothermal vent systems introduce water to the oceans at a rate of 12 Sv, an order of magnitude larger than river input. The section on double diffusion goes far beyond the usual linear treatment by including recent results from lab experiments and observations. Thermohaline interleaving is also discussed.

Chapters 3 and 4 set the stage for a return to internal waves in Chapter 5, this time to discuss breaking. Mechanisms discussed include convective overturning and shear instability induced both by wave-driven shear alone and by wave-driven amplification of ambient shear. Wave interactions, including parametric instability and caustics, are included. I was especially happy to find a discussion of recent work on wave amplification via double-diffusive convection.

The dramatic increase in our understanding of ocean turbulence in the past few decades has been driven largely by the development of innovative techniques for measuring small-scale structures at depth. Accurately measuring centimeter-scale structures at depths of up to several kilometers from the deck of a rolling ship is no trivial problem! These techniques are the subject of Chapter 6. A major revelation from the measurement techniques described here is that the deep ocean is organized into layers on a range of scales that extends down to centimeters. Chapter 7 describes this fine structure and possible mechanisms for it, building on previous discussions of wave breaking, shear instability, and diffusive convection. Two-dimensional turbulence is also introduced.

Having covered turbulent processes that affect the ocean's interior, the book now turns to mixing near boundaries, beginning in Chapter 8 with the benthic boundary layer. Dr. Thorpe discusses the canonical structure of the flat plate boundary layer as revealed by theory and laboratory experiments, then describes observations made near the bottom in the deep ocean. Of particular interest is the effect of the geothermal heat flux.

The upper-ocean boundary layer is covered in Chapter 9. Surface waves and wave breaking, Langmuir circulations, and entrainment at the base of the mixed layer are all covered, as are less-standard topics like temperature ramps and injuries to small organisms by turbulence. Shallow seas, the dominant site for turbulent dissipation of tidal energy, are the subject of Chapter 10. Tidal effects on the bottom boundary layer are discussed in

UPCOMING BOOK REVIEWS

Atmosphere-Ocean Interactions (Volume 2)
edited by W. Perrie, WIT Press, 240 pages

Introduction to the Physics and Techniques of Remote Sensing (2nd Edition)
by Charles Elachi and Jakob van Zyl, Wiley, 552 pages

Lagrangian Fluid Dynamics
by Andrew Bennett, Cambridge University Press, 286 pages

Oceans: An Illustrated Reference
by Dorrik Stow, University of Chicago Press, 256 pages

detail, along with interactions with bottom ripples and sediment resuspension.

Chapter 11 gives a unique description and comparison of shoaling effects on surface waves and on the less-documented internal waves. The fascinating array of vertical motions involved in surface-wave breaking in the surf zone is described in detail. Turning to internal waves, the author then describes critical-layer reflection, resonant interactions between incident and reflected waves, and the generation of alongshore and upslope currents. Also described are internal bores and solitons. The chapter closes with a look at gravity currents, both turbidity currents and cascades due to intense surface cooling.

Topographically generated turbulence is increasingly recognized as a major contributor to ocean mixing. Chapter 12 covers flow around headlands and other coastal features, undersea canyons, and seamounts. Also covered is the hydraulics of flow in straits and over sills. A final section describes mixing in lakes, which differs from ocean mixing primarily because (1) tides are insignificant and (2) freshwater has maximum density at 4°C.

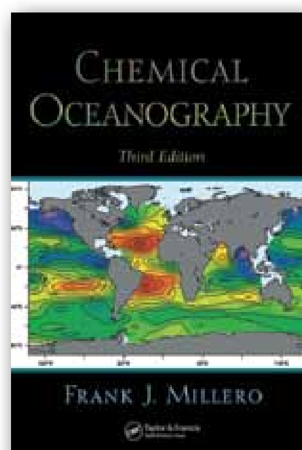
While the main focus is on small-scale processes, ocean currents on scales from meso to global are also turbulent. Chapter 13 therefore completes the picture by covering fluctuations on scales large enough (and slow enough) to be influenced by Earth's rotation. The treatment is based mainly on observations, and includes descriptions of mesoscale eddies, Gulf Stream rings and meddies, as well as planetary waves. Observational quantification of horizontal diffusivity is given significant attention. The book closes with an epilogue focused on the most important of the remaining questions, which will clearly suffice to keep oceanographers busy for the foreseeable future.

For the practicing oceanographer, this book provides a thorough overview of small-scale flows, a fascinating source of historical insight, and a useful introduction to the literature on any aspect of the subject. In the classroom, this book would make a valuable supplement to a standard fluid dynamics text (e.g., P.K. Kundu's *Fluid Mechanics*), which would be used for detailed derivations of standard models. To cover convection, for example, one might explore the classical Benard instability model following the standard text, and then have the students read Thorpe's Chapter 4 for an introduction to advanced topics and oceanic applications.

The Turbulent Ocean will make a very valuable addition to any oceanographer's collection.

William D. Smyth *(smyth@coas.oregonstate.edu) is Associate Professor, College of Oceanic and Atmospheric Sciences, Oregon State University, Corvallis, OR, USA.*

Chemical Oceanography, Third Edition



By Frank J. Millero, CRC Press, 2005, 520 pages, ISBN 0849322804, Hardcover, $99.95 US

REVIEWED BY CLAUDIA BENITEZ-NELSON

Chemical oceanography is one of the core requirements of almost all undergraduate and graduate programs in marine science and oceanography. In this third edition of Frank Millero's classic text, *Chemical Oceanography*, we now have an upper-division undergraduate and first-year, graduate-level text that incorporates the exciting new knowledge gained from significant research programs such as the Joint Ocean Global Flux Study (JGOFS), iron-addition experiments, and the World Ocean Circulation Experiment (WOCE). Having said that, we must remember that above all, Dr. Millero was trained in physical chemistry. As such, this book is a chemist's view of oceanography. While it is perfect for those interested in understanding the underlying molecular-level chemistry of marine systems, beware: students should have a firm grounding in basic chemistry