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members what that student's group had learned, thus combining the information from all the original groups so as to achieve the goals for the class lesson. The instructor caught any mistakes or "oversights." Voila! Was it that simple? Of course not. He underestimated the time necessary for this mode of teaching. He fought departmental tradition. He bumped up against entrenched student expectations of class structure. Mainly, he confronted the "Principle of Economy:" Teach a little material well rather than a lot of material poorly. Something other than just course structure had to go.

Thus began a personal journey best explained by the author himself. His techniques might not work for you (his students were juniors and seniors, oceanography majors). You may not be as amenable to change as he was. But this beautifully annotated book (with copious references to the education literature and probing reflective questions at the end of each chapter) will give you an irresistible nudge, and, as it has me, might push you over the cliff.

McManus ends this splendid exposition with a paragraph strikingly similar in tone to the Leonard excerpt with which I opened this review:

Do you eagerly look forward to your class period, athirst for it to begin, still excited after it's over? If not, why do you settle for a middling experience? Teaching is part of your life. Does your class bring you joy or gladness? If not, why do you settle for receiving less than joy or gladness in what you do? How much better life is when we are excited and joyful in our work!

To which I can only add, "Bravo!"

Tom Garrison *(tomgarrison@sbcglobal.net) is an instructor at Orange Coast College, Costa Mesa, CA, USA. He is also one of the education editors of* Oceanography.

Marine Turbulence

Theories, Models, and Observations: Results of the CARTUM Project

Edited by Helmut Z. Baumert, John H. Simpson, and Jürgen Sündermann
Cambridge University Press, 2005, 672 pages, Hardcover: ISBN 0521837898, $275 US

REVIEWED BY WILLIAM D. SMYTH

Ocean turbulence is a rich and fascinating field of study, both for its own sake and in the service of large-scale circulation and climate modeling efforts. *Marine Turbulence* is a collection of chapters by 53 authors describing results from the Comparative Analysis and Rationalization of Second-Moments Turbulence Models (CARTUM) project. The project was funded by the European Union and took place over three years (1999–2001). Although intended only as a summary of CARTUM, which focused on the practical goal of reconciling closure models with ocean observations, the book provides a remarkably comprehensive overview of the present understanding of ocean turbulence.

The book is thick (630 pages, letter size) and detailed. Auxiliary information, including selected datasets and source codes for turbulence models, is provided on a compact disc. Color illustrations are regrettably absent, no doubt to help control the cost, but color versions of some figures are provided on the CD. Most of the shaded images could have been made much clearer had they been designed for black and white rendering in the first place. Unfortunately, images intended for color rendering were rendered in black and white, often making it impossible to distinguish high and low values without reference to the CD.

The book is divided into eight sections, each of which contains about half a dozen articles plus a prologue and an epilogue. As is inevitable in a large collection, the quality of the chapters varies. Most will make fascinating reading for expert and novice alike, but occasional chapters are essentially rehashes of research articles in which little attempt is made to relate the material to the broader themes of the book or to guide the uninitiated reader into the discussion. Even some of the better chapters contain flaws that would have been caught in a journal-style review. This unevenness is mitigated by the inclusion of the prologues and epilogues, which assist the reader by summarizing the chapters and identifying the overall themes.

Part 1 (Chapters 1–9) covers contributions to turbulence theory, beginning with a beautiful overview by the late Joel Ferziger. Subsequent chapters cover a new two-equation closure describing turbulence and internal waves in a stratified shear flow, a spectral closure model for stably stratified turbulence, and theoretical discussions of vortex dynamics and intermittency. The final chapter, a favorite of mine, discusses horizontal mixing at the sea surface due to random accelerations by surface waves.

Techniques for the *in situ* measurement of marine turbulence are described in Part 2 (Chapters 10–18). This section includes chapters on shear and temperature microstructure measurements, on the theory that underlies their interpretation, and on their validation via tracer-release experiments. Measurement of salinity microstructure is not discussed. A chapter on optical sensors is included, along with a discussion of acoustic Doppler techniques for the measurement of macroscale turbulent velocities and hence turbulent kinetic energy and Reynolds stresses. The section concludes with brief discussions of particle imaging velocimetry and hot film anemometry.

Part 3 (Chapters 19–27) discusses numerical modeling methods, culminating in a description of the General Ocean Turbulence Model (GOTM). A weak spot conspicuous to this reviewer is the highly cursory description of direct numerical simulation studies, which is confined to a few paragraphs in the inaccurately named chapter "Direct and Large Eddy Simulation of Turbulence." On the plus side, this chapter provides an excellent introduction to large-eddy techniques as applied in both geophysical and engineering contexts. The section also includes a discussion of data-assimilation methods for the systematic estimation of empirical parameters. Next comes a useful discussion of the modeling of turbulence length scales. A chapter on numerical aspects of closure models discusses maintaining positivity of positive definite quantities such as kinetic energy, conserving energy, and handling sharp gradients near boundaries. Also included is a chapter on the advection of discrete particles in a closure model. The section concludes with two chapters on GOTM, a one-dimensional model of vertical mixing processes in which the user may experiment with various flux parameterizations. The first chapter introduces the model and describes results for both idealized test cases and validation exercises using observational data. Both the source code and these data are made available on the CD. The final chapter discusses the coupling of GOTM with various three-dimensional, large-scale ocean models.

Part 4 (Chapters 28–36) covers surface and bottom boundary layers. Material on the surface layer includes an overview, two chapters on surface wave effects, and discussions of Langmuir cells and rotating convection. The overview chapter is useful, but contains some potentially serious errors. For example, equation 29.1 and the accompanying text state that the net vertical heat flux must vanish at the ocean surface. (Imagine what the world would be like if this were true!) In fact, the flux need only be continuous. The subsequent discussion of surface momentum fluxes is confusing in a similar way, though not actually incorrect. The next chapter gives a detailed description of the boundary layer directly adjacent to the surface, both with and without breaking waves. The Craig-Banner model of turbulence generation by breaking waves is then summarized, along with comparisons with observations. Next, large-eddy simulations (LES) are used to quantify the effect of Langmuir cells on the mixed layer. Examples illustrate the effects of surface forcing and planetary rotation. A description of the basic mechanism would have been a nice addition, either here or in the overview. Turbulence in the equatorial surface layer is also examined by means of LES. This turbulence regime is complicated by the beta effect, which acts on the upper ocean both directly and in the form of strongly sheared near-surface currents driven by the Trade Winds. The single chapter on bottom boundary layers contains a very careful treatment of log layers, Ekman layers, effects of waves and tides, and effects of sediment loading. Nocturnal convection is touched on in a few places but is not described specifically. A more general description would make a nice introduction to the final chapter of the section, which discusses the effects of planetary rotation on convection. That chapter is confusing in that it appears to focus on a convective boundary layer, but often mentions deep convection as if it were synonymous. Also, the flow geometry appears to describe the atmospheric (rather than the oceanic) boundary layer. These distinctions may be superficial, but they should at least be mentioned.

Part 5 (Chapters 37–43) describes mixing process in smaller geofluid systems, primarily various classes of estuaries. A strongly turbulent tidal channel off Vancouver Island is the site for tests of the Mellor-Yamada closure assumptions. The Hudson River estuary oscillates between weak and strong mixing (or strong and weak stratification) and is nicely described in Chapter 39 along with results from a k-epsilon model. In a strongly stratified estuary (Chapter 40), intermittent mixing by localized Kelvin-Helmholtz and Holmboe instabilities presents a unique challenge to modelers. Figure 40.3 is described as "incorrect due to format conversion," but the nature of the error is not revealed. The section concludes with very clear and interesting summaries of mixing processes in fjords and in lakes.

Part 6 (Chapters 44–49) discusses the all-important shelf environment. The discovery that mixing in the bulk of the ocean interior is relatively weak (the "missing mixing" problem) has been accompanied by the realization that mixing must be intense in smaller regions, especially the shelves and shelf seas. The prologue guides the reader with an especially useful diagram of the various spatial regimes of the shelf environment that are discussed in subsequent chapters. The section then begins with a review of research on the nearshore regime. Chapter 46 gives a very interesting account of different mixing regimes found in shelf seas, but it contains several minor flaws that an independent review should have caught. (The chapter is far from unique in this sense; I merely cite it as an example.) Figure 46.1 omits the Mersey and Dee Rivers, from which the transect shown in Figure 46.2 originates. Figure 46.2 is an example of a graphic that could have benefited from optimization for black and white rendering. The kinetic energy dissipation rate is given in different units in the text and the figures. Chapter 47 describes the use of the k-epsilon closure in a general circulation model of the Baltic Sea. Though the Baltic is presented as an example of a doubly stratified regime, no mention is made (here or elsewhere in the book) of mixing due to double diffusive processes. Chapter 48, on internal waves at the shelf edge, appears to have been published in draft form; several parenthetical comments seem to be directed at the author. I searched in vain for a definition of the "efficiency" of tidal energy dissipation. Despite these flaws, the chapter gives an interesting description of wave-driven mixing at the shelf break, as well as other topographic features such as seamounts.

Large-scale ocean turbulence departs dramatically from the idealized models of classical turbulence theory, as it is affected not only by ambient shear and density stratification but also by planetary rotation, the high aspect ratio of the ocean basins, and interactions with continental margins. Of particular interest is the tendency for large-scale motions to be two-dimensional, and therefore to exhibit a cascade of energy from medium to large spatial scales (in contrast to the downscale cascade of three-dimensional turbulence). These issues are addressed in Part 7 (Chapters 50–60). Chapter 51 discusses the relationship between two- and three-dimensional motions. The former are often best modeled as geostrophic turbulence, the focus of a clear and detailed review in Chapter 52. Two subsequent chapters address the parameterization of geostrophic motions in large-scale models. Two further chapters are devoted to turbulence on the beta plane. Chapter 58 describes the effects of eddy mixing on zonal currents. The final chapter of the section contains an excellent account of the formation of fronts in passive scalar fields advected by large-scale turbulence. An account of small-scale mixing at the resulting frontal zones would have been a useful addition to the book.

Part 8 (Chapters 61–64) is a description of the materials included on the CD. The CD functioned without difficulty on Windows, Apple, and Linux platforms.

Overall, the editors have done a fine job of assembling what could have been a disparate collection of research articles into a coherent and comprehensive overview of the field. The price is steep, but not outrageous for a work of this scale. The book will make a useful addition to the library of any researcher or research group interested in ocean mixing.

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