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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.

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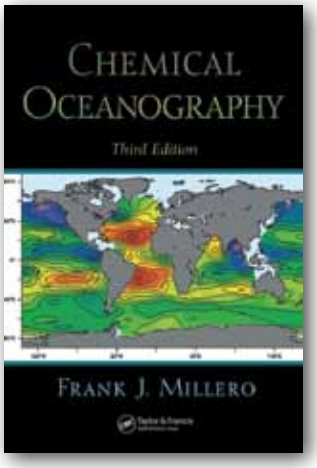
Chemical Oceanography, Third Edition

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

before professors use this as a classroom text. Otherwise, students will be woefully lost and not able to appreciate the vast wealth of information contained in this book. It describes not only essential marine chemistry concepts, but how many of these concepts came into being. This material is wonderful for the many new students entering the field who do not have this historical perspective.

Millero's text begins with a chapter on descriptive oceanography, which details basic information on ocean circulation, including closed basins and estuaries. The latter half of this chapter incorporates classic studies of how chemical tracers have been used to determine circulation patterns and water-mass age. Chapters 2 and 3 describe the composition and distribution of major and minor elements in seawater, as well as sources, sinks, and residence times. Chapter 2 also includes a beautiful discussion on salinity, a reminder to all who rely on this concept, but who have forgotten the subtleties associated with its measurement. Chapter 4 delves into traditional aquatic chemistry with a focus on molecular models of water structure and ion pairing (e.g., ionic strength and metal speciation). Chapters 5 and 6 set the stage for understanding the abiotic parameters that are involved in atmosphere-oceanic exchange and, combined with Chapter 7, provide an excellent overview for understanding the carbonate system and the effects of increasing CO_2 on marine systems. Chapters 8 and 9 discuss the major nutrients and trace elements involved in biological production, and the role of organisms in these elements' distribution and redistribution in seawater. Of particular interest is the discussion of the iron-addition experiments. One weakness of Chapter 9, however, is in the organic geochemistry. Millero recognizes this and even states in the preface that it is, "largely due to my ignorance of this field and the problems my students had in getting through this area."

The final chapter, "Processes in the Ocean," is mistitled. Rather than discussing chemical oceanography from a global perspective, this section focuses on areas such as photochemistry and redox reactions. While still essential concepts, the lack of a true "Process" section points to one of the overriding problematic issues in Millero's book: it fails to consistently provide an overarching view as to why each of the described concepts is important. General guiding themes are absent, and many students will likely get lost in the trees on their way through the forest.

Overall, the revised version of Millero's *Chemical Oceanography* will continue to be a stalwart reference in courses taught at the upper-division undergraduate and graduate levels. However, students will be disappointed by the lack of problem sets; graduate students in particular will be frustrated by the poor referencing in the text. Supplemental references that focus on organic, isotope, and radioisotope geochemistry will be necessary as well as a professor who can clearly place the concepts taught within the revised edition in the context of global-scale geochemical processes.

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