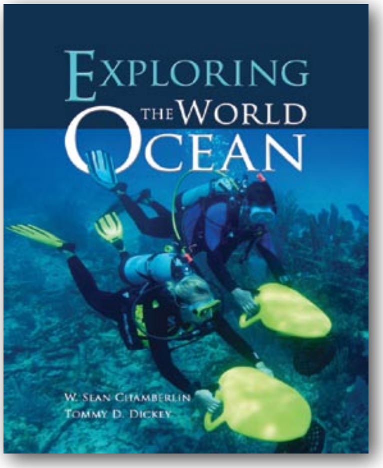
Exploring the World Ocean



By W. Sean Chamberlin and Tommy D. Dickey, McGraw-Hill Higher Education, 2008, 394 pages, ISBN 0073016543, Paperback, $117.90 US

REVIEWED BY CYNTHIA CUDABACK

A college-level introductory science textbook should have three purposes, two of which are often underserved. First, it should present large quantities of information, which results in a text that is bulky and expensive. Second, it should help students understand the nature and process of science, and allow them to practice scientific techniques such as critical thinking and inquiry-guided learning. Third, in the case of an oceanography text, it should help students understand the complex interdependence of humans and the ocean. The new text by Chamberlin and Dickey is the first I have seen that promotes all three purposes equally.

The interdependence of humans and the ocean is at the heart of ocean literacy, as defined by a national consensus of marine scientists and educators (see *Ocean Literacy* pamphlet available online at http://www.coexploration.org/oceanliteracy). The ocean literacy definition includes lists of topics that students should understand, and also describes what students should do with that understanding. An ocean-literate person is one who (1) understands the science of the ocean, (2) is able to communicate clearly about the ocean, and (3) can make informed decisions about policy and behaviors that affect the ocean. The consensus was made in the context of elementary and high school education, but the concept of ocean literacy is starting to gain more attention at the college level.

College-level oceanography instructors now stand at a crossroads—shall we teach only the science of the ocean, or shall we promote ocean literacy? Some universities, concerned only about oceanography majors and future graduate students, seem to have an implicit policy that only scientific understanding matters in these introductory courses. But I believe we have a duty to the many nonmajors in our courses, to help them become well-informed citizens of this ocean planet. Furthermore, study of human impacts helps students understand the relevance of science to their own lives.

If we are to teach ocean literacy and not just ocean science, we need a textbook that integrates human impacts with the more traditional scientific content. My top bookshelf is crammed with texts, each offered by an earnest publisher's representative, each described as the best and latest thing. But in fact, the texts seem pretty similar. They are all written by men in southern California, and they all present the same topics in the same order, from the origins of the solar system to marine biology. Although most authors express a deep concern for the ocean's wellbeing, issues related to human impacts are not well integrated in the older texts. Many texts, on the last page of the last chapter, point out that the ocean is in trouble, and make a stirring call to action. Most students never see that last chapter. One popular text discusses human impacts in Chapter 18, but many of my colleagues teach one chapter per week in a 15-week semester.

By contrast with the earlier texts, Chamberlain and Dickey start out with a discussion of ocean science and human impacts on the ocean. In the first chapter, they provide a table listing the types of human impacts, and encourage students to research one impact more thoroughly (an exercise I have used with great success in my own classes). This inquiry-guided learning experience promotes ocean literacy and gives students a reason to care about oceanography.

The themes of human impacts and inquiry-guided learning appear repeatedly throughout the text. Each chapter starts with an attractively presented list of "Questions to Consider," and ends with an extended "Exploration Activity." The success of these aids to inquiry-guided learning will depend on students' willingness to consider the questions and teachers' willingness to grade the exploration assignments, but having these ideas in the text is a good start. The Questions could be used to start discussions either in class or via some electronic medium, such as a wiki or bulletin board.

The bulk of the information in the

text is similar to that in other texts, but many figures are a bit better than usual. I especially appreciate the conceptual sketches that promote a more intuitive understanding of ocean science. For example, one classic figure shows the different amounts of sunlight intercepted by one square meter of Earth's surface at the equator and at the poles. Chamberlain and Dickey added thought bubbles indicating that the sun is high in the sky at the equator and low at the pole—this concept is more intuitive for students. Similarly, they provide a nice analogy between counting cars and measuring wave period, and a set of thermometers in different units marked with the temperature of the human body as well as the freezing and boiling points of water.

I have a few pet peeves about older textbooks. First, some texts present an obsolete taxonomy. Chamberlain and Dickey have an up-to-date taxonomy with a good discussion of the three domains and a nice comparison of relationships inferred from morphology and genetics (the brittle star gets reclassified). Second, the pervasive myth about toilets flushing backwards in Australia indicates a fundamental misunderstanding about the nature of the Coriolis force. Chamberlain and Dickey do mention the importance of scale in the Coriolis force, but do not specifically debunk the myth.

There is still some undue emphasis on California. Their conceptual sketch of tidal circulation, in which tides propagate along the coast (amphidromic circulation), is accurate for the West Coast of the United States; however, on the East Coast, the tide has a constant phase. My students on the East Coast deserve a more balanced treatment.

My students, and all students, deserve a chance to learn about how their lives touch the ocean, and they deserve a course that promotes critical thinking and inquiry-guided learning. It may be time for me to switch to a new text—by Chamberlain and Dickey.

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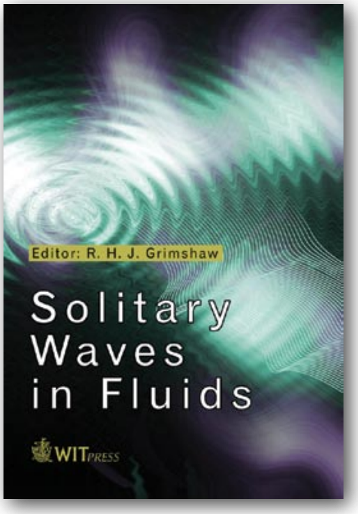
Solitary Waves in Fluids



Edited by R.H.J. Grimshaw, WIT Press, 2007, 208 pages, ISBN 9781845641573, Hardback, $130 US

REVIEWED BY QUANAN ZHENG AND R. DWI SUSANTO

It has been 160 years since the first recorded observation of a solitary water wave in a canal, which British scientist John Scott Russell saw while riding on horseback. Since then, many beautiful and applicable results of the physics and mathematics of solitary waves have appeared. Among them, several are noteworthy: the single soliton solution to the Korteweg-de Vries (KdV) equation (Korteweg and de Vries, 1895), the dnoidal solution (solitary wave packet) to the KdV equation (Gurevich and Pitaevskii, 1973), and analytical and numerical solutions to the perturbed and forced KdV (PKdV and fKdV) equations (Newell, 1985; Wu, 1987; Shen, 1993). Continuous emergence of fresh results in recent years suggests that it is still a brisk field.

The book *Solitary Waves in Fluids* edited by R.H.J. Grimshaw summarizes recent advances in the field. The book concentrates on describing the basic theories of solitary waves beginning with the earliest KdV equation, from which a single soliton solution is solved, to the latest nonlinear Schrödinger equation, from which an envelope solitary wave solution is solved. The book is divided into seven chapters; each chapter has its own references for readers who want to learn more about the topic. After Chapters 1 and 2 provide a historical introduction and the details behind the basic theory of the KdV equation, the subsequent five chapters explain its applications. Chapter 3 describes free-surface solitary waves in water and numerical methods to compute solitary waves. Chapters 4 and 5

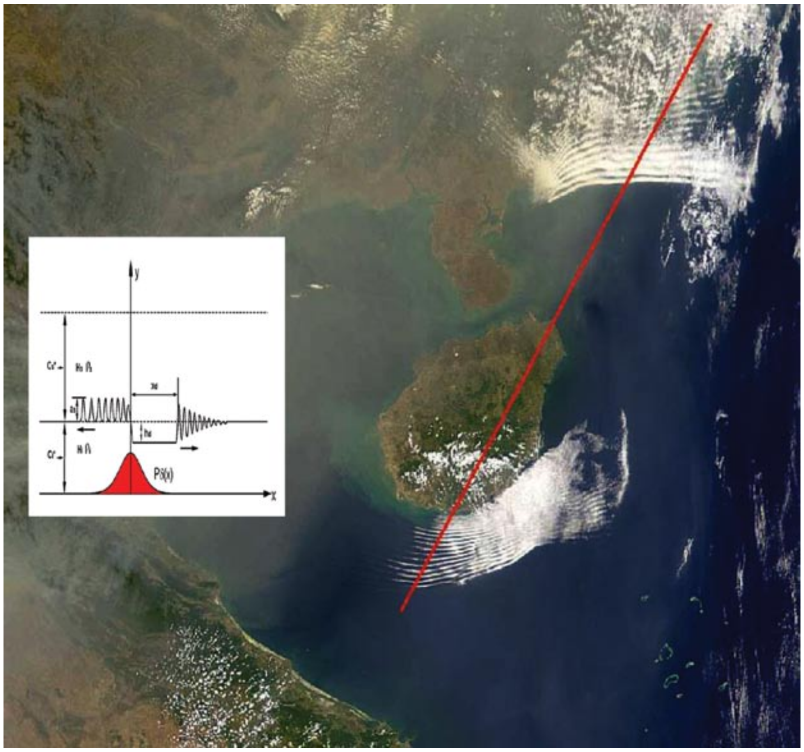


Figure 1. A true color SeaWiFS image taken on March 19, 1999. The waters of the northern South China Sea are dark blue. Two groups of wave clouds in white arrayed above and below Hainan Island are interpreted as signatures of upstream and downstream solitary wavetrains generated in the atmosphere by topographic disturbances. The red line represents the wind direction at 850 mb. At left is a physical model for the generation of forced waves in a two-layer flow with a bottom obstruction. The x- and y-axes represent the horizontal and vertical coordinates, respectively, and the curves represent an approximate solution of the fKdV equation.

discuss internal solitary waves in the coastal ocean and atmospheric boundary layer, and solitary waves in rotating fluids. Chapters 6 and 7 discuss planetary and envelope solitary waves.

Solitary Waves in Fluids provides readers with the methods and skills to solve equations and apply results to areas of the ocean and atmosphere with length scales from meters to thousands of kilometers. Indeed, the book meets its objective, to describe solitary waves on flows in a geophysical framework. This book is suitable for intermediate and advanced readers with backgrounds in fluid mechanics. *Solitary Waves in Fluids* explains the profound in simple terms, making it especially suitable for senior undergraduates and graduate students to use as a reference book. Although this book thoroughly covers theoretical solitary waves, to appeal to a broader audience, it should have included a few papers that concentrate on observational data. Having more examples of solitary waves observed in the real ocean and atmosphere using in situ and remote-sensing instrumentation would guide and motivate beginner and intermediate readers (e.g., Ramp et al., 2004; Zhao, 2004; Susanto et al., 2005; Zheng et al., 2007). Thus, we provide the following paragraph as a "suffix" to the book:

Earth observation technologies have also made tremendous advances compared with the "horseback sensing" used by the pioneer of solitary-wave science 160 years ago. In particular, the development of satellite remote-sensing technology since the 1960s has provided scientists and other users with excellent platforms from which to observe the atmosphere and ocean from space. Many previously unseen phenomena have shown up clearly on high-resolution satellite images. These phenomena include solitary waves in the atmosphere, such as the morning glory (Christie et al., 1978); island lee waves (Vachon et al., 1994); solitary wave packets in the lower atmosphere (Zheng et al., 1998); mountain waves (Eckermann and Preusse, 1999); and waves in the ocean, such as internal waves that appear as a single soliton and solitary-wave packet (Osborne and Burch, 1980; Liu et al., 1998; Zheng et al., 2001), and the collision of two internal solitary wave packets in the deep ocean (Zheng et al., 1995). These fresh observations have enriched our knowledge of solitary waves in fluids. Some of them have been used to verify theoretical solutions or predictions, and some have raised new questions. Figure 1 is an example of upstream and downstream solitary wavetrain coexistence in the atmosphere. The graph at left illustrates the physical model and its solution (Shen, 1993); the satellite image shows the evidence observed ten years later (Zheng et al., 2004).

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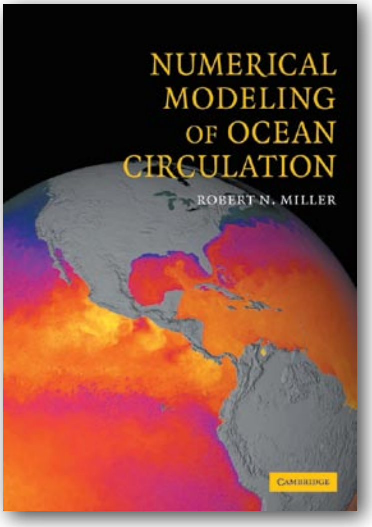
Numerical Modeling of Ocean Circulation



By Robert N. Miller, Cambridge University Press, 2007, 242 pages, ISBN 052178182, Hardcover, $65 US

REVIEWED BY ROBERT HALLBERG

Numerical ocean models have become increasingly valuable tools as we strive to understand the nature of the ocean's dynamics. They have progressed from the necessarily crude and idealized tools of decades past to capture much of the complexity and beauty of the real ocean. Many oceanographic research projects utilize numerical models as a fully equal partner and complement to the long-established physical oceanographic approaches of seagoing observational inference, theory, and fluids lab experimentation. As computers continue to increase in speed and availability at ever lower cost, this trend will clearly continue. Therefore, a solid background in knowing how to use numerical models to test hypotheses, when to trust their results and when not to, and how to relate the output of ocean models to observations has become an indispensable part of the education of an aspiring oceanographer.

Numerical Modeling of Ocean Circulation aims to fill this need as a text for preparing graduate students for modeling studies of large-scale physical ocean circulation. To quote from the preface, "this work is intended as a text. It is not intended to review the state of the ocean modeling art. Rather its aim is to provide the student with the context in which discussion of numerical modeling is conducted." To be read profitably, this book requires an introductory familiarity with geophysical fluid dynamics, consistent with the author's assumed

UPCOMING BOOK REVIEWS

Ebb and Flow: Tides and Life on our Planet
by Tom Koppel, The Dundern Group, 292 pages

Lagrangian Analysis and Prediction of Coastal and Ocean Dynamics
by A. Griffa, A.D. Kirwan Jr., A.J. Mariano, T. Özgökmen, and T. Rossby,
Cambridge University Press, 487 pages

Ocean Circulation: Mechanisms and Impacts
edited by A. Schmittner, J.C. Chiang, and S.R. Hemming,
American Geophysical Union, 392 pages

The Silent Deep: The Discovery, Ecology, and Conservation of the Deep Sea
by Tony Koslow, University of Chicago Press, 270 pages

The Unnatural History of the Sea
by Callum Roberts, Island Press, 435 pages

audience of second-year physical oceanography students. Unfortunately, many critical topics are covered with such a dated exposition that this book will probably only have limited success in meeting this worthwhile aim.

The first two chapters are exceedingly brief. The first chapter is a single-page introduction tying numerical ocean modeling back to the pioneering work of L.F. Richardson in the 1920s. The second chapter is a short (30-page) introduction to basic numerical analysis, with detailed analysis limited to the rudimentary approaches of second-order centered differencing and leapfrog time stepping. Finite element methods and higher-order finite differencing are mentioned to draw attention to their existence, but for more than a cursory exposure to numerical techniques the reader is referred to other texts (such as the excellent, if not particularly oceanographic, book by Dale R. Durran: *Numerical Methods for Wave Equations in Geophysical Fluid Dynamics*, 1999, Springer, 465 pp.).

The third chapter, on shallow-water models, is where this book really hits its stride. It explores the various wave modes and dynamical balances that are present in the shallow-water equations, and how these can influence the choice of appropriate numerics. It uses these equations in a nice exposition of the issues of open boundary conditions, and concludes with a useful series of examples illustrating how numerical shallow-water models can be used to elucidate the dynamics of fluid flows, and how knowledge of the dynamical balances influences the choice of parameters in shallow-water models. This chapter should provide a solid basis for further work using numerical models.

The fourth chapter, however, on primitive equation models, is strikingly dated. As primitive equation models are the basis for most regional- and large-scale ocean studies, this is a serious flaw. There is an extended discussion of the dynamics of rigid lid models, and how the rigid lid should be treated numerically, but only the barest mention of the split-explicit or split-implicit treatment of the external mode that has been used almost exclusively for a decade. There is a careful and detailed description of the algorithms of the well-known Bryan-Cox model of the 1970s and 1980s, but almost no mention at all of the developments of the past decade—such as the Gent-McWilliams eddy closure, the partial cell treatment of topography, improved discretizations of tracer advection, or proper rotation of the diffusion tensor—that have made this class of model such a powerful tool for climate studies. Even more alarmingly, this chapter describes the purpose of using a rotated diffusion tensor as *increasing* the vertical mixing in models. Instead, the primary challenge for Z-coordinate climate models for the past 20 years has been to limit the levels of diapycnal mixing to the very weak values we now know the ocean to exhibit, and a properly rotated diffusion tensor is a key step in *reducing* spurious diapycnal mixing. There are numerous other glaring anachronisms in this chapter. Isopycnal (layer) models are described as being unable to represent the flow of Antarctic Bottom Water under North Atlantic Deep Water due to the use of potential density referenced to the surface as the vertical coordinate, but the solution to this issue has been known and widely used for a decade now—using potential density referenced 2000 dbar as the vertical coordinate along with a careful treatment of the effects of the nonlinear equation of state when calculating pressure gradients. In describing terrain-following-coordinate models, the challenges arising from the pressure gradient errors over steep topography are described, but the past decade's progress in dramatically reducing this issue, particularly by the Regional Ocean Modeling System

(ROMS) group, is wholly ignored. The poor representation of topographically constrained flows in traditional, full-cell, Z-coordinate models is described, but not the partial cell numerics that have so dramatically reduced these biases. There is no meaningful discussion of the treatment of tracer equations—something that has become more and more prominent as predicting the carbon cycle, ecosystem management, and water-quality issues emerge as increasingly important applications of ocean models. This chapter may be useful for historical documentation of the considerations that once pertained to ocean models, but the student trained with this book will be ill prepared to use modern ocean models.

The fifth chapter is a brief (nine-page) and cogent introduction to quasi-geostrophic numerical models.

The sixth chapter presents the use of analytical and numerical models to study coastal ocean variability, and the examples here are more recent, dealing particularly with the waves and flow structures found off the Oregon coast. Perhaps this reflects an area of more active interest for the author, but even here the presentation of the numerical issues that coastal (terrain-following-coordinate) models must deal with completely ignores the past decade of notable progress.

The seventh and final chapter is an examination of tropical wave dynamics, similar to that found in several classic geophysical fluid dynamics textbooks, with a few examples of how they were represented in numerical models in the mid 1980s, 20 years ago.

One surprising omission from this book is any discussion of data assimilation. This is an increasingly important topic in ocean modeling. Given the author's prominent work on data assimilation, its exclusion from this book seems quite unfortunate.

The great strength of this book is the way that it works to tie ocean models to their use to answer real questions about the ocean's dynamics. This skill is timeless and should easily transcend the changes that have made today's ocean models dramatically more proficient than their predecessors. This book is also valuable for encouraging a healthy skepticism about what questions ocean models are and are not reliable for answering, even if many of the specific issues discussed in detail are much less pressing today than they once were.

This book is essentially a good description of the state of ocean modeling as of the early 1990s. The median publication year of the references therein, 1989, reflects this by now quite dated depiction. For a mature field, such adherence to long-established practice may be reasonable, but numerical ocean modeling is still a very rapidly developing field, and such an archaic presentation is lamentable. This would have been a fine book had it been published 15 years ago, but it is already so out of date, even compared to several numerical ocean modeling texts published a decade ago, that I am reticent to recommend its use as a primary text for graduate courses, and strongly urge that it not be used as a reference.

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