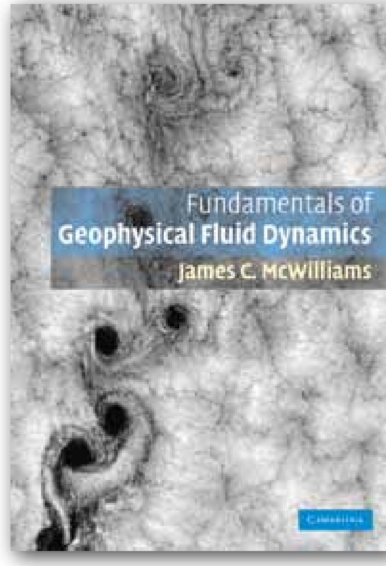
THE OFFICIAL MAGAZINE OF THE OCEANOGRAPHY SOCIETY

Oceanography

Fundamentals of Geophysical Fluid Dynamics



By James C. McWilliams, Cambridge University Press, 2006, 266 pages, ISBN 9780521856379, Hardcover, $79 US

REVIEWED BY CHRISTOPHER A. EDWARDS

Fundamentals of Geophysical Fluid Dynamics is a new textbook that provides an introduction to the basic dynamics governing fluid motion in a rotating system. This book is designed for first-year graduate students and assumes background knowledge of multivariable calculus, partial differential equations, and classical mechanics. It would also be helpful if a student had previously studied nonrotational fluid dynamics and more general phenomenology of the ocean and atmosphere.

The text is divided into six chapters. A very short introduction sets the broader context for the book's subject. The second chapter presents a limited discussion of the basic equations that govern fluid dynamics, for example, those for conservation of momentum and kinetic and potential energy, and it introduces concepts of divergence, circulation, and vorticity. This chapter also provides relevant fundamentals, such as the equations of state and observed stratification for the ocean and the atmosphere. The final section of this chapter focuses on the influence of rotation, introducing geostrophic balance and including a valuable discussion of scaling to identify appropriate limits for approximations.

The third chapter, entitled "Barotropic and Vortex Dynamics," addresses two-dimensional motion in the horizontal plane only. This chapter begins with the barotropic equations and defines the appropriate forms of the vorticity equation, potential vorticity, and streamfunction. By reintroducing geostrophy and extending the discussion to gradient-wind balance, the author prepares for an extensive discussion of stationary vortex flow and movement of multiple vortices. The chapter includes a section on barotropic and centrifugal instability, and concludes with a section on two-dimensional turbulence, with a concise discussion of the energy and enstrophy cascades. This chapter's emphasis on vortex processes is excellent and unique among existing geophysical fluid dynamics texts. Providing this emphasis adds meaningfully to existing resources for students with material that extends easily across multiple geophysical systems.

The topic of Chapter 4 is rotating shallow-water and wave dynamics. It begins with classical discussions of linear wave solutions and geostrophic adjustment, but then expands into nonlinear wave steepening leading to wave breaking. After an introduction to quasigeostrophy, the chapter discusses Rossby waves and ends with mechanisms for their generation. In general, the author very clearly does not try to exhaustively cover all aspects of geophysical fluid dynamics, particularly when a subject is discussed extensively in other texts. Rather, he includes sufficient information to make this text (and associated course) self-contained, and directs interested readers to other references for further study. The author's treatment of linear waves in geophysical systems is an excellent example. The text solidly addresses many introductory aspects and then moves on to important extensions, for example, nonlinear bores and the coupling of vortices on the beta-plane to Rossby wave modes, which are not covered in commonly used geophysical fluid dynamics texts.

Chapter 5 introduces baroclinic motion with layered hydrostatic models. The chapter's central topic, baroclinic instability, is covered in two parts. The first part is an analytical treatment of two-layer flow, described using a normal-mode approach. The second part describes the processes resulting from instability of a three-layer zonal jet. This section draws heavily on numerical experiments carried out by the author decades ago, but provides useful, intuition-building ideas about eddy-mean flow interaction and along- and cross-jet balances.

The final chapter focuses on boundary layers and the physics of ocean gyres. It derives appropriate dynamical approximations for atmospheric planetary boundary layers and surface and bottom boundary layers in the ocean. There is a subsequent discussion of classical wind-driven ocean gyres. Both of these sections include interesting and important material focused on numerical support for the analytical treatments provided. In particular, there is a discussion of direct numerical simulations to test the validity of Ekman theory. In addition, the author uses scaling arguments to alert the student that real ocean gyres are more nonlinear than classical theory demands. He presents numerical experiments to reveal the influence of such nonlinearity.

Overall, this textbook is extremely successful as a reference for an introductory graduate course. It balances two goals: discussing a wide range of interesting topics to engage the student reader and providing sufficient depth to offer students a rigorous foundation. By presenting relevant images of oceanic or atmospheric features, each chapter begins with classical material for which analytic approaches apply; each subject ends with more realistic, nonlinear regimes explored usually using idealized numerical output for phenomenological description or further analysis. There is some uneven treatment, for example, the discussion of the rotational coordinate transformation and the introduction to the N-layer system, but these areas are very few in number. The book's scope is limited, omitting, for example, dynamics of internal waves in a continuously stratified medium, but it includes more than enough material for an introductory course—which is its intent. The book is systematically organized, and the exposition is extremely clear and chock full of short, effective definitions and illuminating descriptions of important geophysical processes. On top of this, the text includes a collection of useful and challenging problems that are perfect for a class. These problems fill out derivations not offered in the text and also extend material and ideas brought forth within the chapters. Their inclusion further helps make this text an excellent teaching resource.

In summary, *Fundamentals of Geophysical Fluid Dynamics* is a valuable addition to the existing collection of texts in this field. It is a well-written, concisely worded, self-contained introduction, emphasizing material, such as vortex motion, not central to other texts of its type. It will be useful as a study guide to incoming graduate students as well as an occasional reference for more advanced researchers in the field.

Christopher A. Edwards *(cedwards@ucsc.edu) is Assistant Professor, Ocean Sciences Department, University of California, Santa Cruz, CA, USA.*

Upcoming Special-Issue Topics

Vol. 21, No. 2, June 2008
Celebrating 50 Years of International Partnerships in Ocean Research
Guest Editor: Peter Ranelli, NATO Undersea Research Centre

Vol. 21, No. 3, September 2008
20th Anniversary of The Oceanography Society
Guest Editor: Melbourne Briscoe, founding Secretary of TOS

Vol. 21, No. 4, December 2008
Coastal Ocean Processes
Guest Editor: Richard Jahnke, Skidaway Institute of Oceanography

Vol. 22, No. 1, March 2009
HERMES: Hotspot Ecosystem Research on the Margins of European Seas
Guest Editors: TBN

Vol. 22, No. 2, June 2009
Tenth Anniversary of the National Oceanographic Partnership Program
Guest Editors: Eric Lindstrom, National Aeronautics and Space Administration; Jim Kendall, Minerals Management Service; and Ben Chicoski, Consortium for Ocean Leadership

Vol. 22, No. 3, September 2009
The Revolution in Global Ocean Forecasting – GODAE: 10 Years of Achievement
Guest Editors: Mike Bell, National Centre for Ocean Forecasting, and Pierre-Yves Le Traon, IFREMER

Vol. 22, No. 4, December 2009
Ocean Acidification
Guest Editor: Richard Feely, National Oceanic and Atmospheric Administration

Future Topic
Future of Satellite Oceanography

The editorial staff also encourages unsolicited manuscripts on other oceanography themes for consideration and publication under the Regular Features banner.