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the field of marine geology and geophysics. He attended every major society meeting, which always included his contributions to a dozen or more abstracts, whereas Marie mostly remained isolated in her module at Lamont or in her home in South Nyack, New York. Upon Bruce's sudden death in 1977 and the soon-after publication of the World Ocean Floor panorama painted by Heinrich Berann, Marie's ambitions for continued ocean floor mapping essentially ceased.

At a 2001 ceremony honoring Marie Tharp's accomplishments, I superimposed the 1977 panorama over the current digital compilation of predicted bathymetry using satellite-derived gravity to reveal the astonishing similarity of all of the fracture zone trends. The very fine-scale segmentation of the mid-ocean ridge spreading centers first detailed in the 1968 diagram—to great criticism at the time—was confirmed. That the Tharp-Heezen partnership could achieve this level of accuracy with such sparse coverage of actual soundings must mean that the mapping of the ocean floor was accomplished not by the soundings alone, but by a prescient understanding of how the earth works.

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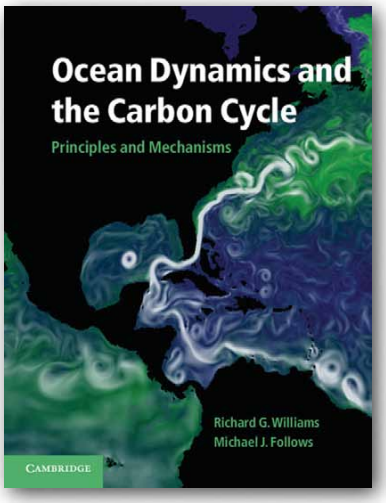
Ocean Dynamics and the Carbon Cycle: Principles and Mechanisms

By Richard G. Williams and Michael J. Follows, Cambridge University Press, 2011, ISBN 978-0-521-84369-0, Hardcover, $73 US

REVIEWED BY DENNIS A. HANSELL



Williams and Follows combined their expertise to write a book targeted at honors undergraduate or graduate students, as well as at professionals in ocean science who need to learn the fundamentals of disciplines outside their own. The authors began their science careers in physical oceanography and atmospheric sciences, respectively, at the University of East Anglia. Each evolved toward a strong research interest in ocean biogeochemistry, though from their own unique perspectives of ocean circulation and biogeochemical modeling. The content and structure of the book reflects this training and these interests.

The book's two introductory chapters constitute Part I, describing the ocean in broad terms and in global relevance. Ocean heat storage and transfer, the global ocean carbon budget, and climate are treated in the first chapter, followed by quick surveys of descriptive physical oceanography and the essentials of life, nutrients, and carbon in the ocean. The four chapters of Part II cover the fundamentals of ocean transport (with a strong focus on tracers of many transport/mixing processes), the physics of circulation, biological processes, and the inorganic carbon system. The authors describe Part III as "physical phenomena and their biogeochemical signals." It begins with a chapter on seasonality, which includes physical, biological, and biogeochemical temporal variability. Then, three chapters focusing on ocean physical phenomena (gyres and intense currents, eddies, and ventilation) are followed by one that seeks to tie ocean physics to upper-ocean biological systems and the nutrient fields in the ocean interior. The section closes with a chapter on the deepest realms of the ocean and overturning circulation. Finally, Part IV synthesizes at the level of the Earth system, considering variations in the ocean-atmosphere carbon cycle, the fate of fossil fuel CO_2, and glacial-interglacial changes in atmospheric CO_2.

Each chapter offers approximately four end-of-chapter questions, commonly written such that they add more insights on the system considered. These questions force the reader to delve more deeply into the concepts; presumably the authors will provide the solutions if requested! Also, at the conclusion of each chapter is a recommended reading list that includes useful descriptions of why the authors recommend the readings.

The book closes with an appendix of mathematical definitions, derivation of momentum equations, and the carbonate system equations and solutions. Symbols, definitions, a valuable glossary, and references conclude the book.

As a biogeochemist, I was very interested to see what I could learn from the chapters on fundamental physics, the subject matter that I need to understand but that I often struggle to keep straight. The authors explain simply and clearly the most basic aspects of, for example, advection, molecular diffusion, stirring, and mixing, and they provide well-constructed figures to help the reader visualize the processes. Each process is mathematically described, with one providing foundation for the next. In general, I found the figures to be very well chosen. For example, in explaining the physical basis for global distributions of variables, rather than simply showing the distribution of surface salinity and briefly explaining its forcings in the text, the authors provide figures on global ocean precipitation, evaporation, and the net freshwater balance that together constitute a solid foundation for understanding salinity distribution. The figures are well used to explain phenomena more fully.

The chapter "Biological Fundamentals" is true to its title, though it focuses on the lowest trophic levels and their controls; higher trophic levels and ecosystems are not included. It starts with primary production and respiration, moves to autotrophic and microbial biomass composition and elemental stoichiometry, then considers nutrient uptake kinetics and phytoplankton growth limitations. It continues with phytoplankton community structure, export production, the diagnostic parameters DIN_{xs}/N^*, and HNLCs (high-nutrient, low-chlorophyll regions).

The chapter covering carbonate chemistry does a great job of explaining the basic knowledge required: solubility of CO_2, carbon system equilibria, DIC/TCO_2, alkalinity, and air/sea exchange.

I find the book to be a good resource as I prepare lectures for the marine biogeochemistry classes I teach, and a good reference for my own weaknesses in understanding ocean processes. However, I'm not sure that it would be appropriate to use as the main textbook in my classes. The treatments of ocean physics and biogeochemical phenomena are complete in the sense that they touch on most of the needed topics, but for my purposes, there is an imbalance in those treatments: seven chapters on the physical system, one on the biological system, one on the chemical system (DIC), and one covering the biogeochemical system. In order to provide my students with the right depth of coverage, it would take me several weeks of a term to adequately cover all the topics in the chapter on biological fundamentals. That means I would have to leave out some of the chapters elsewhere in the book. I'd like to see a better integration between the physics and biogeochemistry as well. There is a chapter on ocean ventilation where I would have liked to see inclusion of the concepts of AOU (apparent oxygen utilization), OUR (oxygen utilization rate), preformed and regenerated nutrients, and others. Similarly, the physical controls on new nutrient addition to the euphotic zone could be merged with sections on, for example, upwelling, vertical stability, and convective overturn. (Integrated consideration of these processes is how I teach it, so that is how I'd like to see a textbook present these concepts.)

As stated above, scientists with strong ocean circulation and biogeochemical modeling skills wrote the book, and so it is probably those who wish to pursue similar paths that are the best targets for the book. The essential processes that must be considered in modeling the biogeochemical system are certainly well presented (e.g., nutrient uptake kinetics). But for graduate students pursuing observational oceanography, I typically want them more broadly trained in the core disciplines of physical, chemical, and biological oceanography. Part II certainly addresses topics a student should learn in those core courses, but the book will not suffice for any one of those disciplines alone. It has too much physical content and too little biogeochemistry to stand alone in my ocean biogeochemistry courses (graduate and undergraduate levels).

I will use the book as an aid in preparing my lectures and explaining material, but without better disciplinary balance, expanded coverage of the nutrient cycles, and integration of physical and biogeochemical concepts, I cannot use it as a primary textbook. The authors may wish to better define their target audience and prepare the next edition accordingly. All books can be improved, especially first editions, so I look forward to future versions of this solid book by these two wonderful scientists. Meanwhile, I will use this version as a handy learning tool for myself and for my students.

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