An Introduction to Three-Dimensional Climate Modeling

By Warren Washington and
Claire L. Parkinson
2nd Edition, University Science
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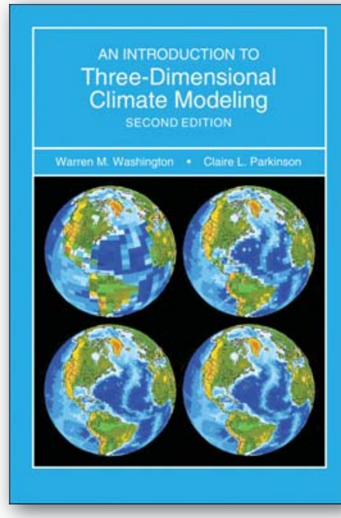
REVIEWED BY HANS VON STORCH

The first edition (1986) of *An Introduction to Three-Dimensional Climate Modeling* was an excellent book. After almost 20 years, however, it has become a bit outdated and has been replaced now by an equally excellent second edition. This book is even more urgently needed than 20 years ago. The science of climate dynamics has changed, and the book provides students and newcomers entering the field from outside with the required background for confronting the contemporary challenges of climate-forecast and climate-change studies.

In the 1980s, process understanding was the dominant quest in the mostly curiosity-driven climate research field, with special emphasis on understanding and predicting the El Niño-Southern Oscillation (ENSO). The concept of anthropogenic climate change in these pre-IPCC (Intergovernmental Panel on Climate Change) days was just emerging. Now, in 2005, three major Climate Change Assessment Reports have been published by the IPCC (available online at http://www.ipcc.ch/pub/reports.htm), and the major activity in climate science is climate model simulation and analysis. Many of the most important aspects of climate science are based on the techniques and methodology described in Drs. Washington and Parkinson's updated book.

The problem with climate science, as with almost all environmental science, is that we have only one copy of our system at hand; we cannot replicate this system, and we cannot undertake experiments (the term "experiment" is notoriously misused in our field) on the system as a whole. But, we have built detailed, process-based models of the climate system, the details of which depend on the availability of adequate compute power, the model's space-time detail, and the length of time over which the integration shall be run. These are the "three-dimensional climate models" that the book is about. These models feature a wide range of components, which depend on the application, but they all include the lower atmosphere, the world's oceans and sea ice. The authors concentrate on the latter, which is not surprising as Claire Parkinson earned her original reputation with her studies of sea ice, and Warren Washington with models of the troposphere. These models constitute artificial laboratories, within which we can study the dynamics of the climate system, the sensitivity of the system to external disturbances, and the predictability of phenomena. Indeed, the methodology required to use these models is another challenge, which equals the challenge of constructing such models.



The real-world features that the models endeavor to replicate are described in Chapter 2, which is on the phenomena in the climate system. The very extensive Chapter 3 describes the basic equations, plus for beginners, the mysterious art of approximate equations for the effect of unresolved processes on the resolved scales (called parameterizations)—such as clouds, radiation and boundary fluxes in the atmosphere, or mesoscale eddies in the ocean. But, differential equations are not yet the complete recipe for implementing a model—numerical treatment of the complex equations is far from trivial. Different techniques such as finite differences or the spectral decomposition are explained in detail in Chapter 4. Also, the hairy problem of non-negative mass-conserving transport is considered.

There are other climate models described as well; indeed, the word "model" gives rise to frequent confusion when used by different disciplines. The models in this book are "quasi-realistic models," which do not live up to the concept of Occam's razor of minimum complexity to describe a given phenomenon. Instead, they are of maximum complexity, only limited by computational constraints. Such models do not provide immediate insight into dynamics—in the same way as the uninformed look at observed data provides knowledge about reality only when the analysis is guided by appropriate "conceptual" (minimum complexity) models. The quasi-realistic models are obviously not as complex as reality, but they are supposed to approximate the real world's complexity as much as possible. Thus, using the models is not a trivial affair either.

The usage of such models is dealt with in Chapters 5 and 6. First, the satisfactory performance of the models in reproducing the present state is demonstrated; this includes the simulation of modes of variability, in particular ENSO. Then, in Chapter 6, a series of experiments on the sensitivity of the climate system on scales of decades to centuries is discussed. The authors present paleoclimatic studies, the understanding of climatic history of the past one thousand years, and the effect of increased atmospheric concentrations of greenhouses gases and aerosols. The carbon cycle is considered as well as the possible climatic effects of a nuclear war.

An Introduction to Three-Dimensional Climate Modeling (second edition) concludes with a detailed call for further improvements of quasi-realistic climate models—maybe we will enjoy a third version of the book in another 10 or 20 years? In an appendix, a variety of useful technical aspects (such as computer architectures) are described; the 36-page reference list is very useful; the index is done well.

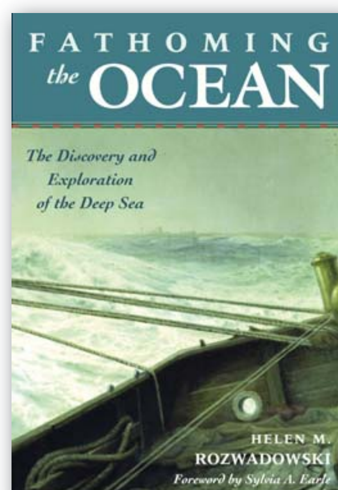
Before concluding, it may be worthwhile pointing out what the book does not cover—among other things, models of intermediate complexity, which are needed for integrations of many thousands of years. Only little is said about regional modeling, which likely will acquire more prominence after the Tenth Conference of the Parties to the UN Framework Convention on Climate Change rightly pointed out that after having broadly understood the dynamics of anthropogenic climate change, more emphasis has to be given to the possible impacts a changing climate may have on environmental risks, on societies, and on ecosystems.

I conclude with compliments to the authors for a useful and carefully written book. I will assign *An Introduction to Three-Dimensional Climate Modeling* (second edition) to my new Ph.D. students in the same way as I have asked them for almost two decades to read the first edition.

Hans von Storch *(Hans.von.Storch@gkss.de) is Director, Institute for Coastal Research, GKSS Research Center, Geesthacht, Germany.*

Fathoming the Ocean

The Discovery and Exploration of the Deep Sea



By Helen M. Rozwadowski
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REVIEWED BY CHARLES H. GREENE

As oceanographers contemplate a renewed commitment to ocean exploration (National Research Council, 2003), Helen Rozwadowski has given us a book chronicling the importance of discovery and exploration in the early Anglo-American roots of oceanographic science. Prior to the mid-19th century (approximately 1830-1880), what lay beneath the ocean's surface was a great mystery, fertile ground for the imagination and superstitions of mankind. During these dark ages, navigators considered the deep sea to be anywhere that their 100-fathom sounding lines failed to touch