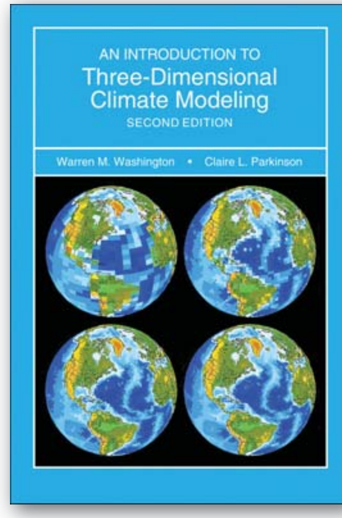
An Introduction to Three-Dimensional Climate Modeling



By Warren Washington and Claire L. Parkinson
2nd Edition, University Science Books, 2005, 354 pages, Hardcover: ISBN 1891389351, $62.50 US

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 After almost 20 years, however, it has become a bit outdated and has been replaced now by an equally excellent second edition.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.

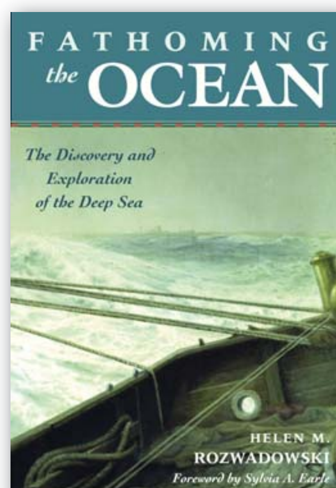
Before concluding, it may be worthwhile pointing out what the book does not cover—among other things, models of intermediate complexity, which are needed for integrations of many thousands of years. Only little is said about regional modeling, which likely will acquire more prominence after the Tenth 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
Belknap Press of Harvard University Press, 2005, 276 pages, Hardcover: ISBN 0674016912, $25.95 US

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 bottom. Furthermore, while incredible monsters and denizens of the deep were believed to inhabit the sea, most naturalists thought that ocean life could not survive at depths greater than 300 fathoms. Remarkably, in less than 150 years, ocean explorers and scientists would go on to visit the great depths of the Marianas Trench and discover the amazing communities of deep-sea animals living entirely off the inorganic chemicals spewed forth from the hydrothermal vents of mid-ocean ridges. How did ocean exploration and science emerge from a seafaring tradition in which mariners attempted to minimize their time at sea and rarely strayed from proven trading routes? In her timely and carefully researched book, Rozwadowski answers this question not only by documenting the people and events involved, but also by providing the societal context for this 19th century period of ocean enlightenment.

As a historian of science, Rozwadowski is interested in telling her readers what people did, where they did it, when they did it, and, most importantly, why they did it. The first forays into ocean exploration were an outgrowth of the navigational needs of mariners. While the sounding of coastal bottom depths had a long maritime tradition, it was only in the mid-19th century that naval officers and hydrographers began testing the limits of just how deep they could drop their sounding lines before touching bottom. What they found astounded them. The deep sea was much deeper than previously imagined; this finding had important implications for a variety of commercial and scientific enterprises, including the eventual successful deployment of the first Trans-Atlantic telegraph cable.

As the more educated members of society began to fathom the newly discovered depths of the ocean, their curiosity was aroused and they began to wonder what other secrets remained hidden. This new intellectual engagement with the sea coincided with an emerging and broader cultural obsession with all things marine. In both Great Britain and America, maritime commerce gradually awakened the general public's interest in the sea. First flocking to the beaches by rail, and then to the coastal and open ocean in vessels ranging from rowboats to luxury steamship liners, middle- and upper-class citizens began to view the sea as a destination where they could enjoy and put to useful purpose their leisure time. It was within this intellectual and cultural context that benthic dredging became popular and the science that would later become marine ecology began to emerge from its roots in shell collecting and descriptive natural history.

During the latter portion of the mid-19th century, interests in hydrography and marine zoology converged, and a new breed of professional ocean scientist, the oceanographer, took to the sea. While the *Challenger* expedition is often viewed as the beginning of modern oceanography, Rozwadowski clearly shows that its roots were much deeper. The questions addressed and the technologies employed by *Challenger*'s oceanographers were not new; rather, the expedition simply represented a scaling up of ongoing practices. This being the case, perhaps the *Challenger* expedition is best viewed as the culmination of the first stage in oceanography's evolution as a scientific discipline.

If a summary of oceanography's early evolution was the only thing that Rozwadowski's book had to offer, then I could only recommend it to a rather small group of individuals interested in the history of ocean science. Fortunately, this is not the case. *Fathoming the Ocean* draws together many cultural and scientific threads, challenging its readers to reflect not only on oceanography's past but also to think about how that past influenced the events that followed. For example, the author explicitly discusses how the *professionalization* of oceanography during the latter half of the 19th century led to the virtual exclusion of women from this field of study for nearly a century. This professional exclusion of women occurred, in part, due to the practice of oceanographers going to sea to conduct research on ships that banned women. The eventual lifting of this ban in the 1970s, combined with the field's active encouragement of young women to pursue careers in ocean science, led to the recent renaissance of women in oceanography (see Special Issue: Women in Oceanography, *Oceanography* Vol. 18, No. 1, March 2005).

While reflecting on Rozwadowski's description of oceanography's *professionalization* during the latter half of the 19th century, I began to think about some of its other consequences. For example, sometime during the late 19th and early 20th century, the interests of marine ecologists and oceanographers began to diverge, subsequently creating a rift that became institutionalized in Anglo-American universities and research laboratories and remains so to this day. What were the factors leading up to this schism? As with the exclusion of women, part of the answer is likely associated with the seagoing habits of oceanographers. Going to sea on extended cruises to conduct their research, oceanographers typically require specialized equipment and ships, both of which involve significantly greater investments of government funding. However, I am certain that the answer to this particular question lies deeper than simply the financial implications of oceanographers going to sea in ships. Eric Mill's (1989) *Biological Oceanography: An Early History, 1870-1960* picks up the story of biological oceanography where Rozwadowski's *Fathoming the Ocean* leaves off, weaving together Anglo-American traditions with influences from the European continent. Although both books provide many of the clues necessary to answer my question, neither addresses it directly. On the other hand, perhaps the sign of a really well written book, especially one devoted to history, is not only the story it tells, but also the number of intriguing questions it inspires its readers to ponder on their own.

REFERENCES

Mills, E.L. 1989. *Biological Oceanography: An Early History, 1870-1960*. Cornell University Press, Ithaca, NY.

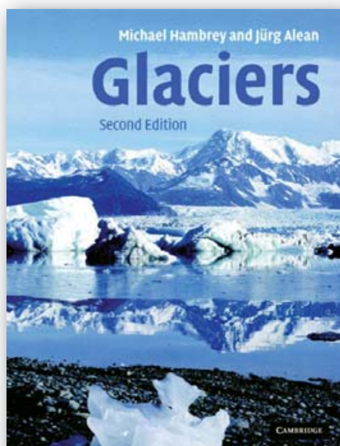
National Research Council. 2003. *Exploration of the Seas: Voyage into the Unknown*. National Academies Press, Washington, D.C.

Charles H. Greene *(chg2@cornell.edu) is Director, Ocean Resources and Ecosystems Program, Department of Earth & Atmospheric Sciences, Cornell University, Ithaca, NY, USA.*

Glaciers

By Michael Hambrey and Jürg Alean
2nd Edition, Cambridge University Press, 2004, 394 pages.
Hardcover: ISBN 0521828082, $60 US

REVIEWED BY W.T. PFEFFER



Glaciers have, with dinosaurs, woolly mammoths, Egyptian mummies, and pyramids, a kind of intrinsic allure that causes people to become fascinated by them not as a particular representative of a broader interest, but simply for their own sake. Consequently, glaciologists are frequently drawn into their subject based on a life-long attraction to glaciers and the world of snow and ice rather than as geologists or physicists simply seeking an application of their skills. The authors of *Glaciers*, like so many of us, evidently fall into this category, and their book is written for an undergraduate audience already attracted to glaciers and seeking an introduction to them as a field of study. The book is qualitative in nature—not the only approach to the subject, but reasonable for this audience—and filled with inspirational photographs on nearly every page. Taken on its own terms, the book might work for an undergraduate geography or geology class. However, I am troubled by a number of aspects. A student using this as a primary text would require some rather devoted guidance on the part of the instructor to wend a path through the world of glaciers as it is presented here—the instructor being a sort of a Virgil to Hambrey and Alean's Dante.

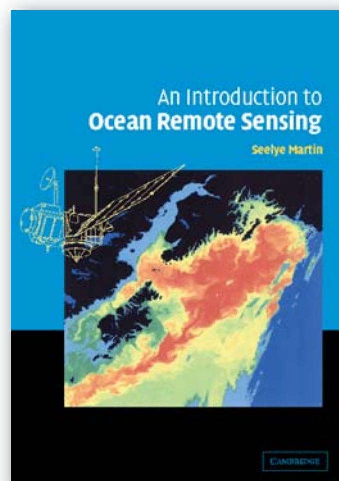
The descriptive approach is good for an introduction to a complex subject, but description alone can become confusing without a conceptual context. The authors adhere doggedly to categorization, indicating in bold face not only the definitions of principal features such as moraines, firn, and foliation, but also those for minutiae like "basket-of-eggs topography," "ice ships," and "knock-and-lochan topography." You can even learn about the relative merits of dog-sledging, man-hauling, and mechanized transport, and the distinctions between Temporary Scientific Research Camps and Permanent Stations. This information gets disorienting after a bit, and I doubt the introductory student will have much success separating the critical concepts from the ephemera. In the chapter on mass balance, snow swamps are introduced with the same emphasis as fundamentals like the equilibrium line or ablation area; at the same time, many really critical concepts are absent—in this case, for example, those of summer and winter balance, balance gradients, accumulation area ratio, or balance amplitude.

More troubling to me, though, than the addition of what could be confusing detail, is the absence of fundamentals. Some fundamentals are covered, to be sure: there are excellent descriptions of glacier morphology, good chapters on the structural features of glaciers, on the geological record of glaciation, and on the role of glaciers in global hydrology. But missing is any real discussion of important topics at the level of the dynamic nature of the Antarctic ice streams, the insights gained into ice sheet/climate interaction from the GISP II/GRIP projects, and the significance of Heinrich events. An entire chapter devoted to glacial debris gives a complete nomenclature but no discussion whatever of glaciers in a global context as erosive agents or their role in global sediment transport—no indication as to why we would need such a nomenclature.

Missing altogether is any mention of numerical modeling, of the motivations for making measurements, of our knowledge of the physical properties of water in its various phases, or of the existence of a constitutive law for ice. There is no mention of the existence of a mathematical framework for thinking quantitatively about glaciers, or even a suggestion that one might want to have such a framework. The qualitative view of glaciers is both inspiring and of good scientific utility, but to allow it to eclipse the quantitative view of glaciers in this way will not serve well the needs of any new student of Earth sciences, regardless of their motivations for coming into the subject or their ultimate scientific destination.

W.T. Pfeffer *(pfeffer@tintin.colorado.edu) is Associate Professor, Institute of Arctic and Alpine Research, University of Colorado, Boulder, CO, USA.*

An Introduction to Ocean Remote Sensing



By Seelye Martin, Cambridge University Press, 2004, 454 pages
Hardcover: ISBN 0521802806, $75 US

REVIEWED BY KRISTINA B. KATSAROS

An Introduction to Ocean Remote Sensing by Seelye Martin is an excellent textbook for teaching remote sensing of the oceans at the beginning of the 21st century. Since 1987, Dr. Martin has taught remote sensing to graduate students and senior undergraduates. *Ocean Remote Sensing* is a classical textbook that starts with fundamentals and basic principles. It then covers the entire field, which has been difficult to do in the past because some aspects of remote sensing were better developed than others. Now, with 40 years of meteorology and oceanography from space behind us, (beginning with the *Nimbus I* satellite and the early infrared measurements of sea-surface temperature in the mid-1960s), the time was ripe for a fundamental textbook on remote sensing of the ocean. There are numerous satellite systems currently gathering oceanographic data routinely, and many more are planned. The basics of the techniques are now well understood, so that more oceanographers can rely on remotely sensed data. We have now used a broad range of the electromagnetic spectrum, from the visible and infrared wavelengths, to many frequencies in the microwave region. Remote-sensing techniques have been used in passive and active modes. The active mode has mostly been used from space in the microwave range, but lasers using visible light are being used from aircraft and are planned for satellite missions. Every graduating oceanography student should now be well versed in this important data source.

Although the textbook is about *ocean* remote sensing, I mentioned meteorology because satellite oceanography depends on developments in satellite meteorology, as the ocean is observed from space through the intervening atmosphere. When using visible and infrared wavelengths to view the ocean, images must be "cloud cleared" (cloudy regions in the field of view are identified and such pixels, individual observations, removed). Similarly, signals from the ocean must be corrected for atmospheric transmission and scattering. Dr. Martin points out that 90 percent of the signal that reaches a satellite in these wavelength bands comes from the atmosphere. This signal must be accurately taken into account so that the remaining 10 percent emanating from the ocean will be correctly interpreted.

Dr. Martin should be commended for the systematic and thorough structure of his book. The first section provides the motivation for remote sensing and study of the oceans for societal interests. Commercial, naval operations, fisheries, and recreation are mentioned, as well as the oceans' role in generation of extreme weather and climate variability. He points out that 50 percent of the global population lives within 50 km of coastlines, which are vulnerable to natural hazards such as sea-level rise, tsunamis, and tropical cyclones, but also to the coastal effects of urban run-off, and waste and sewage disposal.

Chapter 1 covers the basics of typical satellite orbits and the associated sampling obtained by satellites. This chapter also covers imaging techniques and provides an overview of satellite systems since 1978 through 2007, which is very helpful for readers of this vast subject. Dr. Martin provides a list of symbols and their definition prior to this chapter, which is a useful feature especially for newcomers to the field.

The next four chapters cover ocean surface phenomena, electromagnetic radiation, atmospheric properties, and radiative transfer. Chapter 2 discusses ocean surface wind and waves, currents, sea-surface height, and sea ice. Discussions of sea-surface temperature (SST) and color are reserved for later chapters. Chapter 3 deals with basic electromagnetic theory, fundamentals of visible and infrared radiation, optics, scattering theory, transmission, and absorption (in atmosphere and ocean). Dr. Martin also discusses the ideal instrument, but does not discuss detectors of radiation. He concentrates on the basic physics of the electromagnetic transmission and on how images are obtained. Chapter 4 covers basic knowledge about the atmosphere, water vapor, clouds, aerosols, and ozone. Extinction of radiation by atmospheric gases and various scattering mechanisms are derived and application of this knowledge to remote sensing of the sea is emphasized. Chapter 5 provides detail about reflection and scattering from the ocean surface and transmission through the air-water interface as well as absorption and scattering in seawater.

Chapter 6 is devoted to ocean color and the interpretation of images. Dr. Martin focuses on the empirical and semi-analytic algorithms for interpreting the images in terms of chlorophyll *a* and discusses reflectance and fluorescence by chlorophyll. In particular, he discusses the Sea-viewing Wide Field-of-view Sensor (SeaWifs) and Moderate Resolution Imaging Spectroradiometer (MODIS) instruments. In this chapter, several sections are devoted to the atmospheric corrections and the role of atmospheric aerosol in modifying ocean color observations.

Chapter 7 examines infrared SST observations. This field is one of the most developed in oceanographic remote sensing and the data are used widely. The subject remains open for research due to the complicated air-sea interaction processes that modify the temperature gradient just below the sea surface. The author covers these details in a succinct and clear manner and discusses the two well-known sensors, the Advanced Very High Resolution Radiometer (AVHRR), and MODIS. The now classic AVHRR is carried by NOAA satellites, whose data are used globally for numerous applications in real time. MODIS is carried on two recent NASA satellites, *Aqua* and *Terra*. Dr. Martin also includes a discussion of the European Along-Track Scanning Radiometer (ATSR). Dr. Martin spends a couple of sections on the important applications of remotely sensed SST, primarily for the El Niño/La Niña observations (especially for the year 1998) and for global SST mapping.

Chapter 8 deals with the fundamentals of microwave passive instrumentation, such as antennas and scanning patterns, and describes some of the well-known instruments such as the Special Sensor Microwave/Imager (SSM/I), which has a history of continuous presence in space since 1987 on U.S. Defense Meteorological Satellites. This chapter also describes the TRMM Microwave Imager (TMI), a new sensor, and the

Advanced Microwave Scanning Radiometer (AMSR). The TRMM is the Tropical Rainfall Measuring Mission, and the TMI operates in conjunction with a rain radar on this satellite. Chapter 9 discusses passive microwave observations of the atmosphere and ocean surface, and includes all the relevant issues, however, this chapter is not bogged down in the enormous amount of detail that this field has garnered over the past 30 years. Dr. Martin still includes the effects of sea foam, azimuthal variation in emission from a wind-roughened sea surface, and variations due to polarization. The chapter discusses temperature and salinity measurements by passive microwave instruments, the latter possibility currently planned only for future missions.

In Chapter 10, Dr. Martin turns to radars, starting with fundamentals of the radar equation, various signal generation processes, and Doppler binning of the retrieved backscattered signal. In Chapter 11, he turns to the use of radar "scatterometers" for measurement of surface wind on the sea. This idea was first tested by Seasat in 1978, and has now become well established with both U.S./Japanese collaboration in launching several such instruments, and the Europeans launching two such scatterometers on the European Remote Sensing (ERS) satellites 1 and 2. The European instruments have employed a different wavelength (C-band) than the U.S.-built instruments (Ku-band), allowing knowledge to be gained about how these scatterometers interact with the sea surface wave fields. This chapter also discusses polar ice studies employing scatterometers.

Another important accomplishment of microwave radars is the development of the altimeter, a nadir-viewing radar, which measures the height of the ocean relative to a geoid. Chapter 12 starts with the fundamentals of Earth's shape and the various orbits selected for sampling by altimeters to account for tides and other temporal variations of sea height and to avoid aliasing. Again, several important instruments are discussed, notably the TOPography EXperiment (TOPEX by the United States and France) and the later JASON missions, as well as calibrations and corrections. Dr. Martin also covers the effects of surface waves on the return, from which wave height within the footprint can be determined. He discusses the effects of swell and the so-called "sea state bias" caused by the asymmetry of ocean swells' crests (narrow and peaked) and valleys (open and wide). Chapter 12 also discusses applications in terms of large-scale geostrophic flow, seasonal variations in sea surface height, and Rossby wave propagation.

In Chapter 13, the author discusses imaging radars, side-looking radars (SLRs), and synthetic aperture radars (SARs). Again, he clearly and simply describes the operation and resolution of SARs. Dr. Martin includes a discussion of the amazing Canadian RADARSAT SAR and its observations of internal waves, surface slicks, and sea ice. He does not discuss the operation of this SAR in wide-swath mode, which is contributing information of structures in the surface wind (based on knowledge from scatterometers) on scales of 100 m and longer over areas about 400 x 400 km^2. This reviewer has had the opportunity to study atmospheric convective

BOOKS RECEIVED FOR REVIEW

Satellite Monitoring of Inland and Coastal Water Quality: Retrospection, Introspection and Future Directions
by Robert P. Bukata (CRC Press, 272 pages)

Sounds in the Sea: From Ocean Acoustics to Acoustical Oceanography
by Herman Medwin (Cambridge University Press, 670 pages)

Marine Turbulence: Theories, Observations and Models, Results of the CARTUM Project
edited by Helmut Baumert, John Simpson, and Jürgen Sündermann (Cambridge University Press, 672 pages)

Leaving the Lectern: Cooperative Learning and the Critical First Days of Students Working in Groups
by Dean McManus (Anker Publishing, 232 pages)

Baroclinic Tides: Theoretical Modeling and Observational Evidence
by Vasiliy Vlasenko, Nataliya Stashchuk, and Kolumban Hutter (Cambridge University Press, 351 pages)

clouds, rain band structures, and wind fields around hurricanes over the ocean with this instrument. It is a newer application of SAR, which is also available from the European Environmental Satellite (ENVISAT) launched in 2002. This chapter is an excellent survey of most of the uses of SAR, but cannot cover all possibilities. In general, Dr. Martin should be commended for his restraint in telling the facts and including the most important applications of each instrument without drowning the reader in detail.

Chapter 14 describes future oceanographic satellite systems from 2004 through 2019, including missions approved or proposed. It will be a very helpful reference for anyone wishing to keep up with this field in the coming 15 years. There is much more to come, so the serious oceanographer would do well to obtain this book and catch up on the field, even if he/she is not actively using remote sensing in his/her work.

Dr. Martin includes acknowledgements to all the folks who helped him in each chapter, as well as suggestions for further reading. Both of these features are valuable in terms of giving credit, and to assist the reader to go further into a subject. He ends the book in section 14.10 with Final Thoughts. Here he mentions how these technologies have given us a new view of the globe and ability to calculate important variables, such as the global uptake of carbon and its dependence on the El Niño-Southern Oscillation cycle. He suggests that, "in the next two decades, it is the task of researchers and policy makers to understand these changes and relate them to national and international societal concerns."

This book is well written and has excellent illustrations. With its judicious choice of subject matter, *Ocean Remote Sensing* is not only eminently practical for students and teachers of university courses, but also for practicing oceanographers and policy-makers. It fills a very different niche than the many conference books and more specialized books that present the state of the art without the fundamentals provided by Dr. Martin.

Kristina B. Katsaros *(katsaros@whidbey.com) is Adjunct Professor, University of Miami, Miami, FL, USA, and President of the Pan Ocean Remote Sensing Conference Association.*