

## Essentials of Oceanography (Fifth Edition)

By Tom Garrison, Brooks/Cole Cengage Learning, 2008, 434 pages, ISBN 978-0-49555-531-5, Softcover, \$145.95 US.

REVIEWED BY THOMAS W.N. HAINE

Introductory marine science classes are tremendously popular on college campuses across the country. They can be superbly rewarding experiences for both students and instructors. Typically, these classes last for a single semester, and are based mainly on lectures, perhaps with a field trip to the coast, or coastal waters, where possible. Very little, if any, prior science knowledge is required, making the courses accessible to science and nonscience majors alike. Indeed, these classes are partly so popular because they deliver natural-science credits toward a nonscience major's distribution (general education) requirement.

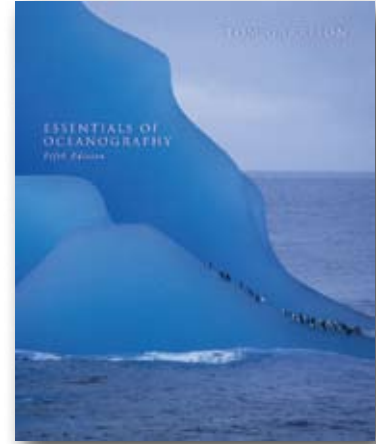
Apart from providing a valuable basic science option in the undergraduate curriculum, introductory marine science classes serve many other purposes. Students in these classes may not yet have declared their main fields of study, and can thus be recruited to departmental majors in oceanography, earth science, or environmental studies, for example. They may be upperclass students studying classical science or engineering disciplines who are potentially interested in graduate opportunities in oceanography or naval architecture. Or, they may be geoscience majors interested in the history of the ocean over geologic time, and are required to take the class for their own major. With enrollments often exceeding 100, this heterogeneity of the student cohort is typical, and diverse backgrounds, academic experience, and scientific ability are the norm.

Moreover, marine science is itself a disparate field. Academic oceanography

is the study of the marine environment and its interactions with the atmosphere, solid Earth, and biosphere. It is an interdisciplinary mix of physics, chemistry, and biology, and a prime example of an "Earth-system" science that emphasizes Earth as an integrated, complex entity that transcends traditional scientific boundaries. Marine science can mean much more than this narrow definition, however. It can extend to include environmental, social, and commercial issues, too, such as marine pollution, sustainable development of recreational beaches, and fishery management.

Given such a broad clientele, and such a wide range of potential topics to cover, designing a successful, balanced curriculum for an introductory marine science class is a challenge. And with so many interested students, a large market exists for freshman textbooks on marine science. *Essentials of Oceanography* by Tom S. Garrison is one of two books in this area by publishers Brooks/Cole Cengage Learning. The other one, *Oceanography: An Invitation to Marine Science*, also written by Garrison, is a longer version of the "Essentials" text.

Garrison, a regular contributor to these pages, is a distinguished educator with a manifest love for oceanography. His overarching aims in *Essentials* are to promote ocean literacy—the understanding of the two-way connection between people and the sea—and to stimulate long-term interest in the ocean, regardless of a student's major. Another aim of Garrison's book is to use the freshman oceanography class as an opportunity to introduce and explain the scientific method. Success in achieving these aims could be judged, for example, by the ability of his readers to grasp media reports on ocean science, and to make informed decisions on stewardship of the



marine environment.

The approach in *Essentials* is to provide a broad-brush, qualitative survey of marine science in 15 chapters and 400-some pages. The chapters are arranged in a phenomenological way, and can be read in (almost) any order; there is little accumulation of knowledge required as one works through the book. Two other common themes stand out. First, the book contains hundreds of photos, illustrations, and schematic diagrams. Almost every page contains a visual image of some kind. Second, a key strategy is to immerse the reader in oceanography through active engagement at every stage. The book achieves this approach using graphics, but there are several other ways, too: each chapter begins with an anecdotal preface of general interest, there are frequent "Study Breaks" that prompt students to review each subsection, and there are "Questions from Students" at the end of each chapter to give a different perspective. An extensive companion Web site also provides glossaries, flashcards, links to source material for every chapter, and many other study tools. Electronic slides and test questions are available for instructors.

The book addresses all aspects of marine science. Topics include the geological origin of seawater and the ocean basins, oceanic (and atmospheric) circulation, waves, tides, coasts, benthic and pelagic

ecosystems, and the history of oceanography. Evolution and natural selection are tackled, and the origin and history of life on Earth—mainly a story about marine organisms—are explained. There is also a long chapter on “Uses and Abuses of the Ocean,” which discusses exploitation of marine resources, anthropogenic impact on the marine environment, and global climate change. Links to relevant physics and chemistry are made where appropriate, although there are no connections to microbiology. Garrison’s text requires no prior knowledge of geoscience at all, so the genesis of our solar system is described, for example, as are spherical projections for chart making.

So, does *Essentials* deliver what it promises? Yes, by and large, it does. This book is strongest where it covers topics of recent public interest, like the 2005 hurricane season and the 2006 Indonesian tsunami. Here, one finds the most conspicuous changes from previous editions (four editions have appeared since 2001), although there are stylistic improvements as well. The book is beautifully illustrated, too. Oceanography instructors have access to such stunning, intriguing, and memorable images that it is a serious mistake not to exploit them in class. *Essentials* does not disappoint here, the visual standards are uniformly high. The pedagogy is also excellent. Garrison makes heroic efforts to facilitate student learning. The material is carefully paced and structured, and there are multiple review and self-assessment mechanisms to make the material stick. The author claims to have taught many tens of thousands of students, and it is easy to believe that every part of the book has been filtered through the collective undergraduate mind. As a consequence, there are no obvious omissions, and no obvious mistakes.

Although the text does not have any major weaknesses, it is not ideal for all

introductory marine science classes.

In particular, the educational style and level are not always suitable. Garrison rightly uses his subject to expound on the scientific method, and appeal to science-phobic students. But science doesn’t often work the way he writes in his book. Oceanography is a quantitative discipline, yet in *Essentials*, only two formulae are emphasized (on surface gravity waves), and no examples or questions involve numbers. Some topics seem obscure and ambiguous because they are handled in this qualitative way. For instance, the explanation of specific and latent heat capacities for seawater suffers because there are no numerical problems. There is no precise statement that heat energy is conserved either, which may further confuse students. Oceanography is also a hierarchical discipline in which knowledge progressively accumulates. For example, an accurate explanation of El Niño, or anthropogenic global warming, necessarily builds on basic (quantitative) understanding of Earth-system components. Garrison’s book does not present a layered intellectual challenge, and most students will find that they struggle to keep up with the material rather than understand it. So the danger exists that readers of *Essentials* will misjudge the nature of marine science, and the scientific method. The book is highly appropriate for students taking a terminal science class, but may well mislead those who plan to study marine science beyond freshman level.

Several other basic textbooks on oceanography compete for instructors’ attention today. These competitors are remarkably similar to one another, and to *Essentials* (a notable exception is the series of books by the Open University Oceanography Course Team). They often exhibit the same chapter structure, interchangeable images, and share anecdotes: see, for example, Spinrad’s (1996) comparison of seven of

these texts. This convergence of design and content is likely driven by the publishers and by student proclivities. Garrison’s text leads the pack, however, and, despite the reservations mentioned above, is an excellent choice for many introductory marine science classes. I should disclose that I have taught from older editions myself, on six occasions, having switched from Gross and Gross’s *Oceanography: A View of Earth* early on. I also regularly recommend Garrison’s book to students entering oceanography at the PhD or post-doc level, when remedial study on ocean literacy is needed.

With large enrollments and little assumed knowledge, students in introductory marine science classes sometimes feel anonymous, and may hope to slide by with minimal effort. Instructors can also sometimes feel pressured to entertain rather than to educate. A reliable textbook is critical to anchor such courses, and to provide an organized basis for learning. *Essentials* serves this purpose. But it exceeds being merely adequate via its clear vision, immersive style, high quality, and readability. Most importantly, the author’s enthusiastic love of oceanography shines through, and inspires the reader’s interest. Led by Garrison, even the most indifferent student will find it hard not to experience genuine wonder at the curious, fascinating ocean. ☑

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## REFERENCE

- Spinrad, R.W. 1996. The oceanographic text pattern: A review and comparison of introductory oceanographic texts. *Oceanography* 9(3):194–201. Available online at: [http://tos.org/oceanography/issues/issue\\_archive/issue\\_pdfs/9\\_3/9.3\\_spinrad.pdf](http://tos.org/oceanography/issues/issue_archive/issue_pdfs/9_3/9.3_spinrad.pdf) (accessed January 21, 2009).

## Tides of History: Ocean Science and Her Majesty's Navy

By Michael S. Reidy, University of Chicago Press, 2008, 392 pages, ISBN 0-226-70932-1, Softcover, \$40 US

REVIEWED BY HELEN ROZWADOWSKI

Oceanographers today are more aware than ever of the importance of ocean science, particularly for understanding global issues such as climate change and the repercussions of fishing on ecosystems. Now, historian Michael Reidy offers a book that argues for the importance of ocean science historically on an equally global scale. Improved navigation is certainly part of his story. More strikingly, ocean science was an integral part of both the process of European expansion and the emergence of the modern scientist.

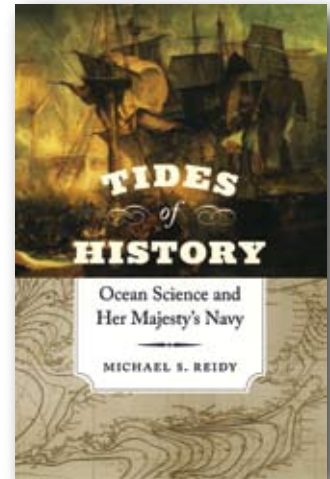
The book's focus is, of course, tidal science. It begins with the establishment of the Royal Society, covers developments through Newton's general theory of tides, then follows tidal theory to the Continent, especially to France. But the focus is not restricted to theoretical study of tides, and thus the story does not stop with Laplace's essentially correct hydrodynamic approach to tides because it did not lead to successful prediction of actual tides. From the end of the seventeenth century through the early nineteenth, although individual tide table makers worked to refine their products, no systematic study of tides was undertaken. By the mid nineteenth century, scientists could accurately predict tides in British ports and colonial possessions overseas. This book tells how governments, scientists, tide table makers, calculators, surveyors, dockyard officials, Admiralty leaders, and others contributed to the emerging science of tideology in the first half of the nineteenth century.

For readers interested in environmental

history, the book's most striking contribution is its second chapter, which describes changes to the Thames and its banks that altered the river's tides dramatically. Construction of bridges, wharves, and embankments, along with dredging and straightening efforts, radically transformed the river and created the practical problem of prediction under new tidal regimes. Because most shipwrecks occurred near shore, ship owners, insurers, and underwriters pressed for study of tides. Reidy's work emphasizes the role that humans and their activities played in what we think of as a natural environment; changes to the river caused by people altered the tides and, as a result, produced interest in tidal science.

Readers accustomed to thinking about terrestrial history might rightly identify industrialization as an important theme for the early nineteenth century, but might be skeptical about the importance of tides. Yet industrialization depended entirely on coastal and overseas shipping, so England's strength in shipping was a cause and consequence of the industrial revolution. Since the sixteenth century, world power depended on sea power but, with industrialism, Britain required—and fiercely promoted—freedom of the seas to ensure free trade. Under freedom of the seas, what mattered for the extension of power was knowledge. Increased understanding of tides led to the ability to predict them; prediction provided an unprecedented degree of control over sea lanes, ports, and estuaries where safe entry and departure of British ships enabled the extension of empire. It comes as little surprise, then, that study of tides represents an early instance of government support of science.

Although the general public may still think of science as work done by lone geniuses, today's environmental scientists



recognize the combined efforts of an array of people and funding sources and, therefore, may be interested to see how this kind of modern science came to be. In Reidy's account, tidal science was collaborative, requiring theoreticians to seek out expert calculators. Men of science, such as the banker William Lubbock and his former Cambridge professor William Whewell, who was drawn into tidal studies by Lubbock, depended utterly on the calculator Joseph Dessiou and other "associate laborers," to use Reidy's term for the small army of people who took tidal measurements, invented tide gauges, created tables, and carried out other related tasks. Whewell called such helpers "subordinate labourers" because he envisioned science as a hierarchical endeavor led by theoreticians. Reidy's thorough study documents clearly, however, that calculators and others contributed substantively to the development of tidal science in ways not acknowledged by the theorists. Calculators such as Dessiou tested theories, advanced methods, and suggested new avenues of research. The same was true for other Whewell collaborators such as Thomas Bywater, the Liverpool tide table maker; Thomas Gamlen Bunt, who was paid by grants from the young British Association for the Advancement of Science; and Daniel Ross, a calculator employed at the

Hydrographic Office.


Within the history and philosophy of science, Reidy's book makes the valuable contribution of fleshing out the central figure of William Whewell. Long acknowledged for his multi-volume *History of the Inductive Sciences* (1837) and his *Philosophy of Inductive Sciences* (1840), Whewell's own research had not been recognized by scholars. Yet, as he wrote his books, Whewell was engaged in a 20-year study of tides. He coined the term "scientist" in 1833 and used his tidal studies to reflect on the appropriate social and intellectual role for scientists. Reidy convincingly demonstrates that the challenges of studying the ocean, including its global extent, influenced Whewell's articulation of what it meant to do science and to be a modern scientist.

A powerful artifact linked knowledge of the ocean to power and, thereby, made scientists the arbiters of knowledge about the sea. The product of systematic ocean investigation under Whewell was the iso-

tidal map of the world. Charts with co-tidal lines represented knowledge visually in a way that could pass easily between men of science and mariners. Similarly, in the same period, other geophysical sciences recorded meteorological data and measurements of magnetic variation on equally practical charts. The co-evolution of modern science, state funding, and political and economic uses of knowledge of the ocean is emphasized in a small section of the book examining the United States. Systematic study of tides by the Coast Survey was underway by the 1850s; in the same decade, there were two independent American coinages of the term "scientist." As in Britain, elite men of science in the United States successfully organized their work, linked it with the government, and created knowledge that conferred power on their nation.

Reidy's writing brings his actors, their story, and this time period to life. The volume itself is beautifully made, with over 60 figures that do much more than

illustrate. Photographs and drawings of imperiled and wrecked ships remind modern readers of the overarching importance of tides to a sea-borne economy and society. Tide tables and self-registering tide-gauge tracings help explain the origins and power of co-tidal maps. The press is to be commended for the high-quality illustrations, the brief but helpful glossary, and the useful bibliography.

Near the end of the book, Reidy reminds us that Whewell's tidal theory was not correct; tide prediction is more local than global. Yet this fact only adds heft to his argument that the modern conception of the scientist was forged by studying the global ocean and, thereby, was inextricably linked to imperialism and worldwide trade. 

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## The Dynamics of Coastal Models

By Clifford J. Hearn, Cambridge University Press, 2008, 488 pages, ISBN 978-0-521-80740-1, Hardcover, \$100 US

REVIEWED BY YU-HENG TSENG

*Everything should be made as simple as possible, but not simpler.*

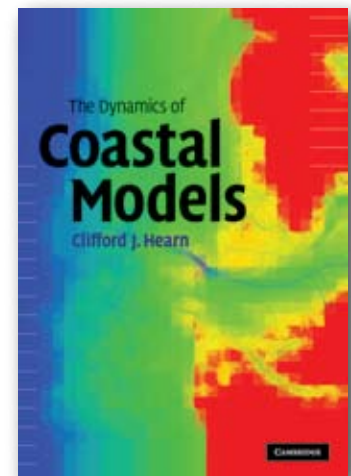
—Albert Einstein

The basic governing equations of coastal dynamics have been known for decades, but how can these equations be formulated to improve our understanding of coastal basins? *The Dynamics of Coastal Models* by Clifford Hearn does a great job of explaining and illustrating fundamental

coastal dynamics and equations through the use of simple analytical and numerical models. It motivates readers to further explore model physics using simple Microsoft Excel or Matlab examples from which basic ideas can be easily extracted (numerical codes are also tabulated). These examples are so simple that interested readers who have a basic math and science background can gain useful physical and mathematical insights into coastal dynamics through the simple models presented (which are never higher than two-dimensional). These models are very powerful tools, enabling clear demonstration and easy understanding of basic principles.

This book, aimed at the introductory

level, lays out the fundamental scientific principles of coastal models. It could serve as the first advanced textbook for graduate students who are interested in modeling coastal dynamics. Hearn's perspective is



very general and keeps explanations as simple as possible, and consequently the book will broaden students' perspectives. Its twelve chapters are written in a coherent and ordered manner. Most of the fundamental dynamics for coastal basins are addressed. Sophisticated numerical methods, modeling techniques, and complicated three-dimensional dynamics are all omitted to maintain simplicity. Thus, this book does not help students understand complicated models used in realistic applications, but rather introduces the concepts step by step.

The book starts by defining coastal basins and their characteristics. Although interacting directly with land and atmosphere, coastal basins usually contain a mixture of marine and freshwater. This book explains the basic dynamics and boundary fluxes of coastal basins using simple box and one-dimensional models. The box models represent a coastal basin as a box (zero order) varying with time, which can simplify the intrinsic dynamic using a simple system. The physical bases of the models are clearly illustrated, including some fundamental ingredients (e.g., continuity and conservation laws).

After introducing basic concepts, Hearn runs through chapters on other fundamental dynamics and processes that feed into coastal models. These chapters are more suitable for graduate students because they require some background in ordinary differential equations and dynamic systems in order to better understand the underlying physics and processes. Fortunately, the mathematical formulation provided in the book is derived as simply as possible, and easy examples are given. Readers can follow these chapters without losing generality. For example, the influence of the Coriolis force on the rotating Earth is explained and discussed by means of interesting examples such as Foucault's pendulum. Some simplification is definitely made

so that analytical solutions can be obtained and programmed easily. The chapter on the physical processes of hydrodynamic models focuses on wind stress, Ekman balance, and geostrophic current. Simple mathematical models are then used in the text for further explanation, although more detailed models would lead to much greater accuracy in terms of describing circulation realistically. Hearn follows these chapters with discussions in a very coherent way.

Hearn's discussion of simple models for tides and long waves is very helpful for beginners. Useful Matlab codes explore the behavior of surface elevation (including wave motions) and effects of coastal slopes. Numerical approaches are inevitable in this chapter. Basic numerics, such as grid arrangement, the selection of vertical and horizontal coordinate systems, and finite difference, are provided and discussed, although not in great detail. Nevertheless, the book provides enough information for a beginner to choose the required numerical methods.

Various aspects of mixing and turbulence are also emphasized in this book. In coastal basins, molecular processes of mixing and turbulence should both be addressed because the coastal ocean includes not only relevant open ocean dynamics but also bottom boundary layer dynamics (logarithmic layer). Chapter 7 starts from very general concepts of turbulent mixing, such as classical mixing length and Fick's law. It even discusses molecular viscosity in great detail using Stokes' law. Several different length scales are briefly introduced without detailed derivation, followed by the complicated turbulence closure. A reader who does not have any background in turbulence or fluid dynamics will find this chapter difficult but useful further reading is suggested at the end of the chapter.

It is helpful that the basic ideas behind

modeling advection in coastal basins are described in a separate chapter. To facilitate understanding of advection, Hearn starts with the inertial force, tidal jet, and Bernoulli model. He also emphasizes the hydraulic jump and flow over a slope using several numerical examples. Readers could also practice the coding themselves. Avoidance of further discussion of nearshore processes in the coastal basins makes this book more concise and focused.

In general, this book is well organized except for some discussions close to the end. Several miscellaneous topics related to coastal basins are presented without clear organization, detracting from the specific focus of this book. For example, Chapter 9 discusses several aspects of stratification, such as temperature, vertical mixing, and potential energy. An example of wind-driven currents in stratified basins is also provided here as a separate section. An improvement would be to include a brief introduction at the beginning of all chapters describing how the following sections are organized and arranged. This addition would help advanced readers decide which materials they want to read or skip, and is very important for an advanced textbook. Similar miscellaneous can be found in the final chapter, which discusses, without going into great detail, available wave models for coastal basins and the physical conditions that lead to sediment erosion, transport, and deposition.

Chapter 10 discusses more complicated dynamics in partially mixed basins and emphasizes the dominant processes of salt and heat transport. It again raises the issue of vertical mixing, which may also lead to horizontal advection resulting from the vertical shear induced by tides and winds. Hearn gives a logical explanation for the turbulence mixing process and the dispersion and exchange rates in basins. Some fundamental ocean processes such

as El Niño are also briefly introduced for information purposes, although the discussion is not very detailed. More advanced students can also use the phase planes to understand the Stommel transitions in a basin. This book provides many useful realistic examples at the end of each chapter.

In addition to boundary layer dynamics, the other important surface process that deserves specific attention in coastal dynamics is surface friction, owing to the very nature of solids and fluids. Roughness plays a major role in models of coastal basins at a variety of spatial scales. Chapter 11 on roughness, fractals, and self-similarity introduces ideas that target

multiscale dynamics in coastal basins.

In order to cover the comprehensive subject of coastal dynamics, the book briefly introduces some chemical and biological processes using simple models. Both are important dynamics in the coastal ecosystem. Further detail, however, is absent because of irrelevant mechanisms and topics.

The failure to discuss nonhydrostatic influences, not even to mention the topic, is the main weakness of this comprehensive textbook on coastal dynamics. It is well known that nonhydrostatic dynamics plays an important role in coastal dynamics. It is the critical characteristic of coastal basins, where vertical acceleration is as important

as other dynamics. Nevertheless, this book represents a significant improvement in advanced textbooks on coastal models. It brings together coastal dynamics through simple code development and encourages readers not to be afraid of using models. Most important of all, the clearly written text and materials will motivate the interested graduate student to seek a better understanding of coastal dynamics. ☐

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## Chasing Science At Sea: Racing Hurricanes, Stalking Sharks, and Living Undersea with Ocean Experts

By Ellen Prager, University of Chicago Press, 2008, 162 pages, ISBN: 978-0226678702, Hardcover, \$22.50 US

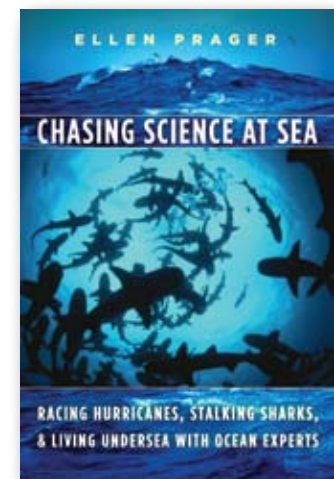
REVIEWED BY ALICE ALLDREDGE

All marine scientists who work in the field have them—personal stories of amazement, discovery, awe, excitement, and even danger while conducting research. They are the stories we love to tell to friends over a beer or to rapt high school students aspiring to become marine biologists or oceanographers. And in the telling, we ourselves somehow reconnect to the deepest motivations that brought us to marine research in the first place. Reliving those marvelous adventures displaces our disgruntlement with e-mail, proposals, and mundane paper work and reminds us how lucky we are to be marine scientists.

Ellen Prager's delightful and engrossing book, *Chasing Science at Sea*, is a

compilation of hundreds of such field stories from marine scientists of all disciplines. They are woven together with interesting facts, descriptions of various field activities, and the lessons learned from setbacks to create a rich and multifaceted portrayal of the world of marine field research. But the purpose of these stories is more than just to entertain. As ocean science has become increasingly dependent on remote technologies, fieldwork has become harder to fund, less prevalent, and more difficult to undertake. Ellen Prager's hope is that these stories will illustrate the value of fieldwork, inspire the next generation of students to a renewed commitment to field-based research, and help preserve some of the history and experiences of modern marine scientists.

Written in an engaging and highly readable style, the stories in *Chasing Science at Sea* include the wonder of discovering new organisms or of seeing amazing sights such



as many whale sharks feeding together or the magic of bioluminescence. The activities of field science are also realistically described with examples including the complicated dance required to set out a deep-sea mooring and the challenges of developing appropriate technologies to investigate the deep ocean. Some of the stories, such as a firsthand account of observing the *Titanic* from a Russian submarine, make readers feel as if they had been there themselves. Many of the narratives offer riveting suspense, including tales of outrunning a hurricane, of being aboard

a ship making nearly a 90° roll, or of a submersible being attacked by a swordfish. There is good balance among disciplines, with interesting anecdotes from geologists, undersea archeologists, and physical oceanographers, as well as from biologists who study open-ocean and shallow-water habitats alike.

I found the chapter on the challenges of living and working in underwater habitats such as the early Hydrolab or its more advanced successor, Aquarius, especially interesting and filled with humor as well as insight. I had never thought about what happens to a lemon meringue pie when it is subjected to pressure (white slime and yellow goo), the long-term impacts of modest nitrogen narcosis (lots of practical jokes and some very happy scientists), or the activities of the surface support crew in monitoring the scientists and ferrying food and supplies to them. The drama and tension of removing aquanauts during a hurricane or the wonder of feeling fully accepted as just another member of a reef community are very well expressed.

Throughout the book, Prager uses stories to illustrate many principles critical to successful field science, including the importance of being able to adapt to the serendipitous, learning to balance curiosity with safety and common sense, dealing with physical discomfort and Spartan conditions, being prepared for all eventualities, and maintaining a sense of humor in the face of setbacks and downright bad luck. She points out obstacles and hardships as well as rewards. While some of the stories come from the author's own extensive experience, the many that do not are clearly identified with particular researchers. Most professional marine scientists will recognize many of the storytellers and enjoy reading tales from at least a few of their own personal friends and colleagues.

Although *Chasing Science at Sea* will certainly captivate professional field

scientists and lay people fascinated with the ocean, its most important target audience is students. This entertaining and stimulating book would be a popular and sought-after addition to any junior high, high school, or college library and would make an excellent gift for any aspiring young marine biologist or oceanographer. Its realistic descriptions of field research, its ample photographs, and its emphasis on the adventurous and amazing experiences possible in the field are bound to bring many young people into ocean science and inspire them to pursue careers in field-based research. *Chasing Science at Sea* truly succeeds in communicating the challenges, excitement, and sheer fun of marine science in a way that is accessible to all. ☐

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## Upcoming Special-Issue Topics

**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 Chicowski (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**

**THE FUTURE OF OCEAN BIOGEOCHEMISTRY IN A HIGH CO<sub>2</sub> WORLD**

Guest Editors: Richard Feely (National Oceanic and Atmospheric Administration), Victoria Fabry (California State University, San Marcos), Barney Balch (Bigelow Laboratory for Ocean Sciences), and Scott Doney (Woods Hole Oceanographic Institution)

**Future Topics**

SEAMOUNTS

OCEAN ENERGY TECHNOLOGIES

FUTURE OF OCEANOGRAPHY FROM SPACE

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