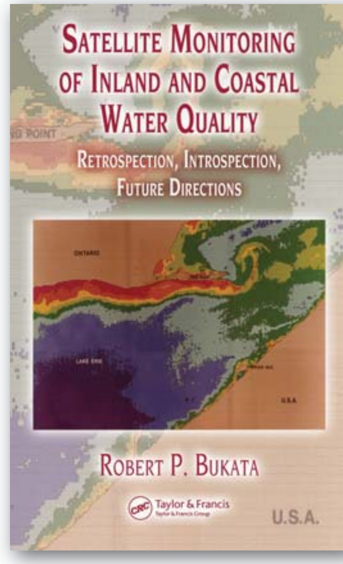
Satellite Monitoring of Inland and Coastal Water Quality

Retrospection, Introspection, Future Directions



By Robert P. Bukata, CRC Press, LLC, 2005, 272 pages, ISBN 0849333563, Hardcover, $129.95 US

REVIEWED BY CURTIS D. MOBLEY

Note the title of this book. It is about remote sensing of coastal and inland "Case 2" waters, not the open ocean. It is a book of commentary about remote sensing, not a text where you learn how to do remote sensing. Robert Bukata, who has decades of experience in "ocean color" remote sensing of optically complex inland and coastal waters, collects the wisdom he accumulated during those years. He allows himself the luxury of waxing poetic and laying out his personal opinions for all who agree or disagree with his viewpoints. I envy him for that opportunity.

Ocean-color remote sensing of open-ocean waters has revolutionized blue-water oceanography and our understanding and monitoring of Earth. Bukata claims that the equally great potential of remote sensing of inland and coastal waters remains unfulfilled. The reason is that the scientific community often has failed to provide potential users with the information they need for resource management and policy formulation. Scientists may get excited about the bumps in a spectral radiance distribution, but most potential end-users of the imagery need to know things like: Has this sea grass bed decreased in size since last year? Is this coral reef healthy? Are sediment or nutrients eroded from nearby farms making this lake uninhabitable for a particular species? In the absence of relevant end-user products, the manager or politician regards the imagery produced by scientists as little more than pretty pictures, and an agency responsible for a wetland continues to collect water samples for laboratory analysis. If remote sensing does not provide the water-quality products needed by these non-scientist end-users, no advocacy group develops to ask for more research, and future scientific development and ecosystem management suffer.

Bukata directs his discussion primarily to scientists—from graduate students to seasoned veterans—to make them aware of the needs of nonscientists who are potential, but not current, users of remotely sensed imagery. His message is simple: if you do not make a product your customer needs, you go bankrupt. Managers are the secondary audience, and the intent is to help them understand the capabilities and limitations of remote sensing and see what they are missing by not utilizing remote sensing.

After an introductory chapter, he gives a non-technical overview of the science underlying remote sensing of inland waters, and then a chapter on the problems associated with extracting water-quality parameters from mineral-laden Case 2 waters. Chapter 4 enumerates various possible applications of water quality products to environmental monitoring, and Chapter 5 describes the water-quality products currently available for Case 2 waters. There are specific examples of successes as well as "lost opportunities" from the Great Lakes and coastal waters. Two more chapters on current remote sensing systems and "truth in advertising" of remote sensing products complete the book. The author includes a useful acronym list, a glossary, and references.

I agree with much of what Bukata has to say. Many pages in my review copy now have sentences underlined where he makes important points. What I do not like about the book is the writing style. There is much extraneous material. For example, page 15 lists the titles and singers of 18 songs, 10 of which I have never even heard of. I confess that I seldom listen to music, but in any case I am unable to see how Bukata's favorite music has anything to do with remote sensing.

Important points are always presented in bullet form. This is acceptable in a PowerPoint presentation, but it is tedious and overdone in this book. Few readers, myself included, are going to wade through his three-page, 53-bullet "summary of what environmental end-users might need." The information is important and logically summarized, but the presentation makes for slow reading.

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Down to the Sea for Science

75 Years of Ocean Research, Education, and Exploration at the Woods Hole Oceanographic Institution

By Vicky Cullen, Woods Hole Oceanographic Institution, 2005, 184 pages, Hardcover, $25 US

REVIEWED BY CHARLES H. GREENE

Since its beginning, the Woods Hole Oceanographic Institution (WHOI) has been the quintessential American oceanographic research institution. Although WHOI was not the oldest American institution dedicated to ocean research, not even the most senior within the town of Woods Hole, its history during the past century has been one of constantly breaking new ground and setting new trends for the world's ocean research community. What is it that set this groundbreaking and trendsetting institution apart from the other oceanographic research institutions that came into existence during the past century? The answer to this question can be found in Vicky Cullen's richly illustrated history of WHOI entitled *Down to the Sea for Science.*

Down to the Sea for Science was written to commemorate WHOI's 75th anniversary. Today, it is remarkable to contemplate how far WHOI and American oceanography have come during those 75 years and how closely intertwined are the histories of both. Although WHOI was founded in 1930, its roots, as well as those for American oceanography as we know it today, can be traced back to the 19th century. Vicky Cullen does a superb job of chronicling in words, illustrations, and photographs how the small village of Woods Hole evolved from the modest home of the U.S. Bureau of Fisheries' first permanent field station in 1885 to what is today one of the most renowned centers of ocean science in the world.

During the decade leading up to the founding of WHOI, two prominent marine biologists, Frank Lillie of the University of Chicago and Henry Bigelow of Harvard, set into motion the events that would alter the history of oceanography. Lillie, considered "the founding father of WHOI," was the driving force behind these events, using his formidable lobbying skills to sway the scientific policies of the federal government while simultaneously securing unprecedented private support for oceanography from the Rockefeller Foundation. As a result of Lillie's efforts, the National Academy of Sciences formed a Committee on Oceanography, chaired by Lillie, which was charged with creating a vision for the future of oceanography in the United States. Under Bigelow's guidance, as secretary, this Committee produced a final report that was not only influential in steering the future direction of American oceanography, but also instrumental in the establishment of WHOI.

"The establishment of a well equipped oceanographic institution on the Atlantic coast" was the first recommendation made by the Committee on Oceanography. With generous support from the Rockefeller Foundation, this recommendation quickly became a reality, and WHOI was born. Bigelow was recruited from Harvard as WHOI's first director, a position he would hold for the initial decade of the new institution's existence. Although "quiet, modest, and unassuming," Bigelow made his mark on the future development of WHOI and American oceanography in general. His interdisciplinary approach to oceanography, as evidenced by his earlier physical and biological studies of the Gulf of Maine, was adopted not only at WHOI, but foreshadowed its subsequent adoption at the Scripps Institution of Oceanography (SIO) and other prominent schools of oceanography throughout the United States.

Bigelow's student and protégé, Columbus Iselin, took over the reigns at WHOI in 1940 and oversaw the war-time boom years between 1941 and 1945, when the Institution made the transition from a small-scale, largely summer-time venture focused on basic research to a large-scale, year-round operation doing applied Navy research. The expansion in staff and facilities associated with the Second World War led to an uncertain period afterwards as both the Navy and WHOI readjusted to a world at peace. This rocky transitional period was eased somewhat by the establishment of the Office of Naval Research and National Science Foundation, the first federal funding agencies in the United States committed to supporting scientific research.

In 1950, Iselin stepped down as director and was replaced by Edward Smith, who served until 1956. WHOI continued to grow during Smith's tenure; however, the relationship between the Institution and its director was an uneasy one. Smith's military background did not lend itself to WHOI's "can do but unstructured atmosphere." In many respects, Iselin continued to serve as WHOI's de facto director, a situation that was formalized when he returned to the directorship from 1956 to 1958. This was a critical two-year period for WHOI as it coincided with the International Geophysical Year (IGY) and Russia's two *Sputnik* launches. American oceanography would be strongly impacted by each of these events, and it was to WHOI's advantage that a spokesperson as highly regarded as Iselin was at the helm.

In June 1958, Iselin passed the directorship on to Paul Fye. Spurred by President John Kennedy's vision "to tap the ocean depths," oceanography in the United States entered its golden age. During Fye's tenure as director, from 1958 to 1977, WHOI's operating budget increased nearly tenfold and its staff doubled in size. To support its enhanced operations and accommodate its enlarged staff, WHOI's research fleet and onshore facilities grew at an unprecedented rate. Larger, more capable research vessels, such as *Atlantis II*, *Knorr*, and *Oceanus*, joined the Institution's fleet, as did the first civilian deep-submergence vehicle, *Alvin*. Onshore, the village of Woods Hole could no longer keep pace with WHOI's demands for more space, so the new Quissett Campus was acquired and construction of new laboratories began. There were many other notable advances at WHOI during the Fye administration, including the acceptance of women participating on oceanographic cruises and the establishment of two new programs that were influential in the Institution's subsequent development: the Joint Program for graduate education, offered with the Massachusetts Institute of Technology (MIT), and the Marine Policy and Ocean Management Program.

When Fye stepped down as director after 19 years in 1978, WHOI was beginning to feel the tightening of federal agency purse strings as the golden age of oceanography gradually came to a close. John Steele arrived from the Marine Laboratory in Aberdeen, Scotland to become WHOI's fifth director. During his administration from 1978 to 1989, the pace of growth at WHOI declined, but there was a focusing of the Institution's intellectual and scientific talents. As Bob Gagosian, WHOI's associate director at the time, observed in the 1989 annual report, "Competition for federal funding sources dramatically increased as the decade came to a close. As a result, our Scientific and Technical staffs have had to sharpen their focus and spend more time trying to market and sell their science." Although staff members throughout the Institution responded well to the challenge of increased competition for federal funding, perhaps no individual and group were better prepared to market and sell their science than Bob Ballard and WHOI's Deep Submergence Laboratory (DSL). Using Navy support to pioneer the development of deep-sea vehicles, Ballard and his DSL colleagues captured the public's imagination with high-profile expeditions to the *Titanic* and other sites of historical and scientific interest. In many respects, the DSL's success during the 1980s and 1990s promoted national and international interests in deep-sea technology that are central to today's major initiatives in ocean observing systems and ocean exploration.

In 1989, Craig Dorman, a former Navy admiral, succeeded Steele as director. Dorman was a graduate of the MIT/WHOI Joint Program and developed a reputation within the Institution as a hands-on and supportive director. With Dorman's encouragement, WHOI formed new international alliances and strengthened its relationships with industry and various federal agencies. Unfortunately, WHOI weathered an aggressive federal audit, a problematic refit for R/V *Knorr*, and a difficult transition to a computerized financial system during Dorman's tenure as director. The role that these events played in Dorman's decision are not detailed by Vicky Cullen, but Dorman left WHOI in 1993 after only four years as director.

Bob Gagosian, WHOI's current director, replaced Dorman in 1993. Gagosian moved up the ranks at WHOI from Assistant Scientist to Director over a period of 21 years. This long relationship with WHOI presumably provided him with the experience and resiliency necessary to steer the Institution through the turbulent, but exciting times oceanography has faced over the past 12 years. Vicky Cullen does not provide much detail here, preferring instead to focus her story on the events and people whose stories are complete. I assume that we will have to wait for the Institution's 100th anniversary before we learn more about Gagosian and WHOI in the new millennium.

After reading *Down to the Sea for Science*, I found myself reflecting on what it was that set WHOI apart from its peer institutions during the first 75 years. WHOI was certainly not the oldest institution dedicated to marine research in the United States, with the Marine Biological Laboratory (MBL) in Woods Hole, the University of Washington's Friday Harbor Laboratories (FHL), and SIO all celebrating their centennials prior to WHOI's 75th anniversary. Given the great rivalry that developed between WHOI and SIO over the past 75 years, I found a comparison of the two institutions' early histories quite revealing (see *Oceanography* Vol. 16, No. 3, 2003 for a centennial review of SIO's history). Despite it seniority in age, SIO did not begin to emerge as the great interdisciplinary oceanographic institution it is today until after Harald Sverdrup became its third director in 1936. Prior to 1925, SIO was called the San Diego Marine Biological Institution, and it was primarily dedicated to the study of marine biology in the same tradition as the MBL and FHL. In 1924, T. Wayland Vaughan, a marine geologist by training, became the San Diego Marine Biological Institution's second director and succeeded in changing its name to SIO the following year. Vaughan had a clear vision of what it takes to make a great interdisciplinary oceanographic institution. This is revealed in an excerpt from one of his correspondences with Bigelow when both were members of the Committee on Oceanography:

> *From the last paragraph of your [January 17] letter it appears to me that you are still looking on oceanography as an adjunct to biology. I would rather turn it around and look on marine biology as an adjunct to oceanography. You have been [led] to study the ocean primarily from a biological motive, whereas my motive was primarily a geological one. Since I am in the oceanographic game I should combat the consideration of the sea as an adjunct to geology no matter how important geology may be… I think that the ocean should be studied as a thing for itself and as one of the most important parts of the earth.*[1]

After reading this quote from *Down to the Sea for Science* and reviewing the SIO centennial issue of *Oceanography*, I conclude that one of the great ironies in the early history of American oceanography is the strong influence that Vaughan, the Director of SIO, had in shaping the future direction of WHOI. Had Vaughan received a comparable share of the Rockefeller funding for SIO, then perhaps the histories of these two great oceanographic institutions may have been reversed, and WHOI would have found itself playing catch up with its west coast rival at the dawn of the Second World War expansion in oceanography. Visionary leadership, political influence, and timing were all key ingredients in shaping American oceanography during the 20th century. WHOI's good fortune in all three enabled it to become the groundbreaking and trendsetting institution it is recognized as today.

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[1] Reproduced in *Down to the Sea for Science* (p. 12-13) from H.B. Bigelow correspondence, Special Subjects 1913-1930, HUG4212.10, Harvard University Archives.

Sounds in the Sea

From Ocean Acoustics to Acoustical Oceanography

By Herman Medwin, Cambridge University Press, 2005, 670 pages, ISBN 052182950X, Hardcover, $100 US

REVIEWED BY WALTER MUNK

My review copy came with the following note attached:

Dear Reviewers of Sounds in the Sea*:*

Some of us have the audacity to believe that ocean exploration is more important to mankind than space exploration. And we have the wisdom to understand that current acoustical studies, which use frequencies from a fraction of a hertz to several megahertz, and which include ranges up to half way around the world, are far more effective at sea than optical efforts which operate over only a single octave (frequency ratio 2 to 1) and achieve ranges of only a few meters.

The accompanying new book on underwater sound written with 25 co-authors, from Australia, Canada, England and the U.S. serves a dual-purpose: it is both a text and a reference volume that starts with fundamentals at the under-graduate level and moves on to 15 chapters that describe current ocean acoustical research. Along the way, it makes predictions of activities for the next five years, and concludes with approximately 500 selected references to the most important and recent literature.

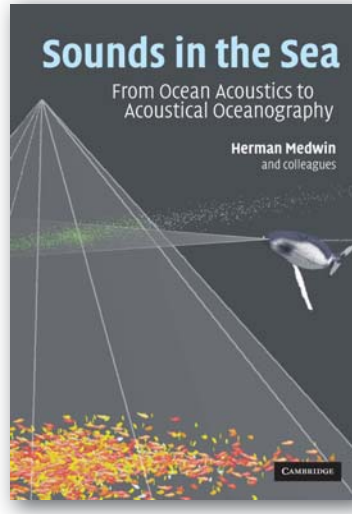
Our aim is to facilitate the integration of ocean acoustics into applied physics, engineering, and biology curricula. It is our hope that Sounds in the Sea *will become a vital component of all college studies of the ocean sciences and ocean engineering, as well as a useful reference for practicing ocean scientists and ocean engineers.*

Sincerely,

H Medwin, author of Sounds of the Sea

The letter states the author's intentions more clearly than anything I could have said; Medwin has admirably fulfilled his quoted intentions.

Medwin has previously published two graduate-level textbooks on this general subject: Clay and Medwin's *Acoustical Oceanography* (1977), followed by Medwin and Clay's *Fundamentals of Acoustic Oceanography* (1988). When I turned to acoustics rather late in my career as physical oceanographer, it was with the help of the 1977 volume. Part I of Sounds in the Sea, written by Medwin, is on the fundamentals of ocean acoustics (311 pages of the present volume) and has been extracted from the 1998 book. Part II (287 pages), written by twenty-five authors, is on acoustical oceanography. Medwin makes the following distinction in "Ocean Acoustics" our "...knowledge of (assumptions about) the ocean ... allows one to use sound to find fish, submarines,



icebergs..."; whereas "Acoustical Oceanography" is devoted to probing diverse ocean processes using acoustics as a tool. (Medwin has fostered a similar distinction in the organization of the Acoustic Society of America.) But the two points of view are strongly interactive and the distinction not always so clear.*

Part I by Medwin, *Fundamentals*, starts with principles of sound transmission, followed by ocean-oriented discussions of biological sounds, and their interactions with the seafloor and the sea surface. Emphasis is on the interpretation of experimental results guided by theoretical considerations (rather than on systematic derivations) with careful attention to the many illustrations. The reader (student) is frequently warned that "this section contains some advanced analytical material." Medwin pays tribute to his many naval officer students at the Naval Postgraduate School who "went on to become Admirals and Captains in the Navies of the USA and Turkey and West

* Note added in proof. Medwin was not the only, nor the first, acoustician to propose such a distinction: Igor Mikhaltsev (personal communication 2006) refers to the "birth of two new sciences ... in the late fifties, 'Ocean Acoustics' and 'Acoustical Methods of Ocean Investigation.'" All of the former papers were classified. For a recent history, see Mikhaltsev I. E. 2002. *Izvestiya Atmospheric and Oceanic Physics*, 38: 738–743.

Germany." Medwin's lifelong teaching effort has made a significant contribution to today's existing capabilities in antisubmarine warfare. Here the presentation of the fundamentals provides the necessary background and structure for the second part of the book.

In Part II, *Studies of the Near-Surface Ocean*, Medwin has made an excellent choice of co-authors. I doubt whether anyone else would have been able to assemble so many leading investigators in such diverse fields. The distinction between active and passive sources in acoustic oceanography appears in many of the chapters. As David Farmer points out, "the ocean provides a natural acoustic signal rich in frequency diversity, temporal variability, and directionality, that can be exploited to learn about the air-sea interface... and the details of wave breaking which play so important a role in air-sea transfer of momentum...." Farmer discusses scattering from bubbles as an example of active acoustics. There are many aspects of bubble dynamics; the role of bubbles as tracers offers particular promise.

Precipitation at sea is one of the most difficult meteorological parameters to measure. Jeffrey A. Nystuen has been pioneer in using the underwater sound of rain to measure oceanic rainfall. The acoustic record can be inverted to quantitative measures of drop size distribution.

The distinct roles of active and passive acoustics are particularly evident in bioacoustics. Scattering of sound by zooplankton is making it possible to observe animal behaviors on temporal and spatial scales that impact individuals. Fishery acoustics is to convert returned acoustic energy into fish lengths, spatial and temporal distributions, and species-specific biomass estimates. Bioacoustic absorption due to fish with swim bladders can have a large effect on transmission loss. Absorption spectroscopy can relate absorption lines to the dimensions of swim bladders and provide estimates of year classes. Studies of fish hearing and avoidance have motivated quieter platforms. Fish-distribution surveys conducted by autonomous underwater vehicles with broad-beam sonars may not be far off.

The high sound levels emitted by some marine animals can be detected at great ranges. This has led to highly

UPCOMING BOOK REVIEWS

Aglow in the Dark: The Revolutionary Science of Biofluorescence
by Vincent Peribone and David F. Gruber
Harvard University Press, 263 pages

Chemical Oceanography (3rd Edition)
by Frank J. Millero
CRC Press, 496 pages

Dynamics of Marine Ecosystems: Biological-Physical Interactions in the Oceans (3rd Edition)
by K.H. Mann and J.R.N. Lazier
Blackwell Publishing, 496 pages

HYDRO to NAVOCEANO: 175 Years of Ocean Survey and Prediction by the U.S. Navy
by Charles C. Bates
Corn Field Press, 329 pages

The Turbulent Ocean
by Steve A. Thorpe
Cambridge University Press, 439 pages

successful passive bioacoustic studies of marine mammals. Among the techniques being developed are matched field filters to detect and identify the calls. Acoustic oceanography may provide the clue of whether and how the animals themselves exploit the acoustic information. Many species of fish are also vocal and contribute significantly to the ambient ocean noise.

Perhaps the earliest application of acoustic methods to ocean science was in the measurement of ocean depth by fathometers. But there are many other seafloor applications under development. Hydrothermal plumes have been acoustically detected by the backscattered intensity and Doppler of particles suspended in the plume. A low-flying aircraft provides a high-speed, low-frequency underwater sound source that can be used to obtain the speed of sound in shallow sediments.

Processes in the water column offer exciting opportunities. Among those discussed in *Sounds in the Sea* are turbulent processes using Doppler and acoustic scintillation techniques. Since the mid-1980s there has been increasing use of the Acoustic Doppler Current Profiler (ADCP) to measure the vertical profiles of horizontal currents. The new ability is to make continuous measurements of turbulent stresses, dissipation, and other crucial turbulence quantities. These Doppler techniques use backscattered sound. An alternate method uses the acoustic scintillations in forward scattered sound. Ultimately such systems deployed at autonomous observatories could provide information on mixing events. The coastal environment with its complex boundary and current system provides perhaps the greatest challenge.

There are many other applications of acoustic methods to the study of ocean processes. I end this brief account with a method closest to my heart: ocean acoustic tomography (aptly described by Robert Spindel). The speed of sound is a sensitive function of temperature and pressure. Together they determine the properties of an oceanic waveguide (the SOFAR channel), which has been exploited since its discovery in the mid-1940s by Maurice Ewing and J. Lamar Worzel. The arrival pattern is a good indicator of the mean temperature profile between source and receiver. Reciprocal transmissions yield the mean current profile (sound travels faster with the current). Acoustic tomography exploits these features. An essential feature is the low-pass filtering associated with the horizontal averaging. Early transmissions at 300 to 900 km ranges suppressed internal wave "noise" to study mesoscale variability. Later transmissions at megameter ranges suppressed the mesoscale processes to provide information on basin-scale variability. This ability to suppress the intensive small scales to study the weak large scales is a powerful tool in an ocean with a "violet" wavenumber spectrum. It is crucial in the study of climate.

Some minor closing comments. A more uniform notation would have been nice, but nearly impossible to achieve. (I have a continuing problem of whether $\theta = 0$ stands for normal or glancing incidence.) In the general bibliography, I miss a reference to Brekhovskikh and Lysanov's *Fundamentals of Ocean Acoustics* (Springer 1982 and 1991), a slim, elegant volume with exquisite taste on what to include and what to omit. I miss a reference to *Computational Ocean Acoustics* (Jensen, Kuperman, Porter, Schmidt 1993, AIP), when so much of recent progress can be attributed to increased computer power. The reference to Flatté's *Sound Transmission Through a Fluctuating Ocean* is without the accent on the author's name and without the names of his four co-authors.

On completing my reading of *Sounds in the Sea*, my overall impression is one of rapid developments along a vast array of subjects, none more daring than in bioacoustics. (This is in stark contrast to the "cautionary principle" followed by some environmental groups, which has impeded progress in active acoustics. There has been no real progress in fifteen years towards finding a common ground in spite of some major efforts [e.g., appendix p. 474].)

Each of the authors was encouraged to comment about the future. In Medwin's words, "it is a vast, complex, mostly dark, optically opaque, but acoustically transparent world that has been only thinly sampled by today's limited technology and science." If you believe, as I do, that the time to write a book is when a subject is under active development rather than when it has settled into a coherent structure, then the time for *Sounds in the Sea* is right.

Editor's Note: Dr. Medwin passed away while this review was in press.

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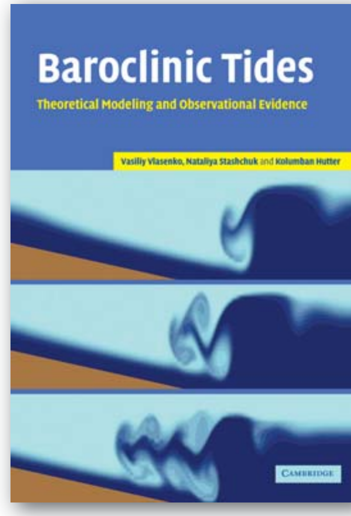
Baroclinic Tides

Theoretical Modeling and Observational Evidence



By Vasiliy Vlasenko, Nataliya Stashchuck, and Kolumban Hutter, Cambridge University Press, 2005, 351 pages, ISBN 0521843952, Hardcover, $120 US

REVIEWED BY PETER MÜLLER

This is a timely book. Baroclinic tides have emerged at the forefront of research in physical oceanography as they might provide a link between large-scale circulation and small-scale mixing. This book summarizes the theories, numerical models, and observations that form the basis of our current understanding of the generation and evolution of baroclinic tides. It is required reading for anyone who wants to get involved in this exciting field of research.

Baroclinic tides are internal gravity waves of tidal frequency. They are generated when the astronomically forced barotropic tidal currents encounter topographic slopes and displace density surfaces. For a long time these baroclinic tides were regarded as an odd part of the oceanic internal wave field. Much of this field is a statistically homogeneous and stationary superposition of many waves that have different frequencies and wave numbers and that propagate in all horizontal and vertical directions. This part is well described by the celebrated Garrett and Munk spectrum. In contrast, baroclinic tides exhibit strong geographic variations, are highly directional, and are often confined to a few low modes. Many of the past efforts were devoted to finding a dynamical explanation for the Garrett and Munk part, while the baroclinic tidal part was largely ignored. Only the acoustic community had an active stake in it, because baroclinic tides are often the major internal wave signal that affects acoustic propagation.

Similarly, the study of barotropic tides has also been isolated from the rest of physical oceanography for a long time. In contrast to most other oceanographic phenomena, the forcing field (the gravitational potential of the moon and sun) is extremely well known and the oceanic response (the barotropic tide) is nearly linear. Fairly accurate predictions had been achieved by solving the Laplace tidal equation. Only recently, issues such as tidal loading, earth tides, and gravitational self-attraction have increased the complexity of tidal modeling.

This all changed when Walter Munk and Carl Wunsch pushed issues of ocean energetics to the forefront of physical oceanography; barotropic tides, baroclinic tides, mixing, and the general circulation all became entangled. Consider the pycnocline. It is viewed as being maintained by a balance of upwelling and vertical mixing caused by breaking internal gravity waves, ignoring mixing by double diffusive processes. Because vertical mixing increases the potential energy of the water column, the breaking internal waves must provide this energy. Where do the internal waves get their energy from? One major source is the conversion of barotropic tidal energy to baroclinic tidal energy at topographic slopes.[1] Thus, the astronomically forced barotropic tides convert energy to the baroclinic tides. The baroclinic tides then transfer their energy to other internal waves, which eventually break and provide the energy for ocean mixing, which affects the oceanic general circulation, which in turn affects climate, with abundant interesting feedback mechanisms. The connection between baroclinic tides and climate makes this book about baroclinic tides all the more important.

In writing the book, the authors could draw on more than twenty years of active research in developing analytic and numerical models of baroclinic tides and in applying these models to concrete oceanic situations. The book covers most of our conceptual knowledge about the generation of linear and nonlinear baroclinic tides over variable bottom topogra-

[1] The other important source is the generation of inertial oscillations in the surface mixed layer by changes in the atmospheric wind stress. Part of this energy leaks into the ocean interior as near-inertial internal gravity waves.

phy and their subsequent evolution. This conceptual knowledge is all based on a simplified geometric configuration: only two spatial dimensions (the vertical and one horizontal) and localized topographic obstacles, either an underwater ridge or a slope shelf configuration. One can thus neatly define reflected and transmitted waves. Some of these simplified models can be solved analytically, but the book spends much effort to define the limits of these analytic solutions and extend them by numerical means. It identifies the three most important parameters of the problem: the ratio of the topographic slope to the slope of the internal wave group velocity, the Froude number, and the critical latitude. If the topographic slope is much smaller than the slope of the group velocity, the topography can be regarded as "flat" or subcritical. If the topographic slope is larger than the slope of the group velocity, the topography must be regarded as "steep" or supercritical. The Froude number is the ratio of the barotropic tidal current to the horizontal phase speed of the generated baroclinic waves. For small Froude numbers, the generation process and subsequent evolution are essentially linear. If the Froude number increases, nonlinear effects come into play. The critical latitude delineates the free from the forced wave response. Equatorward of it, linear baroclinic tides can propagate as free waves; poleward of it, they cannot.

All this conceptual knowledge is derived from basic equations using different analytic and numerical tools and substantiated by selected observations. It is neatly summarized in *Baroclinic Tides* in a table, which is reproduced here as Figure 1. This table contains in concise form most of what we know about the generation and evolution of baroclinic tides. At small Froude numbers, first mode baroclinic tides are generated at flat topography, and multimodal baroclinic tidal beams at steep topography. When the Froude number increases, a whole suite of new phenomena appears, including bores, nonlinear wave packets, solitary waves, solibores, and wave breaking. If you are interested in the theories, numerical models, and observations that lead to the results in the table, you have to consult the book. There it is all laid out: analyses of the general wave equation, the Korteweg-deVries equation, and Long's equation; modal, level, and layer models with often excruciating algorithmic details; and observations in the Barents Sea, on the Portuguese shelf, and at Oporto Seamount. Details of the results depend, of course, on additional parameters as well, such as the height of the topographic obstacle to the water depth (adjusted for stratification) and the ratio of the barotropic tidal excursion to

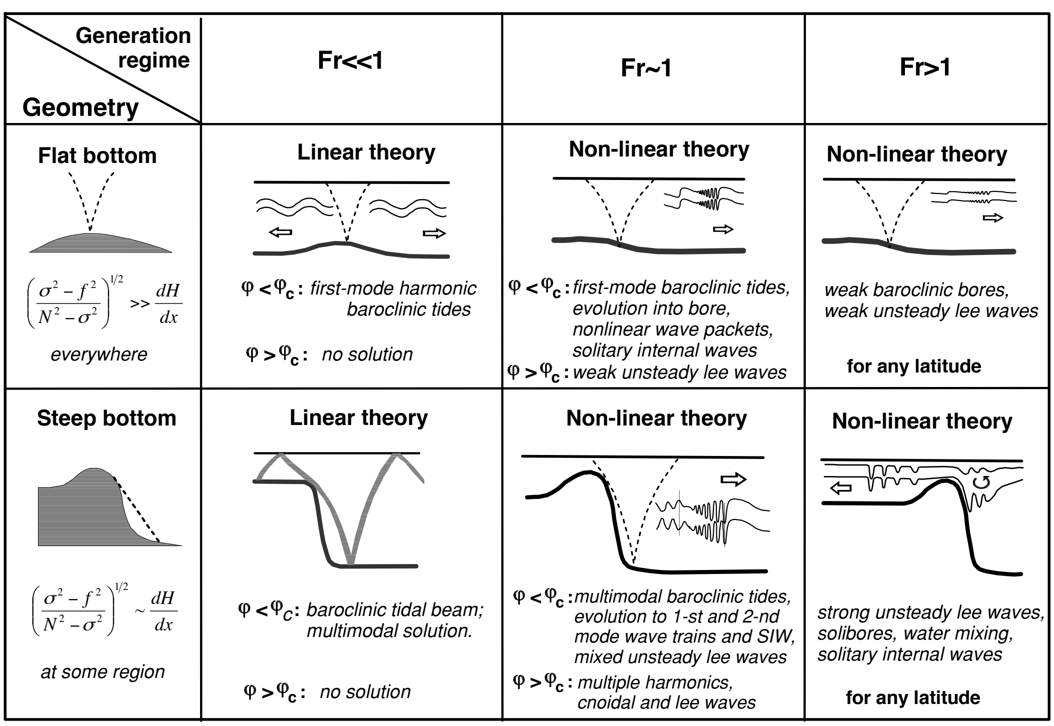


Figure 1. Schematic representation of the generation and evolution of baroclinic tides for different oceanic conditions. *Fr* denotes the Froude number and ϕ_c the critical latitude. Reproduced with permission.

the horizontal scale of the topography. Nevertheless, this table represents in a nutshell most of what we know about the generation and evolution of baroclinic tides and what we use as conceptual models when we must analyze more complex situations, where the topography is not two-dimensional and the oceanic environment is more variable. This can be seen in the special issue of the *Journal of Physical Oceanography* on the Hawaiian Ocean Mixing Experiment (HOME), which will appear at about the same time that this book review will appear. HOME is a multi-faceted study of tidal energy conversion and related processes along the Hawaiian Ridge. In their articles, the HOME investigators make abundant use of the concepts in the table in order to understand what exactly is happening at the Hawaiian Ridge.

In summary, I would like to congratulate the authors on putting together this book at this time. It will be of great value to researchers in this new and exciting field.

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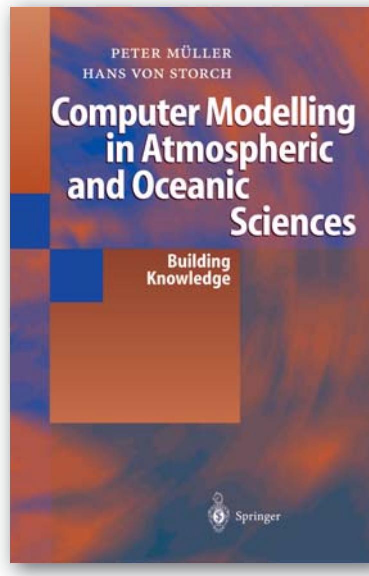
Computer Modelling in Atmospheric and Oceanic Sciences

Building Knowledge



By Peter Müller and Hans von Storch, Springer-Verlag, 2004, 304 pages, ISBN 3540404783, $89.95 US

REVIEWED BY JAMES J. O'BRIEN

This book is sewed together into seven chapters of 200 pages and another 100 pages of appendices. Because this reviewer knows both of these eminent oceanographers, it is straightforward to assign an author to each section. *Computer Modelling* contains much useful information, but it would not work well as a textbook in an Earth system modeling class either for the atmosphere or the ocean. Experienced numerical modelers will find some nice discussion of old and modern concepts. The text contains lengthy discussions of the authors' philosophies with regard to models. It is unusual to find such opinions in a text.

The seven chapters are: (1) Introduction, (2) Computer Models, (3) Models and Data, (4) The Dynamics of Tides and Climate, (5) Modeling in Applied Environmental Sciences, (6) Modeling in Fundamental Environmental Sciences, and (7) Issues and Conclusions.

The Introduction sets the tone for the book with a review of tide and climate modeling. Chapter 2 reviews the fundamental laws and the classical closure problem for a turbulent fluid. Unless the readers have studied these concepts before, they will have a difficult job of understanding this section. In addition, this chapter includes a short discussion of models as dynamical systems and stochastic systems as well as limits to predictability. Chapter 3, Models and Data, contains a useful discussion of validation and assimilation. These concepts are difficult for the new scientist to grasp and they will need additional material. Chapter 4 reviews the tidal problem and modeling the complex climate system. Here we really begin to see some shortcomings of the text. Already in the previous chapters, many concepts are introduced without definitions (e.g., isentropic coordinate system). It seems as if the authors have not decided who their readers are to be. They explain many concepts from fundamental principles, but often skip over "new" words. In discussing tides, the authors reduce the discussion to a very simple problem to show computer details. Then, they include incorrect finite difference equations. An expert who knows this will not be harmed, but a novice will be lost. In

Chapter 4, they introduce the so-called "primitive equations," using height (z) as a vertical coordinate. This is never done in climate models. The material needed for you to understand climate models is covered much better in several other monographs. Chapter 5 discusses several operational forecasts plus a strange set of miscellaneous topics, ranging from reanalysis, to transport of lead, to altimeters and tides, to climate scenarios. Chapter 6 explores the concepts of hypothesis testing and reduced models. Chapter 7 returns to philosophy.

The appendices are quick reviews of Fluid Dynamics (A), Numerics (B), Statistical Analysis (C), and Data Assimilation (D). Appendix A looks at several aspects of fluid dynamics, including boundary layers. Appendix B is a primer for numerical methods. Appendix C is an excellent, but short, explanation of advanced statistical methods. Appendix D on data assimilation is too brief to help newcomers with the complex subject. The two examples used in this last appendix are tides and climate. Tidal models are straightforward because tides are deterministic; decent climate models are extremely complex and demanding because few data are available for validation. The experienced climate modeler will find little to help improve Earth system models.

I will enjoy owning the book and comparing my approach to the authors' approach. Most libraries should invest in this book for completeness.

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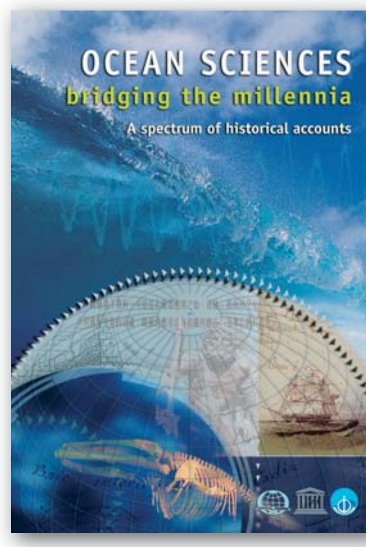
Ocean Sciences: Bridging the Millennia

A Spectrum of Historical Accounts



Edited by S. Morcos, M. Zhu, R. Charlier, M. Gerges, G. Kullenberg, W. Lenz, M. Lu, and E. Zou and English editor G. Wright, UNESCO Publishing, Paris, and China Ocean Press, Beijing, 2004, 508 pages, ISBN 9231039369 and ISBN 7502761195, Hardcover, $80.95 US

REVIEWED BY PETER WADHAMS

This book is based on papers selected and edited from those presented at the Sixth International Congress on the History of Oceanography (ICHO VI), held at Qingdao, People's Republic of China, from August 15–20, 1998. The manuscript was produced as a result of a three-year joint project between the First Institute of Oceanography (FIO, Qingdao) of China's State Oceanographic Administration (SOA), and the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO).

By publishing the volume, IOC and FIO seek to inform scientists and the general public about the development of our knowledge of the sea and its resources. The ICHO VI Editorial Panel, a wide-ranging group of senior scientists led by Selim Morcos, struggled hard to organize a manuscript in which the rather disparate contributions from the conference were given shape and continuity, and in particular, the English-language technical editor and coordinator, Gary Wright of UNESCO Publishing, did a fine job in achieving an acceptable English style to many of the contributions and in adding explanatory and connecting material. The result is a book which is worth dipping into, which in places is fascinating, illuminating many interesting byways of oceanographic science, but which inevitably reflects the rather specialized set of interests of those who attended the meeting in Qingdao.

The book begins with six biographical chapters on famous oceanographers, covering Joseph Louis Gay-Lussac, Otto Petterson, Victor Hensen and Claude ZoBell. To one who remembers school physics classes on the gas laws, it is surprising to see Gay-Lussac in the company of pioneer oceanographers, but he was in fact the first person to accurately measure the salinity of seawater (which he called "saltness") and to speculate on its uniformity of properties. The article by William Wallace describes him as "the first chemical oceanographer."

Next come six chapters of more orthodox historical oceanography on various expeditions and explorations. Rosalind Rolfe Gunther Marsden—a descendant of Rolfe Gunther—describes the economic and political background to the Discovery Committee work in the Southern Ocean during the 1925–1939 exploration of Southern Ocean water structure and biology where until now the political story has remained untold. In another surprising and interesting contribution, Selim Morcos describes the almost-forgotten Anglo-Egyptian work of the *Mabahiss* Expedition to the Indian Ocean in 1933–1934. The work was not in fact repeated until the International Indian Ocean Expeditions of the 1960s. Interestingly, much of the data were never published, and some were spirited away by the scientists involved, only to be reunited decades later (after death in fact) and finally analyzed to reconstruct the 1930s state of the ocean. Yha Yhang describes the explorations of Zhen He in the 1420s, leader of the great Chinese sea voyages to the seas of south Asia and east Africa, and there are several articles on the history of Russian marine exploration in the Arctic and Pacific.

A section on regional and bilateral cooperation reveals the surprising amount of personal jealousy, malice, and politics that surrounded the birth of the International Council for the Exploration of the Sea (ICES), even in those supposedly serene pioneer days of a century ago. Selim Morcos, Jens Smed, and Artur Svansson tell the amusing story of how the mistaken search for the origin of eel larvae in the Mediterranean led to a big boost for the oceanography of that sea. Also amusing are the two quite different accounts by two scientists of the development of marine biological institutions around the Black Sea, one from a Russian viewpoint (Alexandru S. Bologa) and the other from the viewpoint of the nation in which these institutes are now found, the Ukraine (Yuri N. Tokarev). The section ends with two papers on how German marine research before the First World War affected developments in South Africa, and in China via the observatory built at Tsingtau.

"Man and the Sea" has three of the most interesting papers. Charlier et al. deal thoroughly with the development of varied concepts for sea defenses, showing that fashion as much as experience has dictated changes in design—this paper has since been republished in a marine engineering journal. Yuan-ou Xin describes how traditional Chinese navigation (good old Zhen He again) was helped by advanced Chinese technology such as the compass, of course, but also the ability of Zhen He's ships to make progress against the wind by the use of leeboards and the junk rig, which allows sailing closer to the wind than European square sails while being easier to manage than Arab lateen sails. Charlier et al. (again) deal with the history of the tide mill. I was amazed to discover how prevalent these mills were in the tidal waters of Britain and Atlantic France during the Middle Ages and beyond. Some have been restored to working order, including one on the Isle of Wight, while others are now museums, but the authors make a plea to bring them back. Why not? Even though they are no longer needed for grinding corn, they could still be an emission-free method of generating small-scale electricity for local purposes.

The final sections are less interesting in that they deal with national themes of the conference participants. Clearly China is strongly represented here, and we learn from many authors of the development of marine research and marine industries in the Peoples' Republic. So rapid is China's economic development and so quickly do new laboratories spring up that probably these accounts are already out of date.

To say that the quality of this book is variable would be an understatement. However, there are many pleasurable and erudite accounts of interesting facets of marine science history. Historical oceanography is a subject that is clearly well founded, is sometimes very useful (as when it brings to light unpublished data from past expeditions), and is certain to grow as oceanography changes into a mature (though hopefully not moribund) science.

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