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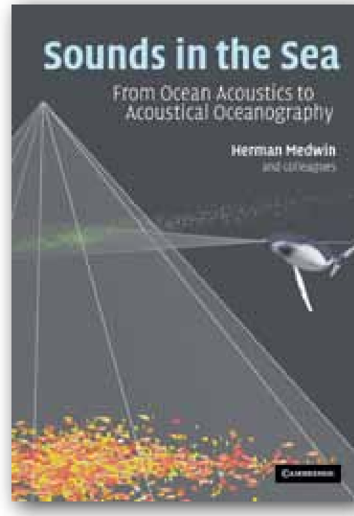
Sounds in the Sea

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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