

REVIEWS

Ocean Acoustic Tomography. By W. MUNK, P. WORCESTER & C. WUNSCH.
Cambridge University Press, 1995. 433 pp. ISBN 0-521-47095-1. £45.

Observing ocean variability on all the relevant time and space scales is a formidable task. From internal waves and mixing to decadal variability (minutes to years), and from fine structure to the global scale (centimetres to megametres), the spectral bandwidths are huge. Since any observing system opens only a narrow spectral window, a satisfactory knowledge of ocean dynamics can be gained only by the implementation of diverse measuring devices.

Ocean acoustic tomography was first proposed in the late 1970s as an ocean observation technique appropriate to resolve the mesoscale processes that are the source of much of the variable ocean kinetic energy and have so profound an influence on its dynamics. The prime advantage of tomography is its ability to sample rapidly and repeatedly in time, with a resolution which is obviously dependent on the number of sources and receivers and their geometrical arrangements. Progressively, as interest in physical oceanography shifted to the larger scales relevant to climate change, acoustic transmission experiments have been performed over longer and longer ranges, culminating in the Heard Island Feasibility Test, where sound was transmitted over nearly antipodal points, from the south Indian Ocean to various sites around the globe. In this type of application, the interest is in measuring averaged properties rather than resolving ocean features, which are then considered as noise.

The basic principle of ocean acoustic tomography, inspired by medical applications and solid Earth geophysical inversions, is to record signals that have propagated through a medium, and deduce properties of the medium from the characteristics of the received signal. In the simplest application of acoustic tomography the travel times of sound pulses are measured over a fixed range, from which the sound speed must be deduced. This last step, the inversion, relies on the methods of statistical estimation theory.

Ocean Acoustic Tomography provides the theoretical background required to understand the scope and limitations of this recent technique, develops a number of academic, didactic examples, presents practical technical information on implementation, and discusses several experimental results. But the scope of the monograph is larger than the theory and practice of tomography: roughly 30% of the book is devoted specifically to tomography, the rest being concerned with acoustic propagation in the ocean (40%) and inversion theory (30%). In fact the developments in underwater acoustics are required because a proper understanding of the forward problem (predicting acoustic fields from known ocean conditions) is a prerequisite to solving the inverse problem (deducing ocean conditions from observed acoustic signals). As the authors note, when acoustic tomography was first proposed it had just been observed that acoustic paths were stable, resolvable, and identifiable, but the forward problem had not been solved in all the necessary details (in fact, for the very long propagation ranges, it is still unresolved). This fact justifies the rather large part devoted to this topic in the book.

There are eight chapters, an epilogue, and two appendices. The first chapter sets the tone and defines the scope of the subject, by presenting an overview of the tomography problem. Here are introduced some basic concepts in ocean acoustics (ray acoustics

and modal propagation), the forward and inverse problem (with simplified numerical examples), and some general ideas on resolution. A valuable point is made on the inadequacy of comparing one type of observations (tomography) with another type which has very different sampling characteristics (hydrological surveys). As is developed in later chapters, the proper approach is to include all available data in a single inversion, and to test the consistency of the results with the known statistics of the errors.

The next three chapters (2 to 4) present topics on sound propagation in the ocean pertinent to acoustic tomography. Although such general concepts as geometrical acoustics and rays, modal representation, WKB and adiabatic approximations, and horizontal refraction, are classical, they are treated here in an original manner, leading to new insights. The use of action variables, inspired from Hamiltonian mechanics, gives a compact notation and a convenient introduction of the ray-mode analogy. Such topics as the structure of ray arrivals and their sampling characteristics, the ambiguity relations related to the signals used, the sensitivity to ocean perturbations, the effects of ocean currents, range dependence and ray chaos, are not usually found in books on underwater propagation. The general approach here is mostly clear and elegant, the only exceptions occurring when specific analytical examples are developed. The detailed computations, some of which are given in appendices, inevitably become somewhat intricate and cumbersome.

The fifth chapter, on observational methods, stands apart from the rest of the monograph. In it are presented the various observational constraints and requirements of tomography in the ocean. The emphasis is on travel time measurements, for which the key concepts are signal to noise ratio, accuracy, and resolution. The experimental design must take into account the limitations imposed by the ocean as a propagating medium and by the available instrumentation. The trade-offs and the particular choices implemented in ocean acoustic tomography are concisely and clearly explained, on such diverse topics as the sonar equation, signal design, the accuracy of travel time measurements, and data processing. The complex signal processing issues are glossed over – they could fill several chapters – the emphasis being on the key concepts.

The inverse problem is then treated in the next two chapters, first in a data-oriented, then in a model-oriented, approach. The first is the more commonly used, the second is somewhat speculative in the present complex as it requires considerable computing resources. The authors note that... ‘little or nothing in this chapter will be new to professional statisticians’, but that the aim is to give ‘a clear account suitable for those engaged in tomography’. They succeed remarkably on both counts of clarity and suitability, with considerable pedagogical skill. The starting point is the classical linear least square problem. Although it is conventional to distinguish over- and under-determined systems (or problems that are not full rank), the point is strongly made that since errors must be estimated, any such problem is always inherently underdetermined. The least squares lead naturally to singular value decomposition and Gauss-Markov estimation, which are closely related, but lead to different interpretations. Chapter 6 concludes with short sections on variant linear and nonlinear methods, and examples of ‘Inversions in Practice’. This is the first place, more than half way through the book, where actual results of acoustic tomography are presented. In contrast, much of the material in the next chapter... ‘represents future directions rather than present methodologies’. The point of view now is to place the emphasis on the dynamics of the system, as described by numerical evolution equations, and to force the model to be consistent with data constraints. The problem is one of state estimation and involves such concepts as Kalman filters and control theory. Those methods require

considerable computing power, not yet available for most practical applications. If the present trends continue, it is likely that it will not be an obstacle in the near future.

The final chapter on basin scale propagation is also somewhat prospective. Acoustic transmissions over distances of up to 16000 km have been conducted with the ultimate goal to monitor global changes in ocean temperature. The subject is at the forefront of present research. A brief historical review is given, and a few of the experimental problems are discussed: horizontal refraction of vertical modes, mode coupling and stripping by bathymetric features. It is fair to say that here again, it is the forward problem that needs to be solved before further progress is made. An epilogue and two appendices conclude the book. The variety of experimental results obtained by tomography are reviewed, including observations of mesoscale eddies, tides, internal waves, vorticity, heat content, and deep convection. A personal chronological, conversational in tone, retraces the involvement of the authors in the development of the technique and of the underlying theory since the late seventies. The final appendix is a brief propagation atlas, 18 pages of figures demonstrating the variety of propagation conditions prevailing in different parts of the worlds oceans. It is not clear of what use it can be in this monograph, except as a demonstration that tomography will not perform equally well under those different conditions.

Finally there is an exhaustive, up-to-date, list of references, most of which are post-1980, and an index. One might have preferred to have separate indexes for authors and subjects. Overall, the books presentation is up to the excellent standards of the publisher. There are very few misprints or mislabelled references. The style is simple, clear and pleasant.

The choice of topics gives a complete overview of the theory underlying ocean acoustic tomography. In fact there is much more than what is needed or used in most implementations today.

There is no doubt that the subjects covered will be useful to stimulate further applications of the technique. However, the *parti pris* is theoretical rather than practical: there is comparatively little space devoted to experimental results or to the complex technical aspects which have perhaps hindered the general acceptance of tomography in the oceanographic community.

For scientists and graduate students involved in acoustic tomography, this volume is the definitive reference. Those engaged in underwater acoustics research will find stimulating new ways to look at familiar concepts, as well as detailed analysis of the specific features of long range propagation. Anyone interested in the general application of inverse methods to oceanography will find the corresponding chapters particularly lucid.

YVES DESAUBIES

Modélisation et Simulation des Écoulements Turbulents. By R. S. SCHIESTEL.
Hermès, 1993. 442 pp. ISBN 2-86601-371-9.

This is an ambitious volume which presents a wide coverage of models for the turbulent stresses and heat fluxes. While the principal focus is on second-moment closure, more than a passing mention is also made of simpler linear eddy-viscosity models, on the one hand, and multi-scale schemes and sub-grid-scale modelling on the other. There are also useful resumés of numerical solving schemes for different flow classes and on tensor calculus, Fourier transforms and the like.

The work has emerged from lecture notes for a master's-level course in the subject taught by the author for the past 15 years. As one might expect in a French language

textbook, there is a series of introductory chapters covering many of the classical, 'pre-closure' topics of turbulence analysis. The book settles into its main theme on p. 151. Second-moment closure is handled first with simpler eddy viscosity schemes emerging as rational truncations in later chapters. This is followed by what might be called 'special topics': handling the viscous sublayer; gravitational effects; a glimpse at complex flows and variable-density effects. The final chapters consider more elaborate approaches: multiple-scale modelling (to which the author has himself made several contributions) and large-eddy simulation.

The book makes a valuable addition to the turbulence modelling literature. Perhaps the most serious omission is that there are virtually no examples provided of how successfully (or badly) the various closures perform when applied to different test flows. Thus the book is best used as a companion: one still needs to read the literature critically to form a view of overall capabilities.

Inevitably, the book does not consider (except, sometimes, by the late addition of a reference or two) models emerging over the last few years. This is a drawback, for the nineties have so far been a period of rapid evolution in modelling strategy as CFD is applied to increasingly complex flows and flow domains. The author must be alive to these omissions, however, and is doubtless already working on a second edition.

B. E. LAUNDER

SHORT NOTICES

Annual Review of Fluid Mechanics, vol. 28. Edited by J. L. LUMLEY & M. VAN DYKE. Annual Reviews Inc., 1996. 539 pp. ISBN 0-8243-0728-3.

Here is the list of articles and authors in the current volume of this periodical.

Recalling the Vth Volta congress: High speeds in aviation, Carlo Ferrari

Numerical models for two-phase turbulent flows, C. T. Crowe, T. R. Troutt, and J. N. Chung

New trends in large-eddy simulations of turbulence, Marcel Lesieur and Olivier Métais

Vorticity, free surface, and surfactants, Turgut Sarpkaya

Fully elastic instabilities in viscometric flows, Eric S. G. Shaqfeh

Pore-scale prototypes of multiphase flow in porous media, W. L. Olbricht

Modelling the oceanic general circulation, James C. McWilliams

Computations of nonlinear free-surface flows, Wu-ting Tsai and Dick K. P. Yue

The role of surface-wave breaking in air-sea interaction, W. K. Melville

Fluid phenomena in scramjet combustion systems, E. T. Curran, W. H. Heiser, and D. T. Pratt

The fluid dynamics of parachute inflation, C. W. Peterson, J. H. Strickland, and H. Higuchi

Linear stability theory applied to boundary layers, Helen L. Reed, William S. Saric, and Daniel Arnal

Atmospheric lee waves, M. G. Wurtele, R. D. Sharman, and A. Datta

Vortex dynamics in the cylinder wake, C. H. K. Williamson

A History and Philosophy of Fluid Mechanics. By G. A. TOKATY. Dover, 1994. 241 pp. ISBN 0-486-68103-3. \$8.95.

The first edition of this book was reviewed in *J. Fluid Mech.* vol. 52, 1972, p. 207. An unabridged republication has now been issued by Dover Publications with only small technical corrections. As summarized in the earlier review the book has some historical

errors (the confusion of the Carnots, father and son, and the misrepresentation of their contributions are particularly egregious) and some important ideas are short-changed (e.g. Prandtl's development of boundary layer theory). Also, despite the title of the book, the focus is much more on aerodynamics than on fluid dynamics and its many and diverse applications. Nonetheless, a large number of contributions made by many people from the 1600s to the early 1900s are mentioned and many not-so-well known contributions from Russia are given much space. In this sense the book may be useful to those seeking a starting point into historical developments or a possible citation to an original source. Hence, although the shortcomings of the book may appear significant, this reviewer was made aware of some historical connections and developments.

Flow and Heat Transfer in Rotating-Disc Systems. Volume 2: Rotating Cavities.

By J. M. OWEN & R. H. ROGERS. Wiley, 1995. 295 pp. ISBN 0-471-95745-3. £45.

This book is the companion to Volume 1: *Rotor-Stator Systems*, which was published in 1989 and reviewed in *J. Fluid Mech.*, vol. 241, 1992, pp. 724–725.

The present publication extends the earlier volume to situations where a complete cavity rotates but is subject to perturbations such as a radial inflow and/or outflow. Applications to turbo-machinery and to gas-turbine engines are very close to the authors' interests. Bearing in mind the present day emphasis on research directed towards 'national wealth creation', and noting the strength both nationally and internationally of our gas-turbine industry, this book is relevant at the interface between applied science and engineering at the present time.

Although many readers of *JFM* may see the problems discussed as geometrically rather complex and the mathematical and computational techniques as rather empirical at times, they will find that the fundamentals of our subject do lie close to the surface of the authors' writing. Thus some prototype problems do spring to mind from the pages of this book, both of a theoretical and an experimental kind, in such a way as to attract readers of this Journal. One can quibble about certain aspects of the book, the inadequate quality of the reproduction of flow-visualisation photographs for example; but the book is well-written (albeit tersely) and would, I believe, repay study.

Entropy Generation Minimization. By A. BEJAN. CRC Press, 1996. 362 pp.

Using elementary thermodynamical ideas this book first relates generation of entropy and loss of available work from a system. It then discusses at length how to optimize the performance of a system by minimizing this, irreversible, component of entropy increase. The ideas are illustrated with numerous examples, and exercises for the reader, taken from the broad field of engineering, including heat exchangers, insulation systems, power generation, solar-power generation and refrigeration. Such systems are usually assumed to be in a steady state; however, the final chapter describes extension of the ideas to optimization of unsteady behaviour, such as defrosting of refrigerators and cleaning of power-plant heat exchangers.

Naturally, fluid mechanics must be involved in the sort of processes discussed in this book but, necessarily, in a 'broad brush' manner and not in the sort of detail that would interest readers of *JFM*. Those who know the author's previous works, and in particular his book *Entropy Generation Through Heat and Fluid Flow* published in 1982, will recognize the style and content of the present volume.

Nonlinear Dynamics and Pattern Formation in the Natural Environment. Edited by A. DOELMAN & A. VAN HARTEN. Longman, 1995. 331 pp. ISBN 0-582-27371-4. £41.

This collective work on the fascinating subject of pattern formation is made up of 19 separate articles, all selected from 'key contributions' presented at an international conference in the Netherlands in July 1994. The editors give a brief guide to the connections between the articles, although on the whole they can be read separately and profitably. The articles bring out well the relevance of nonlinear dynamics to the occurrence of regular patterns in fields as diverse as cellular flames and rashes on the human body, as well as the more familiar field of fluid convection.

Finite Elasticity and Viscoelasticity. By A. D. DROZDOV. World Scientific, 1996. 434 pp. ISBN 981-02-24338.

This textbook results from lecture courses given by the author in both Moscow and Israel. It is sub-titled 'A course in the nonlinear mechanics of solids', and is said to be self-contained and suitable for graduate students in applied mathematics and mechanical engineering. The book concentrates on two basic models: elasticity and viscoelasticity, and a second volume on plasticity and failure is promised. Readers should not expect the going to be easy.

Fluid Mechanics, 4th edn. By I. GRAVET. Prentice Hall, 1996. 460 pp. ISBN 0-13-352170-2.

Earlier editions of this book were published in 1971, 1981 and 1989. The present edition maintains its user-friendly style, and is essentially a teaching aid, with numerous worked exercises and illustrative examples. The author makes the startling claim in the preface that 'the text... can be used without the use of calculus'. Fortunately he does not mean that literally, for he confesses in the next line that 'at various places, however, calculus supplements for enrichment have been inserted'. I like that 'enrichment'.

Wind-Diesel Systems. Edited by R. HUNTER & G. ELLIOTT. Cambridge University Press, 1994. 249 pp. ISBN 0-521-43440-8. £35 or \$59.95.

This collective work has been compiled by the two editors with the help of about 20 specialists from various countries, and gives a state-of-the-art account of wind-diesel technology. The approach is practical and includes considerations of economic and social aspects. Getting a system to work well is clearly no small enterprise.

Experimentation, Modelling and Computation in Flow, Turbulence and Combustion, Vol. 1. Edited by J. A. DÉSIDÉRI, B. N. CHETVERUSHKIN, Y. A. KUZNETSOV, J. PÉRIAUX & B. STOUFFET. Wiley, 1996. 356 pp. ISBN 0-471-94824-1. £65.

This volume contains the proceedings of a joint French–Russian workshop on fluid dynamics held in April 1993. The contributions are too varied and specialized to allow a useful description. The significance of the 'vol. 1' seems not to be stated.

Water Hammer: Practical Solutions. By B. B. SHARP & D. B. SHARP. Arnold, 1996. 172 pp. ISBN 0-340-64597-0.

This book is arranged in 29 short chapters. Each chapter gives a brief discussion of a single topic related to water hammer, such as 'The no-turn valve', 'Fire protection'

(i.e. water supply to sprinklers), and ‘The resonance problem’. Often, some representative data and plots of pressure against time and/or distance illustrate the problem discussed. The book is not intended as an introduction to the subject: it is not self-contained and makes reference to B. B. Sharp (*Water Hammer – Problems and Solutions*. Edward Arnold, London, 1981) for basic material. The introduction indicates that the examples are chosen to be a presentation of case studies.