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Book reviews

Geophysical Data Analysis: Discrete Inverse Theory by William Menke (Academic Press, 1989)* ISBN 0 12 490921 3. 289 pp., $98.65.

In general, inverse theory centres on mathematical techniques which may be used to determine information about our environment by observations of related data. For inverse theory to be successful, there has to be an effective model for the relationship between the required information and the observed data. Inverse theory provides information about unknown parameters that describe a model, but does not provide the model. Another essential element of inverse theory is its ability to provide statistics which estimate the accuracy of the derived unknown parameters. As the title suggests, the book focuses rigorously on a general introduction into discrete inverse theory, that is, utility and derivation of parameters which are either discrete or can be approximated as discrete.

Chapter 1 provides a good general background, defining inverse problems and introducing the linear inverse problem. Chapter 2 is a brief revision of basic probability theory and sets the semantic tone for the rest of the book. Chapters 3 through 5 focus on the solution of the linear gaussian inverse problem by the length, generalised inverse and maximum likelihood methods. These three chapters capture the essence of each of the methods, particularly Chapter 4 which introduces the Backus-Gilbert inverse for an underdetermined system. After these three primary methods are introduced, Chapter 6 then embarks on the subjects of nonuniqueness of a solution and the determination of localised averages. The use of Householder transformations in vector space is introduced in Chapter 7. The effects of exponential distributions on linear inverse problems and nonlinear inverse problems are introduced in Chapters 8 and 9 respectively. Factor analysis, including empirical orthogonal function analysis, is the subject of Chapter 10, and a fleeting look at continuous inverse theory is given in Chapter 11. Examples of inverse problems are provided in Chapters 12 and 14; computational algorithms (in FORTRAN77) for solving a sample of general problems are described and listed in Chapter 13. The appendixes describe the theory behind the constraining of inversions with lagrange multipliers and introduce inverse problems utilising complex numbers.

Despite its solid foundation in inverse theory, as an atmospheric scientist I initially found little in common with the book as it utilises many examples from the physics of the solid earth or solid objects. The nomenclature and key descriptors of the book are also firmly rooted in solid body problems. In fact, the only application in the book relating to a fluid environment was the brief description of the potential use for studies in ocean circulation, namely the use of inverse theory on the dynamic constraints provided by the Navier-Stokes equations implemented to study ocean circulation — a brief ten-line paragraph in a 289-page book!

The examples and illustrations of technique in the book are commonly brief. Quantitative examples, providing initial conditions and final results, are rare. When examples do appear, they are snapshots of a technique or result to emphasise a crucial point. After introducing a problem one could read on expecting an exposé of a particular problem, but be left puzzled because the example concludes without apparent resolution. At the end of my initial reading I had an ambivalent attitude to the book, quietly suggesting it should be retitled 'The Backus-Gilbert Technique Revisited and Revisited', and subtitled 'A Recurring Nightmare of Unrequited Examples'.

On subsequent readings my attitude to the book changed to a general admiration of the way the book focuses on the crux of each of the myriad of inverse problems and the necessary appreciation of the impact of the model on the problem.

The target audience is not made clear in the preface. Certainly not students who require examples to work through, can be confident of verifying a solution, and for whom the brief examples are no introduction at all. Those requiring recipes for numerical inversion procedures may find solace in Chapter 13, but even here the routines are provided without any example on which to test the algorithms. Rather, the book will find many admirers in the practitioners who either require confirmation of the theoretical basis of a method, or want to examine the utility of different discrete inverse methods for a particular model.

Given such a limited audience and a price of $98.65, the book is destined to be an organisational library purchase, and unfortunately, because of the concentration on solid earth sciences, is unlikely to be a general purchase by atmospheric scientists. However, I recommend

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the book to those interested in the theoretical basis behind the search for a solution; I am glad it graces my library shelves, within easy reach.

Bruce Forgan

Bruce Forgan is the supervisor of the Instruments and Laboratory Subsection in the Bureau of Meteorology. His interests include determining atmospheric composition by remote sensing.

Theoretical Geophysical Fluid Dynamics by A.S. Monin (Kluwer Academic Publishers, 1990) ISBN 0 7923 0426 8. 408 pp., Dfl 290.00.

Theoretical Geophysical Fluid Dynamics by A.S. Monin is a well printed, hard cover book. The book grew from lectures given by the author at the Moscow Institute of Physics and Technology. However, the book is more suitable as a general reference book on the topic than as a text book.

Monin has defined geophysical fluid dynamics as 'the fluid dynamics of natural flows of rotating baroclinic stratified fluids and gases, or in short
GFD = FD RBSF'
The book is concerned almost exclusively with the theoretical aspects of the topic. The presentation is demanding on the reader's mathematical skills and concentration. Both vector and tensor notations are used, as are the results of probability theory. The dynamics presented involve both Newtonian and Hamiltonian formulations. Often the terminology is different to that seen in the more familiar western literature, for example, Monin refers to a modified Bessel function as a cylindrical MacDonald function — a term that I have not heard before. Nevertheless, the book is concise and easy to follow in its systematic presentation. If needed, the reader is required to fill in for himself detailed derivations.

The book is divided into three parts covering: I General Concepts; II Processes; and III Global Problems.

Part I (General Concepts) contains chapters on the Equations of Geophysical Fluid Dynamics, Small Oscillations, and Hydrodynamic Instability. Attention is given to electromagnetic forcing for use later in Part III, where the motion of planetary interiors is discussed. While of little interest to readers with a predominant interest in the application of geophysical fluid dynamics to the atmosphere and oceans, the discussion does not detract from the book. In the chapter on Hydrodynamic Instability there is a well proportioned discussion of stochasticity and stochastisation scenarios which will appeal to those with an interest in the application of chaos theory to fluids.

Part II (Processes) is concerned entirely with wave motions and turbulence. It contains chapters on Surface Waves, Internal Waves, Geophysical Turbulence, and Rossby Waves. Some might argue that a chapter on Surface Waves is outside the author's definition of geophysical fluid dynamics and others might argue that, although mentioned briefly, double diffusive convection and even Kelvin waves have not been given their deserved space. However, while not from my own field of interest, I found the discussion of wind waves in the Surface Waves chapter one of the clearest discussions I have seen of the topic and definitely a useful addition to the book. Unfortunately much of the information contained in Part II is hard to locate within the book. For example, neither the extremely useful Benjamin-Ono equation on page 185 nor the discussion of the important Benjamin-Fair instability on page 148 are referred to in the index. Thus, while Part II is filled with useful information, a glance at the index in order to locate something may lead to the incorrect conclusion that it is not contained in the book.

Part III (Global Problems) contains chapters on General Circulation of the Atmosphere and Ocean, Theory of Climate, and Fluid Dynamics of Planetary Interiors. This part is less demanding on the reader and serves as a good companion to the other parts of the book.

The reference section at the end of the book is largely the work of the translator. (Apparently, the author supplied a list of only 28 books.) The list contains most of the major works although, despite the original publication date of the book being 1988 and that of the translation being 1990, the latest reference is 1981 for a non-Monin contribution and 1987 for a Monin contribution. Also, I found that when results of studies were cited in the text there was often no adequate accompanying reference, see for example the discussion following the Benjamin-Fair instability mentioned earlier.

In brief, this is a well written, clear, concise but demanding account of many of the physical phenomena that make the subject of geophysical fluid dynamics fascinating. However, the supporting framework, that is the index and referencing, do detract from the value of the material it contains. Nevertheless, this book is one of the great books of the field and it would sit well as a reference book on the shelves of anyone who had a place for, say, Whitham's *Linear and Non-Linear Waves*. It is a book that every library subscribing to the Australian Meteorological Magazine should get without question, despite its slightly high price.

Roger Hughes

Roger Hughes is a principal research scientist with CSIRO's Division of Atmospheric Research. In 1989 he received the Priestley Medal from the Australian Meteorological and Oceanographic Society.

Asymptotic Modeling of Atmospheric Flows by Radyadour Zeytounian (Springer-Verlag, 1990) ISBN 3 540 19404 5. xii + 396 pp., DM170.

Radyadour Zeytounian is professor of theoretical fluid mechanics at the University of Lille in France. Professor Zeytounian has published numerous articles on theoretical fluid mechanics, many of them exploring asymptotic methods of obtaining solutions to the Navier-Stokes equations. At present, strict asymptotic modelling is a rather obscure field of research, and is not a popular alternative to the use of numerical techniques for the solution of real-time initial value problems. Nevertheless, Zeytounian believes the method has practical applications for local and regional weather forecasting. Asymptotic methods are examples of singular perturbation techniques. Application of asymptotic methods decreases the order of the partial differential equations involved, and alters their mathematical structure (producing a singular perturbation of the equations). The gain in simplicity of the equations is counterbalanced by extra difficulties in formulating their initial and boundary conditions. Therefore, the text pays a lot of attention to the correct mathematical formulation of the initial and boundary conditions for the equations under discussion, and to questions regarding the well-posedness of the problems.

This book presents many of the results of Zeytounian's work as applied to atmospheric flows. It is an attempt to give an overview of the nature of the difficulties involved, a systematic survey of solutions to many of the problems which have been solved, and an indication of directions for future research.

The book approaches the study of atmospheric motion from an advanced and highly theoretical point of view. It is a pure mathematician's view of atmospheric flow, and the physical aspects of the phenomena under discussion are barely mentioned. The aim is to present dynamical meteorology as a problem in mathematical analysis. An essential prerequisite for understanding the book is a thorough knowledge of meteorology, pure and applied mathematics, and theoretical fluid dynamics.

The point of departure for the text is the set of Navier-Stokes equations on a rotating sphere. These equations are nondimensionalised and written in terms of various nondimensional parameters such as the Strouhal number (which arises because the time-scale is not assumed to be the advective time-scale), the Reynolds number, the Mach number, and the Prandtl number. The only concession made in deriving the equations is to confine attention to motions whose horizontal scale is much less than the radius of the earth. This allows the 'flat earth' approximation to be used. Also, compatible with the book's inattention to physics, the laws of vertical exchange by turbulence are considered identical to those of exchange by molecular conduction (except that transfer coefficients are much greater).

In the first few chapters, the nondimensional equations are used to investigate several topics which are familiar to meteorologists. Subjects such as internal gravity waves, Rossby waves, quasi-geostrophic flow, and filtering are discussed. The method used is to write the unknown nondimensional variables as asymptotic expansions in nondimensional numbers. For example, the Rossby wave equation is derived by expanding the unknown variables in terms of the (supposedly small) Kibel number. Substituting the expansions into the nondimensional Navier-Stokes equations results in a series of equations for the various powers of the Kibel number. The geostrophic approximation, which is allowed one line in the whole book, can be derived as the zero$^{\text{th}}$ order relation of this process.

The formal treatment of the asymptotic methods is postponed till chapter five. Two methods, the method of matched asymptotic expansions (MMAE) and the multiple-scale method (MSM), are described. In the subsequent chapters, these methods are used to explore such themes as the Boussinesq approximation, the isochoric (constant volume) approximation, the theory of low Mach number flows, the analysis of lee waves, and local hill and valley winds. In each case, prominence is given to a rigorous mathematical development of the subject, and physical interpretation is neglected. Zeytounian notes that the systematic study of all approximations and models of interest to meteorologists is a monumental task. Therefore, the book makes no attempt at being exhaustive. The selection of topics largely follows the author's major interests.

Although the subject matter is very complex, the book is well-written, the meaning of symbols is always stated, and each step of the mathematics is clearly explained. Numerous references are given and most chapters finish with a summary and a bibliography. There are a few departures from meteorological convention: the Coriolis parameter is called l rather than f, tan is written tg, and the Greek letter zeta is used for altitude rather than vorticity. The whole book contains only six diagrams. A minor defect is that they are numbered inconsistently. *Asymptotic Modeling of Atmospheric Flows* is a work of scholarship but its level of difficulty and the amount of knowledge presumed are such that it can appeal only to a tiny coterie of academic purists.

Max Adams

Mr Adams currently lectures in Dynamical Meteorology at the Bureau of Meteorology Training Centre. His research interests are in analytical modelling.

Atlas of Ozone Spectral Parameters from Microwave to Medium Infrared by Jean-Marie Flaud, Claude Camy-Peyret, Curtis P. Rinsland, Mary Ann H. Smith and V. Malathy Devi (Academic Press, 1990)* ISBN 0 12 259890 3. $196.40.

Ozone monitoring has become topical with the dramatic reduction in ozone over the South Pole (the 'ozone hole') and the indications that similar chemical conditions exist in the northern hemisphere, hindered only by the physical meteorology of the region.

There has been a long and steady development of techniques to monitor the amount of ozone in the stratosphere, including *in situ* methods based on balloons and remote sensing from ground level and satellite. The satellite measurements involve detection in both the ultraviolet and infrared to microwave region of the electromagnetic spectrum. The majority of remote sensing techniques have concentrated on the ultraviolet region because it is technically simpler, but where measurements are required at night, for example, infrared techniques have proved useful. Many will have noticed the black spot in the South Pole ozone maps produced by NASA from their ultraviolet sensing TOMS satellite which results from its inability to see into the polar darkness. Infrared and microwave techniques then become vital in understanding what is happening in such regions.

In passing, it is worth noting that for many other important chemical species in the atmosphere the infrared absorption signature is the primary measurement technique. It is then necessary to be able to identify the strong absorptions due to such species as ozone and water vapour that complicate the spectrum.

It is with this background that the infrared and microwave atlas needs to be considered. The first 34 pages provide a general coverage of the theoretical background to the line positions and intensities calculated. The second part contains 563 pages of some 90 000 absorption line positions and intensities covering the spectral region from the microwave up to 3200 cm^{-1}. It is indeed impressive that lines presented in this compilation are known to an accuracy of around 1 part in 10^7 in the mid-infrared.

There are a number of annoying features of this book, presumably resulting from an attempt to publish the information rapidly. While this is not the place to go into great detail, it is worth mentioning two problems that face the casual user. Firstly, the notation table (page 35) lists the headings for the eight columns of information in the atlas. However, none of these symbols agree with those that appear in the table. More annoying is the positioning of the figures throughout the atlas. Twenty diagrams are included which compare experimental measurements with the data in the table. Here it is possible to look at how well the results in the table agree with observations. Unfortunately the figures are almost useless. They are buried within the table with no indexing, meaning that they can only be found by flipping through the many pages of tables. This problem is worsened by the fact that there is no description elsewhere of what the figures contain, so that it is impossible to know whether the region that interests the reader is accompanied by a figure. This would not be so bad if the figures were included within the table at a point close to the relevant data, but this is not the case. For example, figure 9 shows the ozone spectrum for the region around 1682 cm^{-1} on page 276. The data for this region are found on page 405.

Finally, who will find this book useful? I suspect that many of those who would use this information would require a computer-readable form. However, for those wishing to develop techniques for measurement of ozone (or other species) in the infrared or microwave region of the spectrum this atlas will prove to be a valuable guide.

Stephen Wilson

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