

Book reviews

Meteorological Fluid Dynamics by Radyadour Zeytounian (Springer-Verlag, 1991) ISBN 3 540 54446 1. xi + 346 pp., DM66.00.

Meteorological Fluid Dynamics by Radyadour Zeytounian is the fifth volume of Springer-Verlag's New Series m: Monographs in physics. The stated intention of the series is to quickly report new developments in physical research, and to teach at an advanced level. As the aim of the volumes of the series is a publication time of about ten weeks, the text suffers from numerous typographical errors, and several cases of stilted English. (The book is a translation from French.) Many of the diagrams are hand-drawn and hand-annotated. However, these are minor drawbacks, and the lack of slickness gives the book a certain charm.

Professor Zeytounian's approach to meteorology is to view it as a fluid mechanics discipline in which the Navier-Stokes equations are rigorously and systematically applied to a gamut of meteorological phenomena. Typically, the relevant equations are first written in nondimensional form. This introduces a large number of nondimensional parameters, and tends to make the equations long and unwieldy. Solutions to these equations for the particular problem under consideration are sought in terms of asymptotic expansions. In the discussion of boundary-layer problems, the powerful technique of matched asymptotic expansions is widely used. In this method, an inner (within the boundary layer) solution is matched with an outer (away from the boundary layer) solution. While the asymptotic expansion method simplifies, and sometimes linearises the nondimensional Navier-Stokes equations, it poses many complex theoretical problems. These problems are studied in detail, and are obviously of great interest to the author. Zeytounian expends considerable effort, for example, in carefully determining the appropriate initial and boundary conditions to the various sets of simplified equations.

The book is divided into ten chapters. The first two are introductory chapters in which the basic equations are developed and discussed. Three full chapters are devoted to atmospheric waves. Topics discussed include Rossby waves and gravity waves, with particular emphasis on orographic lee wave theory. One chapter is concerned with

sea-breeze and slope wind problems; a further chapter examines the complexities of atmospheric adjustment processes (such as geostrophic and hydrostatic adjustment). Atmospheric stability is another major theme of the volume and there are good discussions of convective, barotropic and baroclinic instability, including the Eady problem. About half the book is a repeat of topics covered in the author's 1990 volume *Asymptotic Modeling of Atmospheric Flows*. However, where this is the case, the present text tends to be shorter and easier to follow. Zeytounian suggests that *Meteorological Fluid Dynamics* is a good preparation for the earlier book.

The author's view is that asymptotic techniques have great, but largely untapped, potential in numerical weather prediction. To illustrate, examples are given of the application of lee wave theory to (non real-time) flow over two mountainous regions of France. The results are interesting, and derived vertical velocities are considered to reflect rather well the local pattern of rain in the regions.

Among material not previously covered in the author's 1990 book is the chapter on the deterministic chaotic behaviour of atmospheric motions. Although the material is well presented, the argument is not for the uninitiated. The Lorenz dynamical system and strange attractor are presented, and there is an interesting discussion on possible relationships between turbulent atmospheric motion and fractals.

This is a book for the advanced student of meteorology, or the theoretical fluid dynamicist who wishes to develop an appreciation of meteorology. The emphasis tends to be on the mathematics, rather than the physics of the problems, and the book is more a treatise on the differential equations of meteorological fluid dynamics than a text on atmospheric physics. The material is demanding, but well-explained; any assumptions made are clearly stated, symbols are always defined, and the arguments are lucid. There are numerous references in the text, and most chapters finish with suggestions for background reading. The book is highly recommended to students wishing to seriously grapple with the theoretical basis of atmospheric flow.

Max Adams

Max Adams lectures in dynamical meteorology at the Bureau of Meteorology Training Centre. His interests include analytical modelling of meteorological phenomena.

The Atmosphere—A Challenge. The Science of Jule Gregory Charney edited by R.S. Lindzen, E.N. Lorenz and G.W. Platzman (American Meteorological Society, 1990) ISBN 1 878220 03 9. US\$60.00.

Something of a revolution occurred in our understanding of the atmosphere in the years immediately following the Second World War. During the preceding period there had been a rapid development of the radiosonde network, which gave us our first information about the state of the upper troposphere. Also at this time the first electronic digital computers were being designed and there was much interest in seeing if they could be used for numerical weather prediction. The problem now was to find a tractable formulation of the equations of motion for numerical integration.

Jule Charney was one of the key figures who made this advance possible. He is perhaps best known for his analysis of the conditions for baroclinic instability, in which he saw the development of mid-latitude disturbances as originating in the vertical shear properties of the westerly flow. In this and later work he used scale analysis to justify the selective application of the geostrophic approximation to filter out the troublesome high speed gravity waves from the meteorologically important synoptic-scale motions. Charney's work paved the way for implementing a series of prognostic models of increasing complexity, beginning in 1950 with the numerical integration of the non-divergent vorticity equation, in which the behaviour of the atmosphere was reduced to an equation in a single variable. This was followed by two-level models in which the essential features of baroclinic development could be reproduced.

Before his death in 1981, Charney invited George Platzman to make a recording of his recollections. A memorial volume has now been published which incorporates an edited transcript of this interview and a commemoration of his achievements by a number of his contemporaries. The book also contains photographs and reprints of several landmark papers. It is a somewhat unusual collection, but nevertheless one that struck me as appropriate to the subject.

The biography, if that is the appropriate term, is very definitely written for the dynamical meteorologist, and some of the contributions bristle with equations. Three of the five papers reproduced at the end of the volume are directly related to the birth of numerical weather prediction. Some of the mathematics, particularly in the first paper (on the dynamics of long waves), is heavy going, but in all of his writing the discussion is lucid and a model of scientific prose.

Charney was solidly analytical and contributed to the understanding of fundamental hydrodynamical questions in a number of areas of meteorology and oceanography. He was apparently an inspiring mentor to many students who have since made their mark in the scientific world and he was instrumental in initiating the Global Atmospheric Research Programme and setting up some well known institutions. The book is not only a tribute to a remarkable man: it also provides a perspective of the history of dynamic meteorology and the important issues that he helped to resolve.

Ross Murray

Ross Murray is a post-graduate student in meteorology at the University of Melbourne with interests in ocean modelling and the automated tracking of cyclone centres from numerical analyses.

Radar for Meteorologists by Ronald E. Rinehart (University of North Dakota, 1991) ISBN 0 9608700 7 5. 334 pp. US\$25.00.

This wide ranging little book, despite the title, is as much for radar technicians as for meteorologists. Included is far more technical detail than the average meteorologist really needs to know, nevertheless it is revealing to rediscover the many limitations and assumptions necessary before reasonable deductions can be made about a particular radar return. To really appreciate all that Rinehart covers, one would need to be fairly specialised in radar meteorology with a technical or engineering inclination.

The book starts off with an outline of the history of radar, with a brief introduction of the various types and uses. Next comes a description of radar hardware, transmitter types, modulators, antennae, reflectors, wave guides, transmit receive switches, receivers, displays, etc. An outline on electromagnetic waves is followed by a description of the various radar band designations and frequencies. Snells Law is then used to lead into a brief discussion on superrefraction, anomalous propagation and ducting of radar waves (all familiar to Australian meteorologists). Radar equations are developed for point targets showing the relationship between back-scattering cross-sectional area of spherical targets in relation to radar wavelength. Explaining the concepts of MIE and Rayleigh Scattering. A discussion of types of point targets such as birds and insects reveals that the author has developed some prowess in estimating the weight of birds passing overhead (he doesn't mean 'angels', this older term is covered elsewhere).

The equations are then expanded to cover beam filling or distributed targets. The Doppler principles are introduced, explaining the Nyquist vel-

ocity or frequency and its relationship to velocity folding or aliasing. The Doppler dilemma is outlined, i.e. if we want to detect fast-moving targets, our range of detection is limited, or we must make certain assumptions and select a longer wavelength radar to partially solve the problem. The problem of range aliasing (multitrip echoes) is encountered in various chapters, and suggestions are made as to how to distinguish whether range folding and/or velocity folding is occurring. Clearly much operational experience would be necessary. From here on, the applications of Doppler principles become a major part of the book.

Meteorological targets: discussed are the echoes expected from non-precipitating clouds, and from raindrops and hailstones of various sizes and distributions. The relationship (empirical) between rain rate and reflectivity (indirectly at least familiar to Australian meteorologists) is outlined, as are the vagaries of snow as a radar target. The problem of estimating precipitation which is forming from melting snow or ice — which results in a sudden increase in reflectivity — causing so-called bright banding is discussed.

Some comfort is that bright banding is usually detected in stratiform or stabilising situations. Attenuation due to the atmosphere, rain, hail and snow is detailed, with tips on recognising its potential occurrence. So-called clear-air return is considered by Rinehart to be those echoes from insects and dust as well as refractive index gradients.

A series of 16 colour photos taken from advanced radars with full Doppler capacity (mainly University of North Dakota) with PPI showing both reflectivity and Doppler velocities is referred to frequently through the rest of the book in order to illustrate meteorological phenomena. From a practical meteorologist's point of view these references are the most valuable parts of the book and well worth studying. In several cases these are supplemented with RHI photos again of reflectivity and Doppler velocities.

A chapter on advanced meteorological uses of radar covers such things as dual wavelength radars. That is, if one radar is in the S band the other is the X band, the system can be excellent for hail detection, or, perhaps a C band and X band system could be used for improved rain detection and measurement. Dual Doppler processing radars can also be used to get reasonable estimates of three-dimensional wind fields, most valuable in situations such as microbursts. The author devotes a chapter to NEXRAD (next generation radar) code-named WSR88-D which refers to the types of Doppler-capable radars that will be located through the USA (130 planned sites) during the next few years.

The NEXRAD products to be computer produced will make most meteorologists envious, and include microburst and gust front algorithms,

turbulence and shear displays, mesocyclone and tornado vortex signature products etc. A whole chapter is devoted to quantification of the various radar parameters, e.g. measurements of transmitted power and frequency, wavelength, waveguide losses, radome losses, received power and receiver bandwidth, antenna gain, beamwidths and patterns, etc., probably good material for technicians.

Because so many radar parameters are measured in logarithmic units, the Appendix explains their use in the various parameters. Also in the appendix is a discussion of error analysis. Much of this technical detail I feel will be skipped over by all but dedicated radar meteorologists, though doubtless it will be of value to the radar technician/engineer.

The following discussion summarises the radar phenomena illustrated in this publication and discussed at length elsewhere in the book.

Permanent echoes or ground clutter (colour figure 1) should show zero velocity on the Doppler display. Rinehart expresses a fondness for known ground clutter for various calibration purposes. He also claims success in tracking individual birds and insects and in this figure points out likely echoes from birds or aircraft.

Clear-air return (colour figure 2), we see a PPI filled with fairly weak reflectivities, giving the clue that the widespread return is from insects. The velocity display clearly shows a southerly wind component relative to the radar, matching the known winds, confirming Rinehart's conclusion that insects are the source of the radar return.

Cold fronts. A very good depiction of a cold front approaching the radar is shown in colour figures 3 and 4. It is easy to see the approaching front on the PPI, but less easy to appreciate that all the air behind the front is moving towards the radar. The running back through the colours in the unexpected direction on the Doppler PPI is just velocity aliasing (folding). Possibly even more surprising are the RHI displays which (showing velocity aliasing again) indicate the depth of the air approaching the radar (at least along this radial) is only about 2 km. This is in spite of the considerable depth of the front. Range aliasing (second trip echoes) is demonstrated in colour figure 6 and compared with a real echo (first trip). The Doppler display gives no velocity to the second trip echoes due to inbuilt checks. Also the wedge shape of the second trippers is a good clue that they are not first trip echoes.

Microbursts, especially if wet, can easily be seen by Doppler radar and colour figure 5 shows a powerful microburst with a nearly 75 knots velocity difference from one side of the burst to the other. An algorithm was used to automatically detect this microburst, and enabled aircraft to divert safely.

Dry microbursts are also often detectable, the source of the return usually being lifted dust and debris. Gust fronts usually form as the outflow from a storm moves away into the (relatively) clear air ahead of the storm. An example is shown of a gust front, probably detectable on the reflectivity display because of raised dust or other surface debris. The Doppler display shows the change in wind speed across the gust front (winds are obviously stronger behind the gust front). This example of a gust front is reasonably indentifiable on the reflectivity display and slightly less so on the Doppler display. RHI displays of this gust front illustrate just how shallow such phenomena can be, requiring some experience to identify properly. The RHI display of this event shows clearly the relative flow in and out of the storm at various depths, allowing vivid real-time insight into storm dynamics. Colour figures 9 and 10 show a 'bow echo', really a variation of a gust front, in which a shallow region of air is approaching the radar at velocities around 60 knots. There is no clue that such a region exists on the reflectivity display, except that it occurs just ahead of a line of strong echoes, again the potential of the

Doppler display for short-term severe weather forecasting is beautifully displayed.

Two examples of tornado signatures are shown, but they are perhaps a little ambiguous. Two examples of backing and veering wind situations are shown. These form a striking pattern on the Doppler displays, but only show as general echoes on the reflectivity displays. Presumably these events represent vorticity maxima.

Finally, an example of NEXRAD storm attack algorithm shows extrapolated storm tracks. The precipitation algorithm of the same event is shown and could be a valuable tool for flash flood forecasting.

Personally I would have preferred to see the synoptic situations in parallel with the radar imagery. I guess Rinehart's preoccupation with radar itself though is rather all embracing. Again I would like to have seen some applications to tropical cyclones. All in all a nice glimpse into future possibilities.

S.J. West

Mr West has been involved in forecasting and the use of radars in meteorology for 30 years throughout most of Australia.