J. Fluid Mech. (2004), vol. 506, pp. 407–409.
Printed in the United Kingdom

BOOK REVIEW

Waves in the Ocean and Atmosphere. Introduction to Wave Dynamics. By Joseph Pedlosky. Springer 2003. 260 pp. ISBN 3-540-00340-1. $49.95 (hardback).

J. Fluid Mech. (2004), vol. 506, DOI: 10.1017/S0022112004008729

Joe Pedlosky, a senior scientist at Woods Hole Oceanographic Institution, is well-known, even famous, for his classic books on geophysical fluid dynamics and ocean circulation theory. It is thus a bit of a surprise, albeit a very pleasant one, to find that he has also written a monograph on waves. This is, in fact, the published version of a course that he has given for a number of years to first-year graduate students in physical oceanography and meteorology, with the contents listed as 21 lectures rather than chapters.

This immediately suggests that the book is 'table d'hôte', so to speak, rather than 'à la carte', so there are inevitably omissions of material that one might find in a comprehensive text on waves. I will discuss some of these gaps shortly. On the other hand, what is included is presented with Pedlosky's characteristic precision, elegance and insight, nicely combined with an easy informality of style. The students are fortunate indeed to have had Joe as a teacher. To be sure, the approach is generally theoretical and mathematical, with little discussion of observations, but this is legitimate; it is arguably more important in a first course to grasp the dynamical underpinnings of a field than the complex relationships to the real world. For each chapter there is a short list of well-chosen references, often to other books, and twelve problem sets of three problems each. (The answers are wisely not given, so anyone using the book in his or her own lectures will still have some work to do!)

The course sensibly starts with a general discussion of wave kinematics and group velocity. It continues into lectures on surface waves, including a treatment of the initial value problem and the use of the method of stationary phase. This is followed by four lectures on internal waves, including a good discussion of WKB theory for waves in variable stratification and a discussion of some aspects of the propagation of internal waves in a shear flow. In particular, there is an excellent discussion of the way in which the internal wave drag associated with a rough boundary manifests itself as a retardation of the mean flow behind an advancing wave front.

Rotation is introduced in Lecture 11, initially to show its effect on the dispersion relation and dynamics of internal waves and to introduce Rossby adjustment as well as Poincaré and Kelvin waves. Three lectures on Rossby waves come next, with a nice emphasis on the surprising nature of the dispersion relation and its consequences for wave reflection. A lecture on Laplace's tidal equations follows, with a clear derivation of the important conclusion that "all our previous work on the dynamics of Poincaré, Kelvin and Rossby waves for a homogeneous layer can be carried over, mode by mode, to a stratified layer as long as the motion is hydrostatic and the bottom is flat". This provides a useful framework for Lecture 18 on waves confined near the equator, where the Coriolis force vanishes while the beta effect remains.

The next lecture focuses on quasi-geostrophic motions near boundaries, leading into a short account of baroclinic instability with an emphasis on the classic Eady problem and on general conditions for instability. The final lecture is a brief discussion of the effects of waves on the mean flow, though only within the context of non-dissipative quasi-geostrophic theory, emphasizing the significance of the Eliassen–Palm flux and leading up to the Charney–Drazin non-acceleration theorem.

This is just a bare-bones summary of the contents of the course. A student clearly has the opportunity to learn a very great deal of fundamental importance. On the other hand, the extent of the course suggests that some basic topics may have been omitted. This is indeed the case.

For example, the chapters on surface waves do not mention the Stokes drift, even though this is a key concept. Another surprise is that the concept of critical layers is not introduced, though this could easily have been added to the treatment in Lecture 10 of the vertical propagation of internal waves. It would have provided a good illustration of the effect of the mean flow on the waves and vice versa. Overall, in fact, there is very little discussion of the effect of a variable mean flow on waves, though the kinematics are readily treated and the dynamics leads to the useful general result of wave action, rather than wave energy, conservation. The introduction also promises some treatment of wave–wave interactions, though the only mention of this in the text is a question about Rossby wave triads in the Problems section.

Even the topics that are treated are sometimes illustrated by examples that would not normally be the first choice. For instance, the discussion of the effect of waves on the mean flow is discussed only, as mentioned above, for the changes behind an advancing internal wave front and for quasi-geostrophic motions. I would have welcomed a discussion of the generation of longshore currents by dissipating surface waves (hinted at in the final chapter), and, more importantly given its crucial role in the atmosphere, critical layer absorption.

Further, while it is reasonable to introduce some discussion of stability near the end of a waves course rather than at the beginning of a course on turbulence, given that both wave and stability analyses start with linearized perturbation equations, students should probably see the clever results for non-rotating homogeneous and stratified shear flows before being introduced to baroclinic instability.

Other topics that I like to at least introduce in a waves course include some aspects of nonlinearity, with the ideas of Riemann invariants and shock development carried over from gas dynamics to shallow water dynamics. This can be followed by discussion of the competition between steepening and dispersion in this case and an introduction to solitary waves. Even the physics of diffraction for linear waves is worth a brief discussion, if only to remind students of what they should have learnt as undergraduates!

However, as mentioned earlier, what is treated in this book is generally done very well, though I do have some minor quibbles. One pedantic point concerns the phase progression in waves. The author appropriately points out that, for a plane wave with frequency ω and wavenumber $\boldsymbol{k} = (k, l, m)$, the array of numbers $(\omega/k, \omega/l, \omega/m)$ represents the rate of progression of lines of constant phase along the axes but does not transform as a vector. He states that "... the phase speed is not a vector", where the phase speed is defined to be "the speed of propagation of phase in the direction of the wave vector". This seems to say that a scalar is not a vector, and then almost to define a scalar as a vector! We know what is meant, but the fuzziness can be avoided if we define the phase velocity as $\omega\boldsymbol{k}/|\boldsymbol{k}|^2$, and recognize that its components are not equal to the array $(\omega/k, \omega/l, \omega/m)$ which we could just call the 'trace speeds'. To be sure, this is picky, as is the point I like to make that the waves represented by $(\omega, \boldsymbol{k})$ and $(-\omega, -\boldsymbol{k})$ are one and the same; this can help in avoiding thinking that a dispersion relation offers two solutions when there is really only one.

I found few typographic errors and the appearance of the book is generally clear with respect to both text and figures, although it does seem a bit unconventional to left justify equations, albeit with a small indent, rather than centring them. What is more off-putting is that vectors are presented with a superposed arrow, instead of in bold font, e.g. $\vec{u}$ rather than $\mathbf{u}$ for velocity.

The text is nicely sprinkled with general encouragement for the student, as in "... the physics here seems very strange. But you'll get used to it." when referring to the group velocity of internal waves. There are also more general words of wisdom. In being formal about the derivation of quasi-geostrophy, Pedlosky points out that "... brutal historical experience shows the foolishness of taking the careless path". I also liked the remark made in association with the derivation of Laplace's tidal equations that "... saving us from an absurdity is not a justification for an approximation".

In summary, while Pedlosky's book represents a fine graduate course on waves, there are some serious omissions that need to be filled, and there is no mention of a number of optional topics (described in other texts) that instructors might find more relevant than some of those that are discussed. Thus it seems to me that this is a book to be recommended and used in part, rather than adopted as a whole. I shall certainly use some of the material and, especially, many of the problems. A revised version, filling the serious gaps and possibly extended to be more a monograph than a lecture course, could be outstanding.

C. J. R. Garrett