LEPPÄRANTA, M. 2005. *The drift of sea ice*. Berlin and Heidelberg, Springer-Verlag. 266pp. ISBN 3-540-40881-9, hardback. £77, US$119, €99.95.

The drift of sea ice does an excellent job of covering the theory of drift and deformation of sea ice. This topic has relevance to climate change, operations in ice-covered seas and weather forecasting. The problem of sea-ice dynamics is an ongoing topic of research, and the author has presented the latest research results in a clear and well-organized book. This book does not merely present the theory, but also discusses how to solve the equations to obtain solutions to the problems. Throughout the book, the objective is to derive equations and results that can be solved either analytically or, more often, numerically. For example, the conservation law for sea-ice thickness is given for two to three discrete thickness intervals rather than for a continuum.

Chapters 1 and 2 provide an introduction and describe the sea-ice properties relevant to the subject. The material properties of sea ice are concisely described. The intent is not to present a complete description (which is not necessary and can be found in other books) but to provide an overview of the sea-ice properties which are required to understand the remainder of the book. The remaining chapters systematically derive the equations and explain the methods which have been used to describe sea-ice drift and deformation.

Chapter 3 presents ice kinematics. The velocity vector is introduced, followed by the strain tensor and the strain rate and vorticity. Although these are all standard mechanics principles, values typical of sea ice are given. There is also a section on stochastic models. In both chapters 2 and 3 there are discussions of the methods used to collect data in the field. This is important in understanding the limitations of the data and how the equations can be applied. This combination of theoretical development and practical application is clearly one of the strengths of the book, and mirrors the author's experience which combines theoretical developments with field and laboratory experiments.

Chapter 4 discusses ice rheology, including both viscous and plastic rheologies. There is also a section on granular flow rheology. This discussion starts with the basic stress tensor and then proceeds to specific examples of different stress states and rheologies. Plastic rheologies and their application to sea ice are discussed in detail. There is also an interesting discussion of scaling of ice strength.

Chapter 5 derives the general form of the momentum equation for sea ice, and discusses the different components of the equation. Boundary conditions to solve the equations are briefly presented followed by the conservation equations. These are the basic equations which most sea-ice dynamics problems utilize, and different authors have used various forms of these sets of equations in the literature, often with little explanation. It is nice to have a comprehensive discussion of the momentum equation and some of the solutions. This is followed by an extensive discussion of atmospheric and oceanic drag forces.

Chapter 6 is devoted to free drift, the solution to the momentum equation when there is no internal stress on the ice. Different results are presented using a range of assumptions. These results include solutions for drift speed as a percentage of the wind speed in the classic case, solutions for channel flow, shallow water and non-steady-state solutions. Coupling the ice to the ocean is then discussed, including inertial oscillations and sea-ice velocity spectra. Although, as the author states, the free drift formulation has severe limitations it is useful for providing insight into the interactions of sea ice, winds and currents. This chapter provides several examples and solutions which help translate the mathematics to a physical picture.

Internal friction is introduced in chapter 7. Creep and plastic deformation are applied to channel flow, followed by a similar discussion for zonal sea-ice drift. In particular, the different rheologies which have been used for sea ice are presented along with some basic results. There is also a section on ice tank experiments which is an interesting aside.

Chapter 8, on numerical modelling, does a good job of covering a large topic in a short space. The results which are presented provide a good overview of the variety of results that can be obtained from numerical simulations. These are divided into short-term and long-term results depending on the type of model and questions being answered. Several plots showing the resultant ice motion are included, and the author discusses some of the results quantitatively where there are data for comparison.

Chapter 9 is a very nice summary of sea-ice research and its applications. In fact it might help to read this chapter first to provide motivation for chapters 1–8. Even for the non-specialist it provides excellent insight into the state of sea-ice drift research and the remaining problems to be tackled. The photographs in this chapter clearly demonstrate the wide range of issues which are impacted by sea-ice drift, including forces on structures, mesoscale drift and navigation.

This book provides the equations and derivations needed to understand the sea-ice drift problem. The material is complete and well presented, and the constants and input data needed to solve the equations are discussed. It is a necessary book for scientists working in the field of sea ice, particularly in its drift and deformation. Overall, the book tends to have more examples from the northern polar regions, reflecting where the bulk of the research has been carried out over the years. In particular, most of the data stem from the Baltic Sea. This is not a problem except where generalizations are made that may not apply to the other regions. The book also includes a series of study problems related to sea ice, and a comprehensive reference list if more detail is desired. There are also a number of websites referenced in the text (it will be interesting to see how many of the web pages are still available in a few years).

This is a book for the specialist. Matti Leppäranta clearly knows his subject and does not shy away from mathematics. This text provides detailed descriptions of the equations of state and is heavy on equations for coupled systems which are often non-linear and may have complicated boundary conditions. However, the author does an excellent job of explaining the physics behind the equations and how the equations can be used in specific cases. There are also well-chosen examples throughout most of the book. This book provides a very good summary of sea-ice drift and is an excellent resource for anyone working in sea-ice research.

Norwegian Polar Institute V.I. LYTLE
Polarmiljøsenteret
N-9296 Tromsø
Norway
E-mail: Vicky@npolar.no

https://doi.org/10.3189/S0022143000209581 Published online by Cambridge University Press