ON SEA ICE. W.F. Weeks. 2010. Fairbanks: University of Alaska Press. 664p, illustrated, soft cover. ISBN 978-1-60223-079-8. $85 US

On sea ice is a long-awaited book by the greatest living master of the art of sea ice research, and it satisfies all the expectations of those who have been waiting patiently for the last decade. It covers every aspect of the geophysics of sea ice and its role in the ocean, and includes references up to 2008. The book is literally the last word on the subject because, given the explosion of research effort in the past few years, the science of sea ice is now going beyond the capacity of one person to fully understand and summarise. Future textbooks on sea ice are bound to be multi-author works.

As Willy Weeks tells us in his preface, he started out in sea ice research in 1955 when the Air Force, to which he was attached as an officer, sent him to Labrador to study the bearing capacity of sea ice runways. Before that, he had studied geology and done research in geochemistry at the Universities of Illinois and Chicago, having grown up in Champaign, Illinois, about as far from the sea (though not from ice) as it is possible to get. His research career began in petrology, but sea ice immediately attracted him. Weeks often claims that one attraction of sea ice research was that it was a virtually a virgin field, as opposed to petrology where 'the first half of any paper you wrote was spent refuting other scientists' misguided opinions on the subject, that sort of business. In sea ice—you only had to reference your own work. That was great. I liked that (quoted from an interview with Brian Shoemaker, 17 April 2000).

He soon discovered that this was not quite true and that, in particular, the Russians had been busy working on sea ice for many decades, but still the body of published work (especially in English) was small. Weeks set out to expand it by his own efforts. Weeks had the good fortune to be able to move to what became one of the world's main centres for sea ice research, the US Army Cold Regions Research and Engineering Laboratory (CRREL) in Hanover, New Hampshire, where he worked alongside legendary colleagues like Malcolm Mellor, Tony Gow, Austin Kovacs, Steve Ackley, Bill Hibler, Andrew Assur, and Steve Mock.

This collection of giants advanced our knowledge of sea ice physics faster than any other research group before or since. Much of the basic sea ice physics in the present book arises from work done at CRREL. After 'retiring' from CRREL in 1986, Weeks went to work at a second great centre for sea ice research, the University of Alaska, Fairbanks, where he was Chief Scientist at the Alaska SAR (Synthetic Aperture Radar) Facility for many years, continuing his personal research and expanding it to remote sensing. He announced in the 1990s that he intended to write a textbook on sea ice; none then existed except a 1943 book in Russian by N.N. Zubov (Zubov 1963).

Having intended to write a textbook for many years, I found myself in a 'race' with Weeks, which was not a race since he was not racing. My own book came out in 2000 (Wadhams 2000), but we all knew that when Weeks' appeared it would be both more comprehensive and more wise in identifying the weaknesses in the structure of sea ice physics theory and proposing ways forward to solve them. We would not be disappointed. Any young scientist reading Weeks' book will find potential PhD topics laid out in every chapter.

The book has 19 chapters, in fact. After a historical introduction, there is a chapter on the ocean setting, the background oceanographic structure of the Arctic and Antarctic, which defines the context in which sea ice is found. Then, sea ice growth is introduced, followed by an analysis of the ice-water phase diagram when added salts are included. Chapter 7 deals with sea ice structure, especially the complexity of the structures that form as the ice-water interface advances during freezing, including the process of preferred c-axis orientation in response to prevailing current direction that was investigated by Weeks himself around the coasts of Alaska. The frazilpancake growth model is also discussed, and this chapter is one of the most fundamental in the book.

Chapter 8 examines sea ice salinity and its evolution in response to brine drainage mechanisms. Chapter 9 more fully deals with sea ice growth, featuring the Maykut-Untersteiner model and its implications. Chapter 10 considers general sea ice properties (thermal, electrical and mechanical). Chapter 11 concerns polynyas and leads, and includes the equations that define the width achieved by a coastal polynya under the influence of offshore winds. The massive question of ice deformation is the subject of Chapter 12, along with the mechanisms that are responsible for the formation of about half the ice volume in the Arctic, which is contained within pressure ridges.

In Chapter 13, the book introduces the topic of sea ice interaction with the seafloor, including the problem of what defines the widths and depths achieved by ice scours. Chapter 14 discusses the physics of the marginal ice zone, especially of the interaction of waves with sea ice, while Chapter 15 describes snow on sea ice and its role.

For Chapter 16, on ice dynamics, Weeks wisely brings in his old friend and colleague Bill Hibler (W.D. Hibler III) as guest writer. Hibler, also now at University of Alaska Fairbanks, is the acknowledged master of sea ice dynamics modeling, and his 1979 paper on this topic is probably the most-cited sea ice paper ever, as it is the basis of the sea ice model used in all modern modelling efforts (Hibler 1979).

Chapter 17 is on another topic that Weeks made his own, underwater ice, that is, ice that appears to form (especially in the Antarctic) in the water column as a result of supercooling, and which then floats up to the surface to contribute to the overall ice mass budget. Chapter 18, on trends, brings the story up to date as it reviews the evidence brought forward by many scientists for changes in the mean thickness and composition of Arctic and Antarctic sea ice as a result of climate change. Thinning appears to be the main climate response, and this process is already reflected in a rapid decline in summer ice extent, a decline that is certain to accelerate. Antarctic sea ice, strangely, is currently showing a slight increase in extent.

Once again, Weeks should have the last word on his book. When he was just starting to write it, during the 17 April 2000, interview with Brian Shoemaker, Weeks said: 'It's written from a personal point of view in the sense that I occasionally pontificate about certain scientific matters that I think I have decent opinion on. But it's not a popular book—it's for someone that really wants to know something about sea ice. It's not my heroic experiences in the Arctic. As a matter of fact, I've done

my best throughout my career to keep from being a hero. . .I've always believed in the adage, "When in doubt, chicken out. . ." However, working on sea ice has been a lot of fun. It was a fascinating business and the subject still fascinates me.' Anyone who reads this book will see why. Weeks refrained from including colour illustrations in the hope that the book could be made cheap enough for graduate students or ordinary citizens to buy. Those who do so will not be disappointed, and will also learn to appreciate Weeks' unique sense of humour. (Peter Wadhams, Department of Applied Mathematics and Theoretical Physics, University of Cambridge Wilberforce Road, Cambridge CB3 0WA. This review was first published in *Oceanography* 24(3) and is reproduced by courtesy of that journal).

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