changes occurring there. In the first goal, the book succeeds admirably; in the second, it offers precious little reason for optimism.

Chapters on geopolitics are solid but offer little that is new except in the fascinating account of the history and future of Norway's Svalbard Islands. Short accounts of the emergence of Nunavut, the tribulations of the reindeer-herding Nenets of Russia's Yamal Peninsula in the face of extensive gas developments, and international legal wrangling over ownership of the Arctic (especially the Arctic sea-bed) are worth reading, but it is in the treatment of the ice and the animals that *After the Ice* sparkles.

For a social scientist with superficial knowledge of either, the chapters on the ice—or, increasingly, the lack of ice—and the animals of the Arctic are at once the most fascinating and the most disturbing. The book's main message here (aside from ringing the alarm bells) is the need to reframe the scientific "problem" posed by changing Arctic ecology. For Anderson, the problem is "not that too little is known but that so much is known which has not been synthesized" (p. 9). His accounts of the complex processes of melting (and changing) sea ice, and of shifting patterns of currents, warming trends, and seasonal migrations, all producing profound alterations in entire ecosystems, are clear yet comprehensive, without becoming overly technical—the audience for this book is not the scientific community but a wider, concerned public. The book sets out the implications of warming/melting trends for all manner of Arctic marine life, from microscopic polychaete worms feeding in Arctic ice, to the appearance of killer whales in regions where sightings were once rare, if not unknown, to the colonies of sea birds threatened by changes to the food chain. Anderson demonstrates convincingly that "an Arctic that freezes over and melts again each year is a completely different place for the creatures and the people that live there now" (p. 97).

The three chapters on "Oil and Ships" are little short of mind-boggling with their accounts of massive, environmentally risky (and often inadequately regulated) oil and gas developments in remote and exceedingly sensitive parts of the Arctic. Events since the book was published suggest that even Anderson's more sanguine assessments of potential ecological disasters are problematic. In the wake of the Deepwater Horizon blowout in the Gulf of Mexico—a far less hostile environment than the Arctic—would he still write, contrasting the risks of tanker wrecks versus drilling operations, "Around a fixed well, an oil company can be well prepared" (p. 223)?

After the Ice is not an unrelieved litany of ecologically troubling, if not disastrous, developments. Among the hopeful possibilities are accounts of rehabilitation of the Siberian tundra (p. 243–244); the prediction that "very expensive [i.e., Arctic] oil will no longer make sense in a decade or two from now" (p. 260–261); and the implication of the estimate that one-quarter to one-half of Arctic warming is caused not by greenhouse gases, but by more easily controlled air pollution (p. 249). Ultimately, however, his assessment is gloomy: "We will see either a sustainable Arctic or an abandoned Arctic...with every year of delay, we need ever stronger action, and the chances of success grow less" (p. 263).

Based as this book is on such extensive distillation of complex and unfamiliar processes and relationships, it is not surprising that the odd error has crept in: as of Anderson's time in Nunavut, there were two communities outside Iqaluit with populations over 2000, not 1000 (p. 30); the totting up of Inuit numbers across northern Canada leaves 22% unaccounted for. Given the apparent target audience, it is understandable, if still annoying, that Grise Fiord hunters are said to range "over an area the size of Connecticut" (p. 24), or that Nunavut is five times the size of California (p. 29). A more fundamental shortcoming is that the book relies far more on conversations with PhDs and scientists than on conversations with indigenous hunters or political leaders, though it is fair to note that Anderson has worked to include the experiences and perspectives of the people of the Arctic. Still, it is telling that such a book contains no extended discussion of traditional knowledge, nor does the term appear in the index.

Such quibbles pale in the face of the sobering analysis of this important book. This is popular science writing at its finest; it deserves wide readership.

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ON SEA ICE. By W.F. WEEKS, with W.D. HIBLER III. Fairbanks, Alaska: University of Alaska Press, 2010. ISBN 978-1-60223-079-8. xv + 664 p. maps, b&w illus, appendix, bib., index. Hardbound. US$85.00.

The subject of sea ice has attracted many since ancient times. The early polar travelers and explorers observed and logged sea ice, mainly to avoid it when navigating through formidable frozen seas. As our knowledge of sea ice has accumulated, in particular after 1950, when the study of sea ice became widespread, curiosity about sea ice has gradually expanded into a fascinating world of science and engineering. Today, we have an unprecedented influx of observations and knowledge of sea ice, with advanced understanding of many aspects from the physical properties of sea ice to its impacts on global climate.

While occupying only about 7% of the earth's surface, sea ice has a profound influence on the polar environment. As ice freezes, it injects salt into the ocean, thus increasing its salinity and density. This process can lead to deep convections that profoundly influence the polar halocline and drive the thermohaline circulations of the ocean. Sea ice cover also reflects significant solar radiation back to space, modulates heat exchange between the ocean and the

atmosphere, and protects coastlines from wind and wave actions. Providing a habitat for a rich diversity of marine life and organisms, sea ice is also critical in shaping polar ecosystems.

Given the importance of sea ice, this book provides a comprehensive and up-to-date review on ice properties, behavior, and change, as well as major advances in sea ice research. Writing in the first person, an uncommon approach for a science reference book, geophysicist W.F. Weeks takes the readers on a journey to explore the complex but fascinating subject of sea ice. Throughout the chapters, readers can find many personal insights on field observations and knowledge, which allow them to examine the world of sea ice with the author side by side.

The first part of the book, up to Chapter 5, can essentially be considered as introductory material. In the *Preface* and *About This Book*, the author reveals his lifelong "addiction" to sea ice research and describes the purposes of the book. In particular, he provides much useful advice to graduate students, encouraging them not only to acquire the existing knowledge on sea ice, but also "to find the cracks in the walls of the research edifice and to remove them by providing new interpretations, insights, and data" (p. x). Such advice holds true for anyone who intends to explore the subject of sea ice in depth. In fact, some chapters that discuss the limitations and challenges of current methods and knowledge will motivate those with curious minds.

In the remaining four introductory chapters, Chapter 1 reviews some basic knowledge on ice types, their distributions, and geophysical setting. The historical overview of sea ice observations in Chapter 2, starting from 350 BC, covers detailed discussions of how our understanding of and capacity to observe sea ice were enhanced in the first and second halves of the 20th century. Chapter 3 describes the basic ocean setting, including hydrology, currents, and water masses in both the Arctic and the Antarctic, and Chapter 4 introduces some basic sea ice growth models, with specific discussions on multiyear ice. All this introductory material is a good appetizer, preparing the reader to delve further into this book on the sea ice.

The subsequent four chapters (Chapters 5 through 8) cover detailed descriptions of chemistry components of sea ice, general structure and properties of different phases, and the phase relations as functions of different temperatures and pressures. The internal structure of various ice types, theories about sea ice salinity, and its measurement are also discussed and compared between the Arctic and the Antarctic. The discussions of sea ice properties at a small scale lead to a further overview on estimating sea ice growth with thermodynamic models (Chapter 9). The different treatment in the models for thin ice and multiyear ice is discussed through a synthesis of theories, observations, and research results. Current research activities and future directions for improving the sea ice growth models are also addressed at the end of this chapter.

Before turning the topic to the large-scale nature of sea ice, Chapter 10 illustrates several important sea ice properties that form the physical bases for interpreting the observed sea ice behaviors. The discussion ranges from ice density, gas content and composition, to ice thermal properties and the overlying snow cover. Other important mechanical properties of sea ice are also considered, such as tensile and compressive strengths, dynamic and static measurements, scale effects, and electromagnetic properties.

In the following chapters, the book focuses its attention on the characteristics and behaviors of sea ice on large scales, putting the significance of sea ice into a climate perspective. Chapter 11 describes polynyas and leads, the open windows of ice cover that expose the underlying ocean to the atmosphere. By reviewing their observed properties and processes, the book addresses the importance of polynyas and leads in affecting atmospheric and ocean circulations. Chapter 12 focuses on another important sea ice process, deformation, including detailed reviews on commonly observed deformation features such as pressure and shear ridges, hummocks, rubble fields, and rafts. The discussion and comparison of ice ridge properties in the Arctic and the Antarctic is followed by a comprehensive review of how these ridges are observed with various field techniques and modeled by numerical simulations. Chapter 13 extends the previous chapter with a discussion of the impacts of ice-induced gouging on the ocean floor, drawn primarily from observations along the coast of the Beaufort Sea. Knowledge of the ridge-seafloor interaction will be very useful for anyone who is interested in coastal engineering in the Arctic. The next two chapters review the characteristics of marginal ice zones, including wave-floe interactions and distributions of snow, in the polar regions. Chapter 16, a joint review by W.D. Hibler and W.F. Weeks on the modeling of sea ice dynamics, is built on a previous review by Hibler (2004). It provides an up-to-date overview of modeling sea ice drift and deformation, as well as an in-depth discussion of the mechanical properties of sea ice and ice thickness distribution theory. This knowledge will help readers who are interested in using numerical simulation to study the evolution of sea ice cover and its dynamic and thermodynamic roles in shaping the regional and global climate.

Chapter 17 reviews the relatively new subject of underwater ice, with updated information on its observed properties and distribution. Given the significance of this type of ice existing under the Antarctic ice shelves, readers interested in the formation of the Antarctic Bottom Water and the general ocean circulation will find this chapter a welcome addition. Chapter 18 describes some recently observed changes in sea ice and discusses the causes and predictions of sea ice pack in the Arctic and the Antarctic, addressing the complexity of the sea ice response to increased CO_2 emissions and a warmer climate. Finally, W.F. Weeks ends the book with a personal touch in Chapter 19.

In conclusion, *On Sea Ice* presents an abundantly illustrated natural history of sea ice. Synthesizing the current literature up to 2008, the book offers a comprehensive review on the long-term variations of sea ice extent and thickness,

both observed and modeled. It provides a wealth of up-to-date information and a thorough review of our understanding of sea ice in the polar regions. While some subjects are covered more briefly than others, in these cases the author adequately points readers to other literature for more specific and comprehensive reading. Thus, this work stands as an excellent reference for graduate students and researchers. With so much accessible information, it is also suitable for nonspecialists who are interested in the general subject of sea ice.

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