Review

THOMAS, D. N. and G. S. DIECKMANN, *eds*. 2003. *Sea ice: an introduction to its physics, chemistry, biology and geology.* Oxford, Blackwell Science Ltd, 402pp. ISBN 0-632-05808-0, hardback, £89.50 (approx. $150, €130).

This book documents the complexity of sea-ice physical and biological processes, interactions and feedbacks that fascinate scientists in a wide range of disciplines, from the microscopic to the global scale, and from deep in the past to the rapidly changing present. Its publication could not be more timely. According to the U.S. National Snow and Ice Data Center, Arctic sea-ice extent in September 2003 almost equalled the record minimum set only the previous year, part of a two-decade-long trend of sea-ice decline revealed by remote sensing (http://www.nsidc.org/news/). Then, in November 2003, Curran and others (2003) reported ice-core and other evidence for a decline in Antarctic sea ice since the 1950s. Such changes in the state of the sea ice have potentially far-reaching physical, biological and human consequences for the polar regions and the global climate.

The multidisciplinary nature of the book reveals sea ice as a medium that encourages interdisciplinary studies that are contributing to progress in the field and which I hope will become the hallmark of sea-ice and polar science and education in the future. The opportunity to provide a thorough synthesis of the book's contents and highlight the successes and future potential of interdisciplinary science has been missed, however, in the poorly organized and unfocused chapter 1. On the other hand, the remaining ten chapters provide an excellent summary of much of the current knowledge and understanding of sea ice, are often thought-provoking and remind us that nothing is simple or always as it seems to be.

Chapter 2 (basic physics and material properties of sea ice) argues quite convincingly that the sea-ice microstructure and small-scale processes are the foundation on which physical and biological characteristics and processes across a broad spectrum of larger scales are built. Chapter 3 (ice dynamics, thermodynamics and thickness) reminds us that there is more to the recently reported decrease in Arctic Ocean ice thickness than just thermodynamics and the influence of increasing air temperatures: changes in atmospheric circulation and thus ice dynamics must also be taken into account. I agree that the high level of dynamically caused (sea-ice) variability makes the detection of temperature-induced climate changes very complicated, but I also think that it is important to remember that climate change is not synonymous with climate warming/cooling. Temperature is not the sole measure of the weather and climate. Changes in atmospheric circulation and their effect on ice dynamics also represent climate change and its consequences.

Chapter 4 is an opportunity for the author to escape from the NASA Team algorithm and apply the Bootstrap algorithm to satellite passive-microwave data to describe large-scale characteristics, variability and change in Arctic and Antarctic sea ice during the period 1978–2000. If the causes of the ice-thickness decrease in the Arctic Ocean, and whether it represents a trend, remain to be determined, there is little question of the veracity of the satellite record of decreasing ice extent and area in the Arctic, and particularly the perennial ice of the Arctic Ocean. On the other hand, the modest trend towards increasing Antarctic sea-ice extent in recent years, described here and elsewhere, might only be a short-term phenomenon superimposed on a longer-term downward trend, if Curran and others (2003) are correct in their interpretation of the Law Dome ice core.

Chapters 5–8 are concerned with sea-ice biology (primary productivity; microbiology; macrobiology; habitat for mammals and birds). Chapter 9 describes a relatively new area of study, the biogeochemistry of sea ice. It helped that I once attended a seminar by the author, who described his work on exopolymeric substances, particularly mucus and slime, excreted by micro-organisms, and their potential effect on microbial interactions and perhaps even ice permeability. The subjects might be unfamiliar, but I encourage physical scientists to take the time to delve into these chapters, and bioscientists to do the same with the physical science chapters. Don't limit yourself to your own narrow area of experience and expertise. As a consequence of reviewing this book, I have learned much about the ecology and biogeochemistry of sea ice, and what fertile territory they are for interdisciplinary research and for making the teaching of sea-ice geophysics more interesting.

Mucus and slime. That's plain English that I can understand. For assistance with less familiar terms and a guide to strange linguistic terrain you can turn to the extensive glossary at the end of the book. However, judging by some of the physical science entries, the glossary's value might be less than it should be in a multidisciplinary book. Here are a few examples. *Nilas* should have its own entry, as it is not *new ice*. The *snow–ice interface* is the ice surface once snow has accumulated on it. It is not, as the glossary defines it, the ice surface before the first snowfall. That is the air–ice interface. Poor editing has allowed two different, not to mention misleading and confusing, definitions of the same quantity (ice concentration (p. 278) and sea-ice concentration (p. 282)) into the glossary. It's disappointing that such a basic sea-ice quantity should be defined so poorly. Perhaps I'm being dogmatic, but communication among scientists from multiple disciplines and the promotion of interdisciplinary studies require consistent and correct use of accurate and well-defined terms.

The final two chapters, 10 and 11, describe the particulate material that is released from sea ice into the ocean, where it might seed an algal bloom, feed organisms in the water column, even reach the sea-floor and become part of the geological record. Marine sediments are examined to reconstruct palaeo-sea-ice distributions and evaluate computer simulations of past climate variability, a complicated field that is subject to great uncertainty, to say the least. Oddly, the lengthy description of palaeoclimate and palaeo-sea-ice distribution is not matched elsewhere in the book by a discussion of the future of the global sea-ice cover and the possible consequences of its continued decline. Also,

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the description of palaeoclimate and palaeo-sea-ice distribution modelling, and the brief descriptions of sea-ice physical and biological models in earlier chapters, lead me to conclude that the book's value would be greater if it had a comprehensive chapter on modelling alone. This is a missed opportunity.

These days no book review is complete without a comment about the price, and this book is expensive by any standard. Perhaps this is because it is hard-bound and there are 26 colour plates. The plates and most of the numerous black-and-white figures, in the form of graphs, maps and diagrams, are useful and have reproduced well from the original. There are some exceptions: neither figure 3.9, its caption nor the description of CryoSat in the text are particularly helpful in explaining how this complicated system will obtain ice freeboard data, and the captions to plates 4.2 and 4.3 have been transposed. However, these are minor quibbles that are more than compensated for by the comprehensive reference lists that accompany each chapter.

Notwithstanding a few weaknesses and faults, the editors and authors are to be congratulated for creating a book that is essential reading and a significant contribution to the literature of polar science. For the moment there is nothing else like it. I recommend it to all sea-ice physical and biological scientists, as well as polar oceanographers, geologists, chemists and atmospheric scientists. It is a basic reference book that provides a comprehensive multidisciplinary summary of the state of the art. It will be valuable across a broad spectrum of levels of experience and expertise, from undergraduates through graduate students to researchers and educators. If you can't afford it, ask your library to purchase it.

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