Chapter 1

Introduction

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1.1 THE NEED FOR SEA ICE FIELD MEASUREMENTS

As much as one-tenth of the world's oceans are covered with sea ice at some point during the year. Where present, sea ice plays an important, often defining, role in the natural environment. It controls heat exchange between ocean and atmosphere and is a key component of the global climate system. Polar and subpolar ecosystems are both dependent on and constrained by the presence of an ice cover. Human activities are intimately tied to and affected by the presence of an ice cover, be it the access to marine mammals from ice platforms by indigenous hunters or the hazards presented by drifting ice to shipping and industrial development. The importance of sea ice in these different contexts is well recognized and has been the subject of a substantial number of publications and monographs dedicated to a specific aspect of the role of sea ice in the world (e.g., Untersteiner 1986; Melnikov 1997; Leppäranta 1998; Wadhams 2000; Krupnik and Jolly 2002; Thomas and Dieckmann 2003; Leppäranta 2005).

Over the past few years interest in sea ice has grown substantially. In part, this increased attention appears to be linked directly to the realization that some of the substantial reductions observed in arctic summer minimum ice extent in recent years figure prominently in a broad suite of environmental, socioeconomic, and geopolitical changes. In 2007 and 2008, arctic summer minimum ice extent was reduced by roughly one-fifth below the previous record minimum observed during the satellite era (1979 to the present) (Figure 1.1) (Stroeve et al. 2008). These reductions appear to be in line with enhanced warming forecast for the Arctic due to ice-albedo feedback, amplifying surface heating by reducing the highly reflective ice cover and exposing the dark oceans underneath (Holland and Bitz 2003). Currently, a number of arctic nations are reevaluating their territorial claims under the United Nations Convention of the Law of the Seas (UNCLOS). Part of this reevaluation appears to be spurred by renewed interest in natural resources in or adjacent to ice-covered waters, such as those of the Chukchi and Beaufort seas (Brigham

2007). Industrial development and shipping, in turn, are paying close attention to changes in the ice cover.

At the same time, arctic ecosystems and the communities and people who depend on these ecosystems are experiencing significant, in some areas rapid, change (Krupnik and Jolly 2002). In arctic (coastal) seas, much of this change is intimately tied to a thinner, less extensive sea ice cover. Such alterations in the ice cover in turn greatly affect key species such as fish, walrus, and other marine mammals (Grebmeier et al. 2006).

While not necessarily expressing causal relationships, Figure 1.1 provides two different perspectives on this suite of changes. On the one hand, the top panel indicates the magnitude of interannual variability, cyclic variations, and a superimposed trend in the summer arctic ice extent. On the other hand, the bottom panel provides an indication of the increasing public attention, as expressed in media coverage, given to sea ice. More detailed analysis indicates that this media attention was both a response to (geo) political and socioeconomic developments (e.g., listing of the polar bear as a "threatened" species under the provisions of the U.S. Endangered Species Act; increasing oil and gas exploration activities in the Arctic, revision of territorial claims under UNCLOS), growing concern over climate change, and a reflection of the media covering scientific research findings associated with a reduction in arctic sea ice extent and in particular the record minimum of 2007.

At present, we find that a diminishing arctic sea ice cover is focusing our attention on the different functions that sea ice performs in a global and regional context. The uses of the ice cover and the services it delivers, such as its role as an important platform for marine mammals, indigenous people, and industry, are not only being impacted by reductions in ice extent and the length of the ice season. Activities on or among sea ice are also increasingly occurring in parallel and in potential conflict as their overall scope grows while the sea ice area shrinks. Here, the concept of sea-ice system services—explained in more detail in subsequent chapters—as the tangible and intangible benefits that ecosystems and humans derive from sea ice can be of significant value in furthering our understanding of how these different processes act in concert.

However, an important aspect that is key to our understanding of sea ice as it receives increasing attention from stakeholders and decision makers, as well as the public, relates to the question of how scientific knowledge and insight into the processes driving variability and change of the global ice cover are actually generated or obtained. The current focus is mostly on information derived from satellite remote sensing and large-scale model simulations. The accuracy and utility of such information hinges on the generation and acquisition of more fundamental knowledge obtained through qualitative and quantitative observation of processes and changes over time in the natural environment. In fact, it is typically only after we have gained some insight into sea ice as a process and a phenomenon that remote

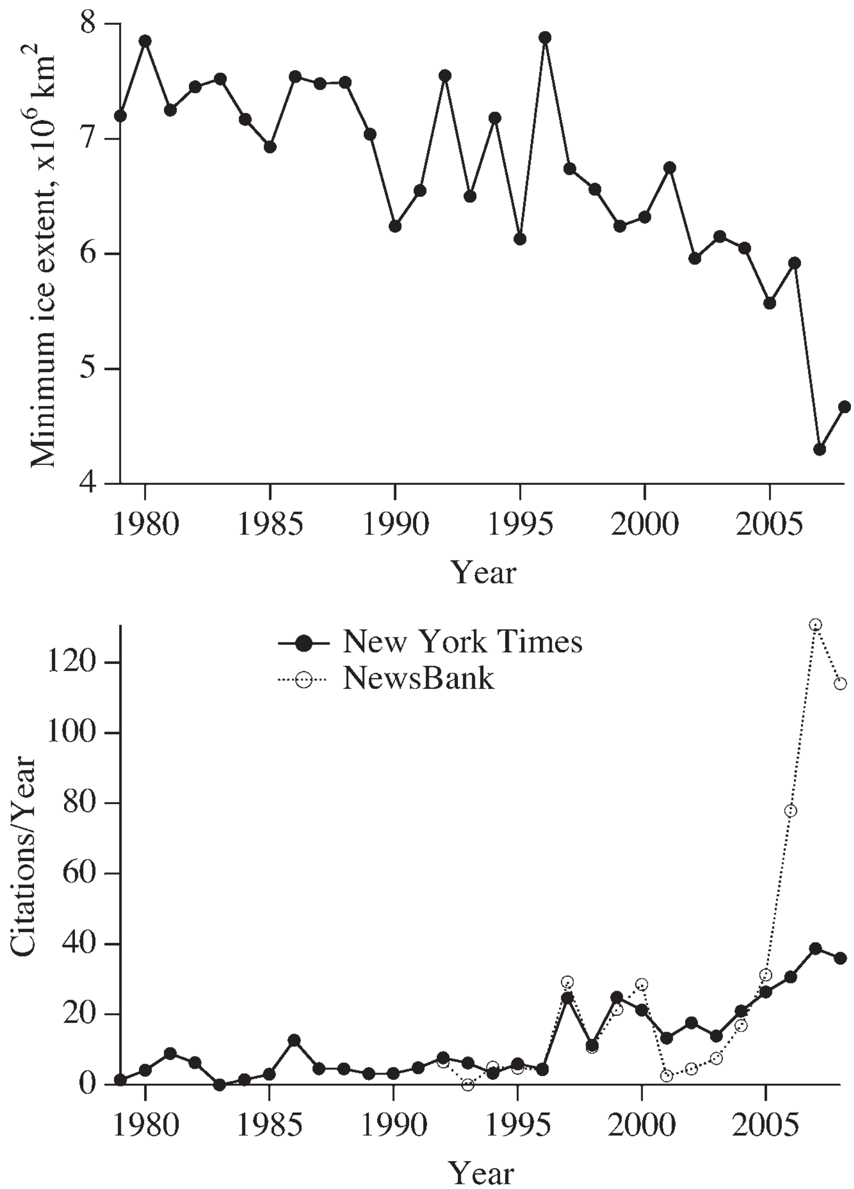

Figure 1.1. Arctic summer minimum ice extent as obtained from passive-microwave satellite data (top; data provided by the National Snow and Ice Data Center) and number of articles published in the New York Times and headlines of United States Newspapers (as referenced in NewsBank database) containing the phrase “sea ice” (bottom). The number of citations per year has been normalized to the keyword “Saturday” to account for the increase in number of publications and articles.

sensing and modeling can come into play. The present book focuses on the different approaches and methodologies that allow us to extract information from sea ice field measurements and that hence shape our current understanding of the role of sea ice in local and global contexts. While exhaustive in neither breadth nor depth, it does also provide a glimpse of the status of an interdisciplinary field of study at the end of the Fourth International Polar Year.

1.2 OVERVIEW OF BOOK CONTENTS

Preceding this introduction is a Foreword, "Encounters with Northern Sea Ice," by Ned Rozell, a science writer, who portrays a number of sea ice experts and sea ice users. His contribution provides a more tangible perspective on what sea ice means to different people and the potential value of information obtained from field measurements.

Chapter 2, "The Sea Ice System Services Framework: Development and Application," is an attempt to provide something of a link between sea ice policy and sea ice research by examining the services and benefits (or costs) associated with the use of sea ice by different groups from within and outside of the polar regions. Even though some of the concepts introduced in the chapter are firmly rooted within political science, it may help shed light on the origins of stakeholders' interests in sea ice and the potential contributions that field-based research can offer.

The next section of the book consists of 18 chapters that constitute the main body of reference material in this volume. Sea ice field research often starts with the removal of a snow layer to gain access to the ice underneath. Chapter 3.1, "Field Techniques for Snow Observations on Sea Ice," provides a broad introduction to the principal methods employed in characterizing snow to gain more insight into its important role in affecting a number of key ice properties and processes.

Chapter 3.2, "Ice Thickness and Roughness Measurements," is a comprehensive survey of the different approaches employed in measuring one of the most important properties of sea ice, its thickness.

Sampling methods and basic ice-core analysis are discussed in Chapter 3.3 ("Ice Sampling and Basic Sea-Ice Core Analysis"), serving in some ways also as a foundation for some of the subsequent chapters. Thus, Chapter 3.4 introduces measurements of the "Thermal, Electrical, and Hydraulic Properties of Sea Ice," covering a broad range of different approaches, including ever-more-important data acquisition through in situ sensor systems.

The mechanical properties of sea ice and measurements of strength are discussed in an applied, structural –engineering–based context in Chapter 3.5, "Ice Strength: In Situ Measurement." This chapter also illustrates how a range of key sea ice uses that depend on the structural integrity of the ice as well as the role of ice as a hazard are tied to fundamental properties discussed in some of the earlier Chapters.

Chapter 3.6, "Sea Ice Optics Measurements," lays the foundation for some of the discussion of biooptics in later chapters, but more importantly, provides guidance on the different approaches to conduct one of the most fundamental measurements over sea ice, that of ice albedo.

Chapter 3.7 introduces the important field of study of ice-ocean interaction by covering the topic of "Measurements and Modeling of the Ice-Ocean Heat Interaction." With a focus on heat exchange, the Chapter also provides a perspective on how these measurements can be employed to estimate exchange of nutrients and other compounds.

Chapter 3.8, "Biogeochemical Properties of Sea Ice," introduces the suite of ice-ecology contributions and focuses on sampling and fundamental measurements in biogeochemical studies of sea ice. It is followed by Chapter 3.9, which introduces a number of approaches for the "Assessment of the Abundance and Diversity of Sea Ice Biota" and demonstrates how both physical and biological processes have to be taken into consideration as the distribution of biota throughout the ice cover is determined.

The study and in particular capturing of ice-associated seals is the topic of Chapter 3.10, "Studying Seals in their Sea Ice Habitat: Application of Traditional and Scientific Methods." An important component of the sea-ice field course as a demonstration of sea ice use by marine mammals, this chapter also provides a good perspective on the successful marriage of local, indigenous (northern Alaska Iñupiaq) knowledge and Western scientific methodology. Discussion of studies of all ice-associated mammals and birds is beyond the scope of this book; however, this Chapter provides some insight into the measurements and methodologies of such studies using the example of ice seals.

Chapter 3.11, "Community-Based Observation Programs and Indigenous and Local Sea-Ice Knowledge," provides an overview and guidance on how to work at the interface between academia and the vast body of knowledge and understanding accumulated by indigenous arctic residents.

Chapter 3.12 focuses on "Ship-Based Ice Observation Programs." With numerous icebreaker expeditions into ice-covered waters each year and more frequent "ship-of-opportunity" cruises, ship-based observations provide an important link between remote sensing and highly localized on-ice measurements.

The use of drifting sensors and longer-term installations of sensor systems is discussed in Chapter 3.13, "Automatic Measurement Stations." It provides insight into the autonomous sensor platforms that have resulted in increasing deployment of ever-more-sophisticated automated systems in recent years.

Chapter 3.14, "Data Management in Sea Ice Research," provides a brief introduction to key principles of data management as pertinent to the other topics covered in this book.

Chapter 3.15, "Principal Uses of Remote Sensing in Sea-Ice Field Research," is a comprehensive overview of the relevant remote-sensing resources. While remote sensing of ice surfaces depends greatly on validation through ground-based observations, modern field studies in turn increasingly rely on remote-sensing data for planning and interpretation of measurements. Along the same lines, Chapter 3.16, "The Use of Models in the Design and Interpretation of Field Measurements," discusses how a similar mutual dependence between field studies and model simulations.

Chapter 3.17, "Integrated Sea Ice Observation Programs," is something of a synthesis of the preceding Chapters and provides two examples or case studies (one of a coastal arctic sea ice observatory, the other of a highly interdisciplinary ship expedition in antarctic waters) of how a suite of different measurements can be tied together in an integrated fashion to help address more complicated questions that transcend disciplinary boundaries.

Alice Orlich, a participant in the 2008 sea ice field course with prior fieldwork experience, presents in Chapter 3.18 an overview of "Personal Field Logistics," touching on a range of important topics that are prerequisite to safe, comfortable, and successful fieldwork. The accompanying DVD contains additional material on field safety as pertinent to the aforementioned field course that may be of interest to readers.

Chapter 4 concludes the main body of the book with a set of observations and a brief outlook on present-day and future relevance of sea ice field measurements.

The book is accompanied by a multimedia DVD, produced by Maya Salganek and a class of documentary film students, with computer animations by Miho Aoki. The DVD features video footage accompanying most of the main book chapters and demonstrating the application of different measurement approaches in the field and laboratory. It also provides a perspective on sea ice and the animals and people that depend on it in a coastal Alaska setting. In addition to these video documentaries, the DVD also contains a range of other resources that link back to specific chapters, including extended versions of some of the book contributions, programs and handbooks for ice observations or derivation of basic ice properties, and other electronic materials. The DVD also contains the data and analyses of the different field course components, edited by Sinead Farrell, one of the course participants.

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