Ola M. Johannessen • Leonid P. Bobylev
Elena V. Shalina • Stein Sandven
Editors

Sea Ice in the Arctic

Past, Present and Future

Springer

Editors
Ola M. Johannessen
Nansen Scientific Society
Bergen, Norway

Leonid P. Bobylev
Nansen International Environmental and Remote Sensing Centre (NIERSC)
Saint Petersburg, Russia

Elena V. Shalina
Nansen International Environmental and Remote Sensing Centre (NIERSC) and Saint Petersburg State University
Saint Petersburg, Russia

Stein Sandven
Nansen Environmental and Remote Sensing Center
Bergen, Norway

University Centre in Svalbard
Longyearbyen, Svalbard, Norway

ISSN 2510-0475 ISSN 2510-0483 (electronic)
Springer Polar Sciences
ISBN 978-3-030-21300-8 ISBN 978-3-030-21301-5 (eBook)
https://doi.org/10.1007/978-3-030-21301-5

This Springer imprint is published by the registered company Springer Nature Switzerland AG.
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Foreword

Sea ice is recognised to have a significant influence on global climate. It has an impact on the heat exchange between the ocean and atmosphere, a critical influence on the high-latitude atmosphere and freshwater balance, and an essential role in regulating the global thermohaline circulation. "What happens in the Arctic doesn't stay in the Arctic" has become an important catch phrase.

The loss of sea ice is just one effect of the increasingly warmer Arctic, which is warming at a rate two to three times faster than the rest of the planet on average. The change in temperatures at the poles can have a major effect on all parts of the globe because of the interconnected nature of Earth's climate system.

Against this backdrop, the book *Sea Ice in the Arctic: Past, Present and Future*, edited by Ola M. Johannessen and colleagues, provides essential information and assesses the current situation of Arctic sea ice. Sketching out the long-term perspective, the book treats a wide range of relevant topics. For example, it discusses the reconstruction of paleo-records (spanning a reference frame for the exceptional nature of today's changes), highlights more recent observations and methods (including measurements from space), and touches upon future trends like the use of artificial intelligence in sea ice classification and corollary effects like the impact of climate change on the Arctic economy.

The European Space Agency (ESA) has been addressing Arctic sea ice through various projects like the Climate Change Initiative (CCI), which features sea ice as an Essential Climate Variable (ECV), and through sea ice monitoring data sets from CryoSat, SMOS, Sentinel-1, and Sentinel-3. They are fundamental to data assimilation into coupled models and for delivering operational services through the Copernicus Marine Environment Monitoring Service (CMEMS).

The ESA remains committed to continue its endeavours in this regard, as the need for sustained sea ice and ocean data sets in the Arctic is recognised by Copernicus users. Three relevant Copernicus Sentinel high-priority candidate missions are currently being studied: an imaging passive microwave mission (for ice concentration), a polar ice and snow topography mission (for sea ice thickness), and an L-band synthetic aperture radar (SAR) mission as a complement to Sentinel-1.

ESA's activities in the domain of Arctic sea ice are just one element of a wide-scale effort to monitor and protect our planet Earth for future generations – a global endeavour by nature – requiring a holistic societal approach. This book is an important element of this endeavour, raising awareness, informing public debate, and sketching a way forward to tackle the strategic topic of Arctic sea ice.

Director of Earth Observation Programmes Josef Aschbacher
European Space Agency
Frascati, Italy

Contents

Contributors

Laurent Bertino Nansen Environmental and Remote Sensing Center, Bergen, Norway

Leonid P. Bobylev Nansen International Environmental and Remote Sensing Centre (NIERSC), Saint Petersburg, Russia

Richard Davy Nansen Environmental and Remote Sensing Center, Bergen, Norway

Denis Demchev Arctic and Antarctic Research Institute, Saint Petersburg, Russia Nansen International Environmental and Remote Sensing Centre, Saint Petersburg, Russia

Pavel Golubkin Nansen International Environmental and Remote Sensing Centre, Saint Petersburg, Russia

Klaus Hasselmann Max Planck Institute for Meteorology, Hamburg, Germany

Ola M. Johannessen Nansen Scientific Society (NSS), Bergen, Norway

Kirill Khvorostovsky Russian State Hydrometeorological University, Saint Petersburg, Russia

Anton G. Kjelaas Norwegian Scientific Academy for Polar Research, Nesoddtangen, Norway

Alexander S. Komarov Environment and Climate Change Canada, Ottawa, ON, Canada

Dmitry V. Kovalevsky Climate Service Center Germany (GERICS), Helmholtz-Zentrum, Geesthacht, Germany

Matti Leppäranta Institute for Atmospheric and Earth System Research (INAR), University of Helsinki, Helsinki, Finland

Valentin P. Meleshko Voeikov Main Geophysical Observatory, Saint Petersburg, Russia

Martin W. Miles NORCE Norwegian Research Centre, Bjerknes Centre for Climate Research, Bergen, Norway
Institute of Arctic and Alpine Research University of Colorado, Boulder, CO, USA

Alexandra Mushta Nansen International Environmental and Remote Sensing Centre, Saint Petersburg, Russia

Einar O. Olason Nansen Environmental and Remote Sensing Center, Bergen, Norway

Tatiana Pavlova Voeikov Main Geophysical Observatory, St. Petersburg, Russia

Lasse H. Pettersson Nansen Environmental and Remote Sensing Center, Bergen, Norway

Stein Sandven Nansen Environmental and Remote Sensing Center (NERSC), Bergen, Norway
University Centre in Svalbard, Longyearbyen, Svalbard, Norway

Elena V. Shalina Nansen International Environmental and Remote Sensing Centre (NIERSC) and Saint Petersburg State University, Saint Petersburg, Russia

Petteri Uotila Institute for Atmospheric and Earth System Research (INAR), University of Helsinki, Helsinki, Finland

Vladimir A. Volkov Nansen International Environmental and Remote Sensing Centre, Saint Petersburg, Russia

Jiping Xie Nansen Environmental and Remote Sensing Center, Bergen, Norway

Natalia Y. Zakhvatkina Arctic and Antarctic Research Institute, Nansen International Environmental and Remote Sensing Centre, Saint Petersburg, Russia