The Global Cryosphere

Past, Present, and Future

This is the first textbook to address all the components of the Earth's cryosphere – all forms of snow and ice, both terrestrial and marine. It provides a concise but comprehensive summary of cryospheric processes for courses at upper undergraduate and graduate level in environmental science, geography, geology, glaciology, hydrology, water resource engineering, and ocean sciences. It also provides a superb up-to-date summary of cryospheric processes for researchers from a range of sciences.

In recent years, studies have shown that the Earth is undergoing potentially rapid changes in all cryospheric components, including Arctic sea ice shrinkage, mountain glacier recession, thawing permafrost, diminishing snow cover, and accelerated melting of the Greenland Ice Sheet. This has significant implications for global climate, hydrology, water resources, and global sea level. This text provides a comprehensive account of snow cover, glaciers, ice sheets, lake and river ice, permafrost, sea ice, and icebergs – their past history, and projected future state.

The book builds on courses taught for many decades by Roger G. Barry in the Department of Geography at the University of Colorado and by Thian Gan in the Department of Civil and Environmental Engineering at the University of Alberta.

- Whilst there are many existing texts on individual components of the cryosphere, no other textbook provides an account of the whole cryosphere.
- Developed from courses taught by the authors for many decades.
- Key processes are explained and observational methods including remote sensing are discussed.
- Includes an extensive bibliography, numerous figures and color plates, and a glossary.
- Includes thematic boxes on selected topics to broaden the scope.

Roger G. Barry is former Director of the World Data Center for Glaciology, a Fellow of the Cooperative Institute for Research in Environmental Sciences, and a Distinguished Professor of Geography at the University of Colorado at Boulder. He served as Director of the National Snow and Ice Data Center from 1981–2008. His teaching and research has been in climate change, arctic and mountain climates, and snow and ice processes. He has published 20 textbooks, more than 200 articles and supervised 55 graduate students. He was co-Vice Chair of the Climate and Cryosphere Project of the World Climate Research Programme from 2000–2005. Roger was a Guggenheim Fellow (1982–1983) and a Fulbright Teaching Fellow (Moscow, 2001). He is a Fellow of the American Geophysical Union and a Foreign Member of the Russian Academy of Natural Sciences. He is a winner of the Goldthwait Polar Medal (2006); the Founder's Medal of the Royal Geographical Society, London (2007); the F. Matthes award of the Cryospheric Specialty Group of the

Association of American Geographers (2007); and the Humboldt Prize (2009–2011). He shared the Nobel Peace Prize with other team members of the Intergovernmental Panel on Climate Change (2007). He has been a Visiting Professor in Australia (1975), France (2004), Germany (1994, 2009, 2010), Japan (1983), New Zealand (1986), Russia (2001), Switzerland (1983, 1990, 1997), and the United Kingdom (1997). He is fluent in French, German, and Russian.

Thian Yew Gan is a Professor at the University of Alberta, Edmonton, and a fellow of the American Society of Civil Engineers. His teaching and research have been in snow hydrology, remote sensing, hydrologic modeling, hydroclimatology, data analysis, climate change impact on hydrologic processes, and water resources management and planning. Thian has supervised 30 graduate students and published over 60 refereed papers in various international journals of the American Geophysical Union, American Meteorological Society, Royal Meteorological Society, Elsevier Science, America Society of Civil Engineers, and others. He has been a Visiting Professor at Ecole Polytechnique Federale de Lausanne (EPFL) (2010); Visiting Scientist at Cemagraf, France (2009); a CIRES Visiting Fellow at the National Snow and Ice Data Center (NSIDC) at the University of Colorado at Boulder (2007, 2008); Guest University Professor at the Technical University of Munich (2006–2007); Adjunct Professor at Utah State University (1998–2005); Honorary Professor at Xian University of Technology, China (since 2004); Honorary Professor at Yangtze University, China (2010–2013); Visiting Professor at Kyoto University and JSPS Fellow, Japan (1999–2000); Guest Professor at Saga University, Japan (1999); Assistant Professor at the Asian Institute of Technology of Thailand (1989–1990); and regional hydrologist of the Indian and Northern Affairs Canada (1992–1993) on snow measurements and mapping at the Arctic.

Praise for this book

'This is the first comprehensive account of the cryosphere. It encompasses all aspects of the Earth's systems influenced by below-freezing temperature. Thus glaciology, permafrost, seasonal snow cover, fresh-water and sea ice, and the all-pervading atmosphere, are interlinked after decades of separate treatment. Roger G. Barry has been a leading exponent of this rationalization that has emerged at a critical time now that climate warming is impinging on the cryospheric "estate." He has been ably reinforced by the low-temperature hydrological engineering expertise of his co-author, Thian Yew Gan. The breadth and depth of coverage and the outstanding scholarship that has typified Barry's life-long dedication here unfolds as the masterpiece of his maturing years. It will long remain the ultimate reference and teaching source and will strongly enhance the urgent present-day quest for understanding how our Earth functions and how we may be inadvertently changing it.'

Jack D. Ives, University of California, Davis and Carleton University, Ottawa

'This is an indispensable reference work on the topic of snow and ice, as it includes both historical aspects, and the latest developments in this urgent field of research. In this compendium you will find aspects of snow and ice that you may have thought about, but never – until now – had the scientific background knowledge to fully grasp – a truly enlightening work!'

Ludwig Braun, Commission for Geodesy and Glaciology,
Bavarian Academy of Sciences and Humanities

'Barry and Gan, with their encyclopedic knowledge and extensive teaching experience, have produced an extraordinary text that covers virtually all aspects of Earth's fragile cryosphere. The authors describe in accurate detail the relevant physical processes and how each part of the cryosphere has changed over time and is anticipated to change in the future. There is no better time for such a reference, and it will be highly valued by climatologists, cryospheric scientists, and students engaging in learning about this important component of our changing planet.'

Anne Nolin, Oregon State University

'With the appearance of this book, our community has acquired the most comprehensive presentation of major aspects of the cryosphere – the world of ice on this planet. No other single book has so successfully integrated the terrestrial cryosphere (snow, glaciers, frozen ground, and other fresh water frozen body) and the marine cryosphere (sea ice, ice shelves, and icebergs) in such an attractively readable manner. Each form of ice is illustrated with respect to research history, observed phenomenon, processes, modeling, and variability, including the present time under the climate warming. As an excellent introductory textbook for all forms of the cryosphere it is well suited for advanced undergraduates and junior graduate students. The book also offers detailed accounts of the processes that have not been available to many professionals, such as the *in situ* visual observations of the formation processes of new ice, frazil, grease, shuga and pancake ice; seasonal development of the snow cover and melt ponds on sea ice; sub-ice shelf circulation; case presentations of glacier dammed lake bursts; iceberg statistics along the Russian Arctic coast, just to mention a few. In all chapters, the remote sensing applications and their basic theories are comprehensively presented. The authors have used excellent photographs for visual explanation and presented one of the most complete bibliographies in glaciology. Each phenomenon is accompanied with web-addresses, many of which provide extended information not only to bring the readers up-to-date, but also to equip them with quasi-real time information that has an enormous practical significance. The book is a useful source of information for researchers in other disciplines, climate modelers, and engineers.'

Atsumu Ohmura, Swiss Federal Institute of Technology

'This text provides an excellent synoptic perspective of the Earth's cold regions, and presents an outstanding introduction to those new to the field. The text should serve as a key reference for upper-level undergraduate instruction and ancillary summary material for graduate-level courses.'

Derrick J. Lampkin, Pennsylvania State University

The Global Cryosphere

Past, Present, and Future

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CAMBRIDGE
UNIVERSITY PRESS

CAMBRIDGE UNIVERSITY PRESS
Cambridge, New York, Melbourne, Madrid, Cape Town,
Singapore, São Paulo, Delhi, Tokyo, Mexico City

Cambridge University Press
The Edinburgh Building, Cambridge CB2 8RU, UK

Published in the United States of America by Cambridge University Press, New York

www.cambridge.org
Information on this title: www.cambridge.org/9780521769815

First published 2011

Printed in the United Kingdom at the University Press, Cambridge

A catalog record for this publication is available from the British Library

Library of Congress Cataloging in Publication data
Barry, Roger Graham.
The global cryosphere: past, present, and future/Roger G. Barry and Thian Yew Gan.
p. cm.
Includes bibliographical references and index.
ISBN 978-0-521-76981-5 (hardback) – ISBN 978-0-521-15685-1 (pbk.)
1. Cryosphere – History. 2. Cold regions – History. 3. Glaciers – History.
4. Ice sheets – History. I. Gan, Thian-Yew. II. Title.
QC880.4.C79B37 2011
551.31–dc22 2011011262

ISBN 978-0-521-76981-5 Hardback
ISBN 978-0-521-15685-1 Paperback

Cambridge University Press
978-0-521-76981-5 - The Global Cryosphere: Past, Present and Future
Roger G. Barry and Thian Yew Gan
Frontmatter
More information

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Preface

This text aims to fill a long-standing gap in the scientific literature. While there are many texts on individual components of the cryosphere – snow cover, glaciers, ice sheets, lake and river ice, permafrost, sea ice, and icebergs – there is no comprehensive account. The text is aimed at upper division undergraduates and beginning graduate students in environmental sciences, geography, geology, glaciology, hydrology, water resources engineering, and ocean sciences, as well as providing a reference source for scientists in all environmental science and engineering disciplines.

The text builds on an introductory graduate-level course "Topics in snow and ice" taught by Roger G. Barry (RGB) at the Geography Department, University of Colorado, Boulder, over the last thirty years, and on part of a graduate-level course, "Advanced surface hydrology" taught by Thian Yew Gan (TYG) as a professor of hydrology and water resources engineering at the Department of Civil/Environmental Engineering, University of Alberta, Edmonton, for the last seventeen years. The former course in turn built on RGB's widening exposure to snow and ice data and literature through the work of the National Snow and Ice Data Center (NSIDC) from 1981 on. Roger G. Barry's earlier field experience at the McGill SubArctic Research Laboratory, Schefferville, PQ, Canada in 1957–1958, Tanquary Fiord, Ellesmere Island, Arctic Canada in summer 1963 and spring 1964, Baffin Island, Arctic Canada in 1967 and 1970, and participation in a summer school on the Russian icebreaker *Kapitan Dranitsyn* in autumn 2005 provided additional insights, as did leaves at the Alfred Wegener Institute for Polar and Marine Research in 1994, the Geographical Institute, ETH, Zurich in 1997, and the Laboratoire de Glaciologie et Géophysique in Grenoble in 2004. Roger G. Barry stepped down from the Directorship of NSIDC in May 2008 and worked half-time from January 2009–December 2010. This phase of the writing was greatly assisted by RGB being a recipient of a Humboldt Foundation Prize Award in 2009–2011. He spent May–October 2009 and August–October 2010 as a visitor at the Kommission für Glaziologie of the Bavarian Academy of Sciences in Munich (BASM), courtesy of its Director, Dr. Ludwig Braun. Thian Yew Gan began his collaboration with RGB during his visit to NSIDC as a CIRES (Cooperative Institute of Research in Environmental Science) visiting fellow in 2007, and worked with RGB on this book at Boulder in 2008 and at BASM in 2009 and 2010. Between 1992 and 2008, TYG has had field experience conducting snow measurement in the Canadian high Arctic and in the Canadian Prairies, also monitoring river ice break-up in the Northwest Territories of Canada, remote sensing of snow, and modeling of snowmelt in the Canadian Prairies and Swiss Alps.

Roger G. Barry
Thian Y. Gan

Acknowledgements

Thanks are due first and foremost to the Humboldt Foundation of Germany for their award of a Humboldt Prize Fellowship in 2009–2011 which enabled RGB to work on the book without other distractions. Roger's time was spent at the Kommission für Glaziologie of the Bavarian Academy of Sciences, Munich, and thanks go to its Director Dr. Ludwig Braun for his hospitality and help; also to research staff Dr. Heidi Escher-Vetter and Dr. Christoph Mayer, and to staff members Lusia Soturczak and Dieter Schwartz for their assistance. Thanks also go to Clark Judy, then NSIDC's Deputy Director, for drawing my attention to the Humboldt Fellowship program.

Thanks also to a Cooperative Institute for Research in Environmental Sciences (CIRES) visiting fellowship that supported TYG´s 2007 visit, and to the National Science and Engineering Research Council (NSERC) of Canada, that supported his 2008 visit to the National Snow and Ice Data Center (NSIDC) at the University of Colorado, Boulder, and to NSIDC for providing the necessary facilities to conduct research on passive microwave radiometry of snow and for working on the book.

We are indebted to the following chapter reviewers for their suggestions. Any remaining errors are our own.

Chris Hiemstra, U.S. Army Corps of Engineers, CRREL, Ft. Wainright, AK (Ch.2A)
Karl Birkekand, U.S.D.A. Forest Service National Avalanche Center, Bozeman, MT (Ch. 2B)
Jack D. Ives, Carleton University, Ottawa (Ch.3)
Mark F. Meier, INSTAAR, University of Colorado, Boulder (Ch. 3)
Ted Scambos, NSIDC, University of Colorado, Boulder (Ch. 4 and Ch. 8)
Fritz Nelson, University of Delaware (Ch. 5)
Glen Liston, Colorado State University (Ch. 6A)
Spyros Beltaos, National Water Research Institute, Burlington, Ontario (Ch. 6B)
Norbert Untersteiner, University of Washington, Seattle, WA (Ch. 7)
Klaus Heine, Department of Geography, University of Regensburg (Ch. 9)

We also thank Drs. Richard Armstrong, Faye Hicks, Jack Ives, Adina Racoviteanu, Vladimir Romanovsky, Nikolai Shiklomanor, and Koni Steffen for photographs, NSIDC student helpers Sam Massom, Yana Duday, and Mike Laxer for illustration assistance; and we thank Matt Lloyd of Cambridge University Press for his enthusiastic support of the project.

Our thanks go to the following individuals, societies and organizations for their permission to reproduce figures from books and journals:

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Cartographer/designer: Hugo Ahlenius, UNEP/GRID-Arendal

The global distribution of the components of the cryosphere. Hugo Ahlenius, http://upload.wikimedia.org/wikipedia/commons/b/ba/Cryosphere_Fuller_Projection.png

Glacier shrinkage since the Little Ice Age in the Cumberland Peninsula, Baffin Island.

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Water Resource Publications, Highlands Ranch, CO 80163-0026
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