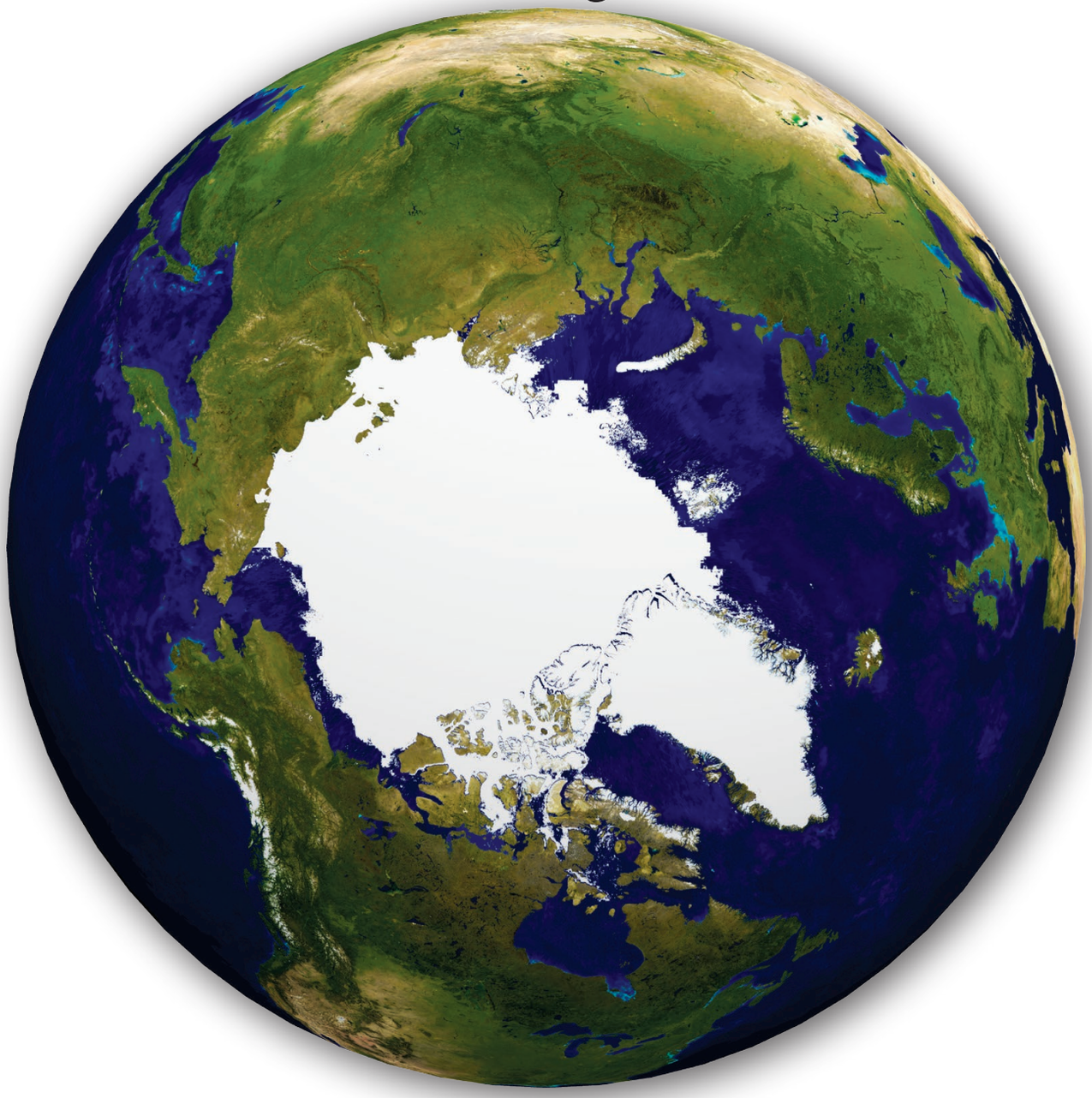
USGS
science for a changing world

Satellite Image Atlas of Glaciers of the World

State of the Earth's Cryosphere at the Beginning of the 21st Century: Glaciers, Global Snow Cover, Floating Ice, and Permafrost and Periglacial Environments



U.S. Geological Survey
Professional Paper 1386–A

Front and back covers—*Mosaics of MODerate resolution Imaging Spectroradiometer (MODIS) images of the polar regions of the Earth. Perspective from the Northern Hemisphere (front cover), with sea ice in the Arctic Ocean at average minimum (~5–7×10^6 km^2) in September. Perspective from the Southern Hemisphere (back cover), with sea ice in the Southern Ocean at average maximum (~18×10^6 km^2) in September. MODIS mosaics courtesy of National Aeronautics and Space Administration, Goddard Space Flight Center.*

STATE OF THE EARTH'S CRYOSPHERE AT THE BEGINNING OF THE 21ST CENTURY: GLACIERS, GLOBAL SNOW COVER, FLOATING ICE, AND PERMAFROST AND PERIGLACIAL ENVIRONMENTS

SATELLITE IMAGE ATLAS OF GLACIERS OF THE WORLD

Edited by RICHARD S. WILLIAMS, JR., *and* JANE G. FERRIGNO

U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 1386–A

Chapter A synthesizes the 11-Chapter Satellite Image Atlas of Glaciers of the World, addressing changes in the Earth's cryosphere at the beginning of the 21st century, including the impact of global environmental change on the cryosphere and on other components of the Earth System, such as intensification of the global hydrological cycle. According to analyses of satellite image data and other satellite data and analyses of ground observations, most of the glaciers on Earth, except for some surge-type and some tidewater glaciers, are retreating (losing mass), thereby contributing to the accelerating rise in sea level worldwide. Analyses of satellite data and of ground observations since the 1970s document a reduction in snow cover globally and in floating ice (sea ice and lake and river ice). In late summer 2007, the area of sea ice in the Arctic Ocean reached a low, significantly less than the average for the past several decades; sea-ice coverage around Antarctica has slightly increased. The permafrost in the Northern Hemisphere is warming, and in the more southerly discontinuous zones its vertical and areal extent is diminishing.

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON: 2012

U.S. DEPARTMENT OF THE INTERIOR

KEN SALAZAR, Secretary

U.S. GEOLOGICAL SURVEY

Marcia K. McNutt, Director

Technical editing by C. Michael Eberle, Alice Koller, and Barbara Korzendorfer

Plate and eight supplemental cryosphere notes designed by Christine T. Mendelsohn, with Earth System and cryosphere graphics designed by James A. Tomberlin

Design, layout, and illlustrations by Denis K. Sun

Text review and typesetting by Janice G. Goodell

Layout review by Anna N. Glover

Publishing process coordinated by Debra H. Foster, Pembroke Publishing Service Center

---

Library of Congress Cataloging-in-Publication Data

(Revised for vol. A)
Satellite image atlas of glaciers of the world / edited by Richard S. Williams, Jr., and Jane G. Ferrigno.
p. cm -- (U.S. Geological Survey professional paper; 1386)
Includes bibliographical references.
ISBN 978-0-607-98287-9
Contents: -- Ch. A. State of the Earth's Cryosphere at the Beginning of the 21st Century: Glaciers, Global Snow Cover, Floating Ice, and Permafrost and Periglacial Environments -- Ch. B. Antarctica, by Charles Swithinbank; with sections on The "dry valleys" of Victoria Land, by Trevor J. Chinn, [and] Landsat images of Antarctica, by Richard S. Williams, Jr., and Jane G. Ferrigno -- Ch. C. Greenland, by Anker Weidick -- Ch. E. Glaciers of Europe -- Ch. F. Glaciers of Asia -- Ch. G. Glaciers of the Middle East and Africa -- Ch. H. Glaciers of Irian Jaya, Indonesia, and New Zealand -- Ch. I. Glaciers of South America -- Ch. J. Glaciers of North America -- Ch. K. Glaciers of Alaska.
Supt. of Docs. no.: I 19.16:1386-A
1. Glaciers-Remote sensing. I. Williams, Richard S. II. Ferrigno, Jane G. III. Series.
GB2401.72.R42S28 1988
551.3'12

87-600497

For sale by the U.S. Geological Survey, Information Services
Box 25286, Federal Center,
Denver, CO 80225

Foreword

On 23 July 1972, the first Earth Resources Technology Satellite (ERTS 1, later known as Landsat 1) was placed in orbit. The success of Landsat inaugurated a new era in satisfying the human desire to better understand the dynamic Earth on which we live. Space-based observations have now become an essential means for monitoring changes in local, regional, and global environments.

The short- and long-term cumulative effects of processes that cause significant changes on the Earth's surface can be documented by and studied through the repeated images that sensors on Landsat and other satellites remotely sense. Such images provide a permanent historical record of the surface of the planet on a specific date; they also make possible comparative two- and three-dimensional measurements of change over time. This Professional Paper demonstrates the importance of the application of Landsat images to global studies by using them to determine the distribution of glaciers on the planet during the 1970s. As images become available from future satellites, the new data will be used to document global changes in glacier extent by comparing them with the baseline Landsat image record of the 10-year period 1972 to 1981.

Although many geological processes, during the course of decades, centuries, and millennia, produce obvious changes on the Earth's surface, other geological phenomena, such as glaciers and volcanoes, cause noticeable changes over shorter periods. Some of these phenomena can have an impact worldwide and are often interrelated. Explosive volcanic eruptions, such as that of Mount Pinatubo, Republic of the Philippines, in 1991, can produce dramatic short-term effects on the global climate. Natural or culturally induced processes can cause global climatic cooling or warming. Glaciers respond to such warming or cooling periods by decreasing or increasing in size, which in turn causes sea level to rise or fall.

As our understanding of the interrelationship of global processes improves and as our ability to assess changes caused by these processes develops further, we will learn how to use indicators of global environmental change, such as glacier variation, to manage more wisely the use of our finite land and water resources. This Professional Paper is an excellent example of the quality of the information about the planet that the earth sciences, using innovative technologies, can provide. The international collaboration represented by this report is also an excellent model for the kind of cooperation that scientists will increasingly find necessary in the future in order to solve important scientific problems about the Earth System on a global basis.

Marcia K. McNutt
Director,
U.S. Geological Survey

Preface

This chapter is the tenth in a series of 11 book-length chapters, collectively referred to as "this volume," in the series U.S. Geological Survey Professional Paper 1386, Satellite Image Atlas of Glaciers of the World. In the other 10 chapters, each of which concerns a specific glacierized region of Earth, the authors used remotely sensed images, primarily from the Landsat 1, 2, and 3 series of spacecraft, in order to analyze that glacierized region and to monitor changes in its glaciers. Landsat images, acquired primarily during the period 1972 through 1981, were used by an international team of glaciologists and other scientists to study the various glacierized regions and (or) to discuss related glaciological topics. In each glacierized region, the present distribution of glaciers within its geographic area is compared, wherever possible, with historical information about their past areal extent. The atlas provides an accurate regional inventory of the areal extent of glacier ice on our planet during the 1970s as part of an expanding international scientific effort to measure global environmental change on the Earth's surface.

However, this chapter differs from the other 10 in its discussion of observed changes in all four elements of the Earth's cryosphere (glaciers, snow cover, floating ice, and permafrost) in the context of documented changes in all components of the Earth System. Human impact on the planet at the beginning of the 21st century is pervasive. The focus of Chapter A is on changes in the cryosphere and the importance of long-term monitoring by a variety of sensors carried on Earth-orbiting satellites or by a ground-based network of observatories in the case of permafrost.

The chapter consists of five parts. The first part provides an introduction to the Earth System, including the interrelationships of the geosphere (cryosphere, hydrosphere, lithosphere, and atmosphere), the biosphere, climate processes, biogeochemical cycles, and the critically important hydrologic cycle, in which glacier ice is the second largest reservoir of water after the oceans. The second part assesses the state of glaciers in all of the glacierized regions of the planet, primarily as drawn in the other 10 chapters. It includes sections on ice cores and the climate record they contain, volumetric changes in glaciers, harnessing spaceborne sensors to measure changes in glaciers, and related topics.

The third part summarizes trends in global snow cover. The fourth part summarizes long-term changes in area and thickness of floating ice, including polar sea ice and freshwater (lake and river) ice. The fifth part assesses the loss of permafrost and changes in periglacial environments at high latitudes and high altitudes.

Richard S. Williams, Jr.
Jane G. Ferrigno
Editors

About This Volume

U.S. Geological Survey Professional Paper 1386, Satellite Image Atlas of Glaciers of the World, contains 11 chapters designated by the letters A through K and collectively referred to as "this volume." Chapter A provides a comprehensive review of the "State of the Earth's Cryosphere at the Beginning of the 21st Century: Glaciers, Global Snow Cover, Floating Ice, and Permafrost and Periglacial Environments"; and a Plate of the "Earth's Dynamic Cryosphere," with a set of eight "Supplemental Cryosphere Notes" about the "Earth's Dynamic Cryosphere and the Earth System." The next 10 chapters, B through K, are organized by glacierized geographic regions; they present glaciological information from Landsat and other sources of historic and modern data on each of the geographic areas. Chapter B covers Antarctica; Chapter C, Greenland; Chapter D, Iceland; Chapter E, Continental Europe, including the Alps, the Pyrenees, Norway, Sweden, Svalbard (Norway), and Jan Mayen (Norway); Chapter F, Asia, including Georgia, China (P.R.C.), India, Nepal, Afghanistan, Pakistan, Bhutan, Tajikistan, Kazakhstan, and Kyrgyzstan, plus the European part of the Former Soviet Union; Chapter G, Turkey, Iran, and Africa; Chapter H, Irian Jaya (Indonesia) and New Zealand; Chapter I, South America; Chapter J, North America (excluding Alaska); and Chapter K, Alaska. Chapters A–D each include map plates.

The realization that one element of the Earth's cryosphere, its glaciers, could most effectively be inventoried and monitored globally by using Landsat images led to the decision, in late 1979, to prepare this Professional Paper. Landsat 1, 2, and 3 multispectral scanner (MSS) and Landsat 2 and 3 return beam vidicon (RBV) images would be used to inventory the areal occurrence of glacier ice on our planet within the boundaries of the spacecraft's coverage (between about 81° north and south latitudes). Through identification and analysis of optimum Landsat images of the glacierized areas of the Earth during the first decade of the Landsat era, this Professional Paper could establish a global benchmark for determining the areal extent of glaciers during a relatively narrow period of time (1972 to 1981). This global "snapshot" of glacier extent could then be used for comparative analysis with previously published maps and aerial photographs. New maps, satellite images, and aerial photographs could then be compared with this global "snapshot" of glacier extent to determine the areal fluctuation of glaciers in response to natural or anthropogenic changes in the Earth's climate.

To accomplish this objective, optimum Landsat images of each of the glacierized regions of Earth were selected from the Landsat image database at the Earth Resources Observation System (EROS) Data Center in Sioux Falls, South Dakota, although some images were also obtained from the Landsat image archives maintained by the Canada Centre for Remote Sensing, Ottawa, Ontario, Canada, and by the European Space Agency in Kiruna, Sweden, and Fucino, Italy. During 1979 through 1981, these optimum images were distributed to an international team of more than 50 scientists who agreed to write a chapter, part, or section of the Professional Paper concerning either a geographic area or a glaciological topic. The total number of contributing authors eventually reached 113. In addition to analyzing images of a specific geographic area, each author was also asked to summarize up-to-date information about the glaciers within the glacierized region and to compare their present areal distribution with historical information (for example, from published maps, reports, and photographs) about their past areal extent. The atlas provides an accurate regional inventory of the areal extent of glaciers on Earth during the 1970s, a period of time, in retrospect (2012), that was cooler climatically than the increasingly warmer period that followed as the 20th century ended and that has continued unabated into the first decade of the 21st century.

Richard S. Williams, Jr.
Jane G. Ferrigno
Editors

Acknowledgments

The writing and publication of 11 chapters, A–K, in the U.S. Geological Survey Professional Paper 1386 series ("Satellite Image Atlas of Glaciers of the World") is a major international collaboration. It has taken more than two decades to complete, involving the concerted effort of hundreds of individuals. The 113 authors of the 11 chapters represent 61 scientific institutions in 24 nations (table 1), and many editors, technical reviewers (table 2), text specialists, graphic-arts specialists, editors, and printing specialists have contributed.

We, the two editors of the Professional Paper, want to thank the 113 authors who agreed to write sections of the completed work, because they shared our vision to have these chapters serve as the major archival reference work for all the glacierized regions on Earth, especially with respect to the distribution of glaciers historically and during the final decades of the 20th century. We also want to acknowledge the skilled publication professionals who readied the chapters for printing. We want to acknowledge the effort by 110 technical reviewers representing 79 scientific institutions (including 8 unaffiliated (retired) glaciologists) in 20 nations (table 2), who carefully reviewed all or parts of the 11 chapters to make certain that each chapter met the highest standards of scientific peer review.

ERTS-1 (later renamed "Landsat-1") was launched on 22 July 1972. Landsat MSS images acquired from that date through July 1981 represent the 10-year baseline period for referring changes in glaciers historically (pre-1972) to changes recorded by later Landsat images, by other satellite images, and through ancillary data (for example, aerial surveys, and ground observations) acquired in the future.

We are especially grateful for the financial and other support provided to the Glacier Studies Project by a succession of scientific program managers of the U.S. Geological Survey (USGS) as the project migrated from its initial home in the Earth Resources Observation Systems (EROS) Program (Director's Office), to the National Mapping Division, and finally to the Geologic Division. Funding has also been provided by a succession of Bureau-wide programs that evolved over time in response to scientific priorities of various Administrations. The scientific program manager most responsible for providing the critical initial staffing and funding support for a global study of glaciers with Landsat images was the visionary geophysicist John N. DeNoyer, Director, USGS EROS Program (Director's Office), and former Assistant Director for Research. During the time the EROS Program was housed in the National Mapping Division, John H. Salisbury, Jr., Director, EROS Program, provided critical support. After transfer of the EROS Program to the Geologic Division, notable scientific mangers who provided support were Benjamin A. Morgan, Chief Geologist, and David P. Russ, Associate Chief Geologist for Program. In the late 1980s, the USGS was one of nine Federal agencies in the U.S. Global Change Research Program (USGCRP), whose former Chair, Robert W. Corell, former Associate Director, National Science Foundation, continues to be a strong supporter of the "Satellite Image Atlas of Glaciers of the World" project. Support for the Glacier Studies Project passed from the EROS Program to the USGS Climate Change and Climate History Program, which was the Geologic Division's component of the USGS part of the USGCRP. Richard Z. Poore, Program Coordinator, was a staunch supporter of the Glacier Studies Project. The USGCRP was folded into the 13-agency U.S. Climate Change Science Program (USCCSP) in the early 2000s. The USGS Geologic Division restructured its Climate Change and Climate History Program and renamed it the Earth Surface Dynamics Program (ESD), after which the original scientific focus on global environmental change (and climate change) was slowly deemphasized. Most funding for the Glacier Studies Project, other than funds previously set aside for publication costs of books and maps, ended at the conclusion of fiscal year 2008.

The editors gratefully acknowledge the contributions of the numerous publication specialists of the USGS who converted the text and graphics of the edited and technically reviewed chapters into the final printed (and Web-accessible) publications. Before 1995, five chapters (1386–B, –C, –E, –G, and –H) were prepared in the conventional style, with text and

illustrations on layout boards, with cropping guides for illustrations, and with other information for the printer. The three key USGS publications specialists who worked on the five chapters during this period before desktop publishing existed were Lynn M. Chandler, text specialist; Carolyn (Lynn) S. Hulett, graphics specialist and layout designer; and John M. Watson, editor. Other USGS publishing staff who contributed to one or more of the chapters were Nancy L. Polend, text; Leslie Weissleader Jones, layout and composition; Susan Tufts-Moore, copy editor; David A. Murphy, cartographer; Maura Hogan Harrison, graphics; Jane B. Russell, graphics; and B. Arlene Compher, graphics.

The remaining six chapters (1386–A, –D (not yet published), –F, –I, –J, and –K) were prepared after 1995 using desktop-publishing technology. The final product was prepared completely in digital format (text and graphics) and repurposed for offset printing and Web accessibility. Janice G. Goodell, text specialist, was an invaluable liaison with the editors, authors, and the computer-graphics specialists for the remaining six chapters. Kirsten C. Healey was the computer graphics, design, and layout specialist for Chapters I, J, and K. John M. Watson, technical editor, edited 1386–I and –J; Kathie Rankin, technical editor, edited 1386-K and did a final edit of 1386–A as the Bureau Approving Official. Others who contributed to one or more chapters were Josephine S. Hatton, text, and Carolyn H. McQuaig, final review of page formatting and design. To guide the completed text and graphics through Government Printing Office requirements and to oversee the press run, we thank Debra J. Sokol.

In 2006, the USGS established an Enterprise Publications Network (EPN), later renamed Science Publications Network (SPN), with several geographically dispersed Publications Services Centers (PSC) to provide publication services to scientists in the USGS. Responsibility for production and printing of the final four chapters (1386–A, –D, –F, and –K) of the "Satellite Image Atlas of Glaciers of the World" series was assigned to the Pembroke PSC. Special thanks to Debra H. Foster, Chief of the PSC, and her capable colleagues in various PSCs for their work on these four chapters. In particular, Debra Foster provided outstanding leadership in assigning work for editing, preparation of graphics, page formatting and design and for preparing each volume for print. All of the graphics staff who worked on these chapters took illustrations submitted by authors in a variety of paper and digital formats and produced high-quality figures and digital files to be transmitted to a printer and the USGS Publications Warehouse.

The editors would like to emphasize the critical roles played by Janice G. Goodell for the remaining six chapters and Kirsten C. Healey for preparation of the graphics for Chapters I, J, and K; their extraordinary professional skills, attention to details, and patience meant the difference between success and failure. We greatly appreciate their help and thank them both.

In addition, Janice G. Goodell spent 2 years of dedicated effort to scan the first five chapters, which existed only in print format, so that they too would be available on the USGS Publications Warehouse Web site. In this effort to scan, review, and correct the files to comply with web-accessibility requirements, Kirsten C. Healey and John M. Watson (Raleigh PSC) provided much needed guidance.

For Chapter 1386-F, the following publishing staff from the Fort Lauderdale PSC provided outstanding services under the leadership of Rhonda Howard, PSC Chief: Jane R. Eggleston, editing; Ronald S. Spencer and James A. Tomberlin, graphic support; and Twila Wilson, layout and design support. Christine Mendelsohn (Pembroke PSC) did an excellent job of coordinating the printing for Chapters A, D (not yet published), F, and K and for graphics and page design for Plate 1 and 8 Supplementary Cryosphere Notes in Chapter A.

For Chapter 1386-A, Christine Mendelsohn (Pembroke PSC) and James Tomberlin (Fort Lauderdale PSC) provided superb graphics support. Michael Eberle (Columbus PSC), Barbara Korzendorfer (Pembroke PSC), and Alice Koller (Pembroke PSC) provided excellent and helpful editing support. Anna Glover (Pembroke PSC) provided layout review. Twila Wilson (Fort Lauderdale PSC) did the layout and design of tables. Denis K. Sun (West Trenton PSC) provided design, layout, and illustrations. Susan L. Bergin (Pembroke PSC) provided the Web services for the Publications Warehouse.

TABLE 1.—*Authors of chapters of the U.S. Geological Survey Professional Paper 1386-A–K ("Satellite Image Atlas of Glaciers of the World") and their institutional and national affiliations*

[The institution shown as the affiliation of each author is the location from which the author submitted their contribution to this professional paper. An asterisk behind the name indicates that the author is shown more than once in this list]

Author	Institution	Country
1386-A		
Jerry Brown	International Permafrost Association	United States
Donald J. Cavalieri	NASA, Goddard Space Flight Center, Cryospheric Sciences Laboratory	United States
Claude R. Duguay	University of Waterloo, Department of Geography and Environmental Management	Canada
Mark B. Dyurgerov	University of Colorado, Institute of Arctic and Alpine Research	United States
Jane G. Ferrigno*	U.S. Geological Survey	United States
Kevin M. Foley	U.S. Geological Survey	United States
Dorothy K. Hall	NASA, Goddard Space Flight Center, Cryospheric Sciences Laboratory	United States
J. Alan Heginbottom	Geological Survey of Canada	Canada
Ole Humlum	University of Oslo, Institute of Geosciences	Norway
Thomas G. Huntington	U.S. Geological Survey	United States
Martin O. Jeffries*	University of Alaska Fairbanks, Geophysical Institute	United States
Jeffrey S. Kargel	University of Arizona, Department of Hydrology and Water Resources	United States
Mark F. Meier	University of Colorado, Institute of Arctic and Alpine Research	United States
Kim Morris	University of Alaska Fairbanks, Geophysical Institute	United States
Claire L. Parkinson	NASA, Goddard Space Flight Center, Cryospheric Science Laboratory	United States
Bruce H. Raup	National Snow and Ice Data Center, University of Colorado	United States
David A. Robinson	Rutgers University, Department of Geography	United States
Harald Svensson	University of Copenhagen, Institute of Geography	Denmark
Lonnie G. Thompson	Ohio State University, Byrd Polar Research Center	United States
Richard S. Williams, Jr.*	U.S. Geological Survey	United States
1386-B		
Trevor J. H. Chinn*	Ministry of Works and Development	New Zealand
Jane G. Ferrigno*	U.S. Geological Survey	United States
Charles Swithinbank	British Antarctic Survey, Earth Sciences Division	England, United Kingdom
Richard S. Williams, Jr.*	U.S. Geological Survey	United States
1386-C		
Jane G. Ferrigno*	U.S. Geological Survey	United States
Anker Weidick	Geological Survey of Denmark and Greenland	Denmark
Richard S. Williams, Jr.*	U.S. Geological Survey	United States
1386-D		
Jórunn Harðardóttir	Icelandic Meteorological Office	Iceland
Árni Hjartarson	Iceland GeoSurvey	Iceland
Tómas Jóhannesson	Icelandic Meteorological Office	Iceland
Trausti Jónsson	Icelandic Meteorological Office	Iceland
Oddur Sigurðsson	Icelandic Meteorological Office	Iceland
Skúli Víkingsson	Iceland GeoSurvey	Iceland

Table 1.—*Authors of chapters of the U.S. Geological Survey Professional Paper 1386-A–K ("Satellite Image Atlas of Glaciers of the World") and their institutional and national affiliations—Continued*

[The institution shown as the affiliation of each author is the location from which the author submitted their contribution to this professional paper. An asterisk behind the name indicates that the author is shown more than once in this list]

Author	Institution	Country
Richard S. Williams, Jr.*	U.S. Geological Survey	United States
Snorri Zóphóníasson	Icelandic Meteorological Office	Iceland
1386-E		
Rosanna Serandrei Barbero	National Research Council (CNR), Institute for the Study of the Dynamics of Large Masses	Italy
Nils Haakensen	Norwegian Water Resources and Energy Directorate	Norway
Olav Liestøl	Norwegian Polar Institute	Norway
Gunnar Østrem	Norwegian Water Resources and Energy Directorate	Norway
Olav Orheim	Norwegian Polar Institute	Norway
Louis Reynaud	Domaine Universitaire, Laboratory of Glaciology	France
Helmut Rott	University of Innsbruck, Institute for Meteorology and Geophysics	Austria
Karl E. Scherler	Federal Institute of Technology, Laboratory of Hydraulics, Hydrology, and Glaciology	Switzerland
Valter Schytt	Stockholm University, Department of Physical Geography	Sweden
David Serrat	University of Barcelona, Department of Geomorphology and Tectonics	Spain
Josep Ventura	Cartographic Institute of Catalunya	Spain
Giorgio Zanon	University of Padua, Department of Geography	Italy
1386-F		
Yutaka Ageta	Nagoya University	Japan
Safaraz Ahmad	Aligarh Muslim University, Aligarh	India
Michael P. Bishop	University of Nebraska, Department of Geology and Geography	United States
L. DeWayne Cecil	U.S. Geological Survey	United States
Liu Chaohai	Lanzhou Institute of Glaciology and Cryopedology, Chinese Academy of Sciences	China
Elizabeth K. Dowdeswell	University of Cambridge, Scott Polar Research Institute	England, United Kingdom
Julian A. Dowdeswell	University of Cambridge, Scott Polar Research Institute	England, United Kingdom
A.K. Dyakova	Institute of Geography, Russian Academy of Sciences	Russia
Hiroji Fushimi	Nagoya University	Japan
A.F. Glazovsky	Institute of Geography, Russian Academy of Sciences	Russia
Jaromy R. Green	Garden City Community College	United States
Syed Igbal Hasnain	The Energy and Resources Institute, New Delhi	India
Keiji Higuchi	Nagoya University	Japan
Shuji Iwata	Nagoya University	Japan
V.S. Koryakin	Institute of Geography, Russian Academy of Sciences	Russia
Vladimir M. Kotlyakov	Institute of Geography, Russian Academy of Sciences	Russia
V.I. Kravtsova	Institute of Geography, Russian Academy of Sciences	Russia

Table 1.—*Authors of chapters of the U.S. Geological Survey Professional Paper 1386-A–K ("Satellite Image Atlas of Glaciers of the World") and their institutional and national affiliations—Continued*

[The institution shown as the affiliation of each author is the location from which the author submitted their contribution to this professional paper. An asterisk behind the name indicates that the author is shown more than once in this list]

Author	Institution	Country
Rajesh Kumar	B.M. Birla Science and Technology Center, Jaipur	India
Mi Deshang	Lanzhou Institute of Glaciology and Cryopedology, Chinese Academy of Sciences	China
David L. Naftz	U.S. Geological Survey	United States
Akio Nagoshi	Nagoya University	Japan
G.A. Nosenko	Institute of Geography, Russian Academy of Sciences	Russia
G.B. Osipova	Institute of Geography, Russian Academy of Sciences	Russia
O.V. Rototaeva	Institute of Geography, Russian Academy of Sciences	Russia
Paul F. Schuster	U.S. Geological Survey	United States
Shi Yafeng	Lanzhou Institute of Glaciology and Cryopedology, Chinese Academy of Sciences	China
John E. Shroder, Jr.	University of Nebraska, Department of Geology and Geography	United States
David D. Susong	U.S. Geological Survey	United States
Shuhei Takenaka	Nagoya University	Japan
Shresth Tayal	The Energy and Resources Institute, New Delhi	India
D.G. Tsvetkov	Institute of Geography, Russian Academy of Sciences	Russia
G.M. Varnakova	Institute of Geography, Russian Academy of Sciences	Russia
O.N. Vinogradov	Institute of Geography, Russian Academy of Sciences	Russia
V.N. Vinogradov	Institute of Geography, Russian Academy of Sciences	Russia
Chander P. Vohra	Geological Survey of India	India
Okitsugu Watanabe	Nagoya University	Japan
M. Williams	University of Cambridge, Scott Polar Research Institute	England, United Kingdom
Yao Tandong	Lanzhou Institute of Glaciology and Cryopedology, Chinese Academy of Sciences	China
Zeng Qunzhu	Lanzhou Institute of Glaciology and Cryopedology, Chinese Academy of Sciences	China
N.M. Zverkova	Institute of Geography, Russian Academy of Sciences	Russia
1386-G		
Jane G. Ferrigno*	U.S. Geological Survey	United States
Stefan L. Hastenrath*	University of Wisconsin, Department of Atmospheric and Ocean Sciences	United States
Ajun Kurter	University of Istanbul, Institute of Marine Sciences and Geography	Turkey
James A.T. Young	University of Edinburgh, Department of Geography	Scotland, United Kingdom
1386-H		
Ian Allison	Australian Antarctic Division	Australia
Trevor J.H. Chinn*	New Zealand Geological Survey, University of Canterbury	New Zealand
James A. Peterson	Monash University, Department of Geography	Australia

Table 1.—*Authors of chapters of the U.S. Geological Survey Professional Paper 1386-A–K ("Satellite Image Atlas of Glaciers of the World") and their institutional and national affiliations—Continued*

[The institution shown as the affiliation of each author is the location from which the author submitted their contribution to this professional paper. An asterisk behind the name indicates that the author is shown more than once in this list]

Author	Institution	Country
1386-I		
Benjamin Morales Arnao	Consult Control S.A.	Perú
Arturo E. Corte	Argentinian Institute of Snow and Ice	Argentina
Stefan L. Hastenrath*	University of Wisconsin, Department of Atmospheric and Ocean Sciences	United States
Ekkehard Jordan	Heinrich-Heine University, Department of Physical Geography	Germany
Louis Lliboutry	Domaine University, Laboratory of Glaciology and Geophysics of the Environment	France
Fabian Hoyos-Patiño	National University of Colombia	Colombia
Carlos Schubert	Venezuelan Institute of Scientific Investigations	Venezuela
1386-J		
John T. Andrews	University of Colorado, Institute of Arctic and Alpine Research	United States
Garry K.C. Clarke	University of British Columbia, Department of Earth and Ocean Sciences	Canada
Daniel B. Fagre	U.S. Geological Survey	United States
Jane G. Ferrigno*	U.S. Geological Survey	United States
Gerald Holdsworth	University of Calgary, Arctic Institute of North America	Canada
Philip J. Howarth	University of Waterloo, Department of Geography	Canada
John D. Jacobs	University of Newfoundland, Department of Geography	Canada
Martin O. Jeffries*	University of Alaska Fairbanks, Geophysical Institute	United States
Carl H. Key	U.S. Geological Survey	United States
Roy M. Koerner	Geological Survey of Canada	Canada
Robert M. Krimmel*	U.S. Geological Survey	United States
Richard K. Menicke	U.S. National Park Service	United States
C. Simon L. Ommanney	International Glaciological Society/National Hydrology Research Centre	England, United Kingdom/Canada
Robert W. Sidjak	University of Northern British Columbia	Canada
Roger D. Wheate	University of Northern British Columbia	Canada
Garnet T. Whyte	University of Northern British Columbia	Canada
Sidney E. White	Ohio State University, Department of Geological Sciences	United States
Richard S. Williams, Jr.*	U.S. Geological Survey	United States
1386-K		
Robert M. Krimmel*	U.S. Geological Survey	United States
William F. Manley	University of Colorado, Center for Geochronological Research	United States
Rod S. March	U.S. Geological Survey	United States
Bruce F. Molnia	U.S. Geological Survey	United States
Dennis C. Trabant	U.S. Geological Survey	United States

TABLE 2.—*Technical reviewers of chapters of U.S. Geological Survey Professional Paper 1386-A–K ("Satellite Image Atlas of Glaciers of the World") and their institutional affiliations*

[The institution shown as the affiliation of each author is the location from which the author submitted their contribution to this professional paper. An asterisk behind the name indicates that the author is shown more than once in this list]

Technical reviewer	Affiliation
1386-A—State of the Earth's Cryosphere at the Beginning of the 21st Century: Glaciers, Global Snow Cover, Floating Ice, and Permafrost and Periglacial Environments	
Richard B. Alley	Pennsylvania State University, Department of Geosciences
Raymond A. Assel	National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory
Spyros Beltaos	Environment Canada, National Water Research Institute
Michael P. Bishop	University of Nebraska, Department of Geology and Geography
James G. Bockheim	University of Wisconsin-Madison, Department of Soil Science
Raymond S. Bradley	University of Massachusetts, Department of Geosciences
Roger Colony	University of Alaska Fairbanks, International Arctic Research Center
Aiguo Dai	National Center for Atmospheric Research (Boulder, Colorado)
Peter T. Doran	University of Illinois, Department of Earth and Environmental Sciences
Andrew G. Fountain	Portland State University, Departments of Geology and Geography
Wilfried Haeberli*	University of Zürich-Irchel, Physical Geography Division (Switzerland)
Dorothy K. Hall*	National Aeronautics and Space Administration, Goddard Space Flight Center, Cryospheric Sciences Laboratory
Stefan L. Hastenrath*	University of Wisconsin, Department of Atmospheric and Ocean Sciences
Andreas Kääb	University of Oslo, Department of Geosciences (Norway)
C. Simon L. Ommanney	Unaffiliated glaciologist (Glenwood, Nova Scotia)
Frank Paul	University of Zürich-Irchel, Physical Geography Division (Switzerland)
Elizabeth Pendleton	U.S. Geological Survey
C. Wylie Poag	U.S. Geological Survey
Terry D. Prowse	University of Victoria, Department of Geography (Canada)
Oddur Sigurðsson	Icelandic Meteorological Office, Hydrological Service
Laurence C. Smith	University of California at Los Angeles, Department of Geography
Konstantin Y. Vinnikov	University of Maryland, Department of Meteorology
H. Jesse Walker	Louisiana State University, Department of Geography and Anthropology
S. Jeffress Williams	U.S. Geological Survey
1386-B—Antarctica	
Colin B.B. Bull	unaffiliated glaciologist (Bainbridge Island, Washington)
Tony K. Meunier	U.S. Geological Survey
John F. Splettstoesser	Unaffiliated glaciologist (Spruce Head, Maine)
1386-C—Greenland	
Carl S. Benson	University of Alaska Fairbanks, Geophysical Institute
Robert A. Bindschadler	National Aeronautics and Space Administration, Goddard Space Flight Center, Cryospheric Sciences Laboratory
Dorothy K. Hall*	National Aeronautics and Space Administration, Goddard Space Flight Center, Cryospheric Sciences Laboratory
Robert M. Krimmel*	U.S. Geological Survey

TABLE 2.—*Technical reviewers of chapters of U.S. Geological Survey Professional Paper 1386-A–K ("Satellite Image Atlas of Glaciers of the World") and their institutional affiliations—Continued*

[The institution shown as the affiliation of each author is the location from which the author submitted their contribution to this professional paper. An asterisk behind the name indicates that the author is shown more than once in this list]

Technical reviewer	Affiliation
David Sugden	University of Edinburgh, School of Geosciences (Scotland, United Kingdom)
Charles W.M. Swithinbank	British Antarctic Survey/Scott Polar Research Institute (England, United Kingdom)
Stuart Watt	Geological Survey of Denmark and Greenland
1386-D—Glaciers of Iceland	
See Acknowledgments in Chapter D	
1386-E—Glaciers of Europe	
Jonas Åkerman	University of Lund, Department of Physical Geography and Ecosystems Analysis (Sweden)
Julian A. Dowdeswell	University of Cambridge, Scott Polar Research Institute (England, United Kingdom)
Wilfried Haeberli*	University of Zürich-Irchel, Physical Geography Division (Switzerland)
Jon Øve Hagen*	University of Oslo, Department of Geosciences (Norway)
Gunnar Hoppe	Unaffiliated glaciologist (Solna, Sweden)
Wibjörn Karlén	Stockholm University, Department of Physical Geography (Sweden)
Gunnar Østrem	Norwegian Water Resources and Energy Administration
Gernot Patzelt	University of Innsbruck, Institute of High Mountain Research (Austria)
Valter Schytt	Stockholm University, Department of Physical Geography (Sweden)
Harald Svensson	University of Copenhagen, Institute of Geography (Denmark)
François Taillefer	University of Toulouse, Institute of Geography (France)
Jean-Pierre Tinay	University of Pau and the District of L'Adour (France)
Robert Vivian	University of Grenoble, Institute of Alpine Geography (France)
Anker Weidick	Geological Survey of Denmark and Greenland
1386-F—Glaciers of Asia	
Yutaka Ageta	Nagoya University, Graduate School of Environmental Studies (Japan)
Vladimir B. Aizen	University of Idaho, Department of Geography
John T. Andrews	University of Colorado, Institute for Arctic and Alpine Research
Richard L. Armstrong	University of Colorado, Boulder, National Snow and Ice Data Center
Yves Arnaud	Laboratory of Glaciology and Geophysics of the Environment, Domaine University (France)
L. DeWayne Cecil	U.S. Geological Survey
Mark Dyurgerov	University of Colorado, Institute for Arctic and Alpine Research
D.R. Gurung	Bhutan Department of Geology and Mines
Jon Øve Hagen*	University of Oslo, Department of Geosciences (Norway)
L. Flint Hall	Idaho Department of Environmental Quality
Gordon Hamilton	University of Maine, Climate Change Institute
Herman Häusler	University of Vienna, Center for Earth Sciences (Austria)
Kenneth Hewitt	Wilfrid Laurier University, Department of Geography and Environmental Studies (Canada)
Jianli Song	U.S. Geological Survey
Andreas Kääb	University of Oslo, Department of Geosciences (Norway)
Ulrich Kamp	University of Montana, Department of Geography

TABLE 2.—*Technical reviewers of chapters of U.S. Geological Survey Professional Paper 1386-A–K ("Satellite Image Atlas of Glaciers of the World") and their institutional affiliations—Continued*

[The institution shown as the affiliation of each author is the location from which the author submitted their contribution to this professional paper. An asterisk behind the name indicates that the author is shown more than once in this list]

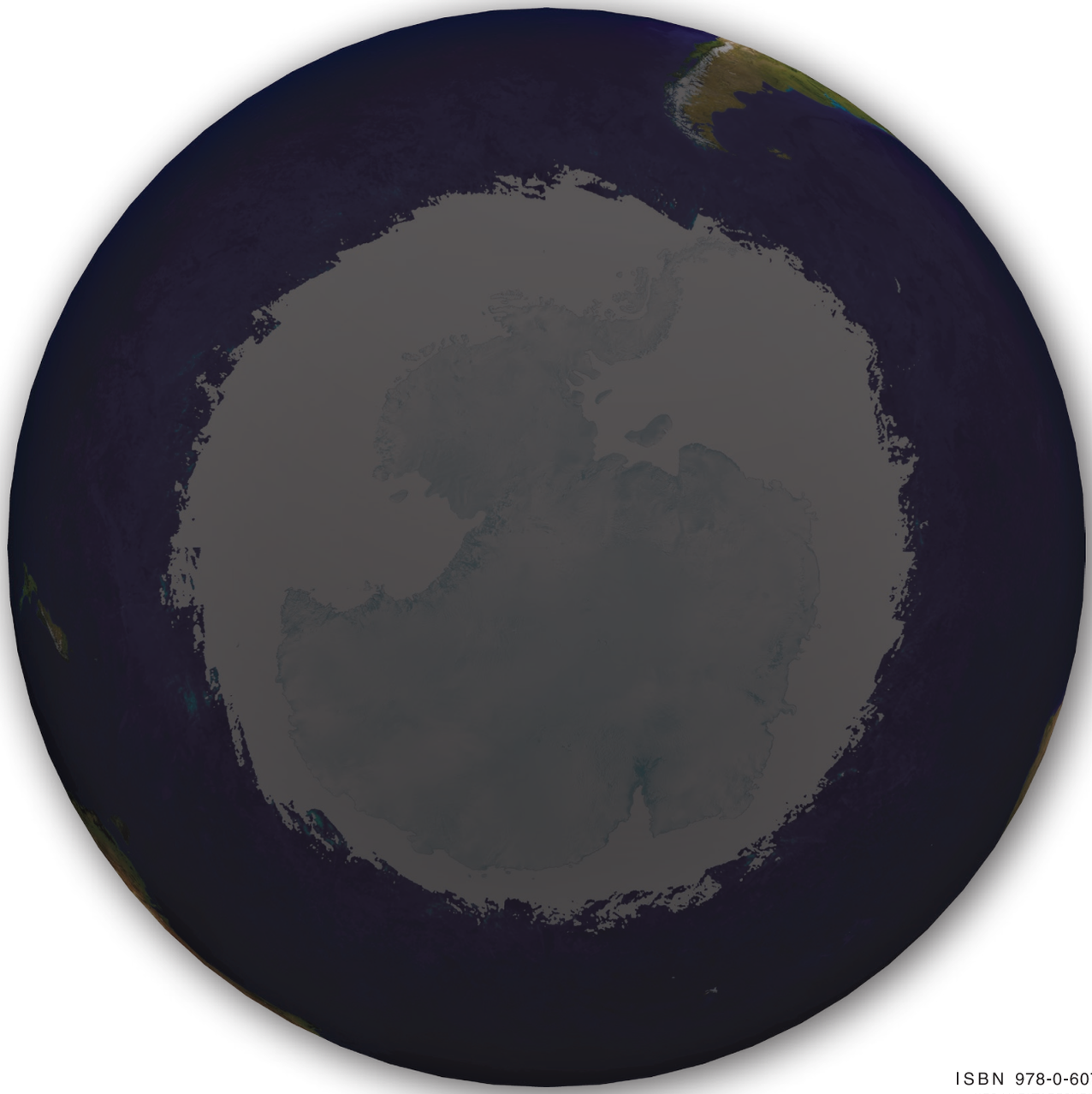
Technical reviewer	Affiliation
V.I. Kravtsova	Moscow State University, Faculty of Geography (Russia)
Robert M. Krimmel*	U.S. Geological Survey
Karl Kreutz	University of Maine, Climate Change Institute
Li Jun	National Aeronautics and Space Administration, Goddard Space Flight Center
Nozomu Naito	Hiroshima Institute of Technology, Department of Environmental Information Studies (Japan)
Masayoshi Nakawo	Research Institute for Humanity and Nature (Kyoto, Japan)
Mitchell A. Plummer	Idaho National Laboratory
Charles F. Raymond	University of Washington, Department of Earth and Space Sciences
John F. Shroder*	University of Nebraska at Omaha, Department of Geography and Geology
Patrick Wagnon	Domaine University, Laboratory of Glaciology and Geophysics of the Environment (France)
1386-G—Glaciers of the Middle East and Africa	
Attila Kilinç	University of Cincinatti, Department of Geology
Wendelin Klaer	University of Mainz, Institute of Geography (Germany)
Daniel B. Krinsley	U.S. Geological Survey
Phillip D. Kruss	World Meteorological Organization (Switzerland)
Celia K. Nyamweru	St. Lawrence University, Department of Anthropology
John F. Shroder, Jr.*	University of Nebraska at Omaha, Department of Geography and Geology
Lonnie G. Thompson*	Ohio State University, Byrd Polar Research Center
1386-H—Glaciers of Irian Jaya, Indonesia, and New Zealand	
Stephen C. Porter	University of Washington, Quaternary Research Center
Uwe Radok	unaffiliated glaciologist (Australia)
1386-I—Glaciers of South America	
Masamu Aniya	University of Tsukuba, Institute of Geoscience (Japan)
Norman G. Banks	U.S. Geological Survey
Gino Cassasa	Center for Scientific Studies (Valdiva, Chile)
George E. Erickson	U.S. Geological Survey
Lydia Espizúa	Institute for the Study of Snow, Glaciers, and Environmental Sciences of Argentina
Robert F. Giegengack	University of Pennsylvania, Department of Earth and Environmental Science
Kurt Graf	University of Zürich-Irchel, Physical Geography Division (Switzerland)
Wilfried Haeberli*	University of Zürich-Irchel, Physical Geography Division (Switzerland)
Stephan L. Hastenrath*	University of Wisconsin, Department of Atmospheric and Ocean Sciences
Ekkehard Jordan	University of Heinrich-Heine, Institute of Physical Geography (Germany)
Robert M. Krimmel*	U.S. Geological Survey
Louis Lliboutry	Domaine University, Laboratory of Glaciology and Geophysics of the Environment (France)
Charles Porter	Unaffiliated geologist (Damariscotta, Maine)
Louis Reynaud	Domaine University, Laboratory of Glaciology and Geophysics of the Environment (France)
Andrés Rivera	University of Chile, Department of Geography

Table 2.—*Technical reviewers of chapters of U.S. Geological Survey Professional Paper 1386-A–K ("Satellite Image Atlas of Glaciers of the World") and their institutional affiliations—Continued*

[The institution shown as the affiliation of each author is the location from which the author submitted their contribution to this professional paper. An asterisk behind the name indicates that the author is shown more than once in this list]

Technical reviewer	Affiliation
Antonio V. Segovia	University of Maryland, Department of Geology
Pedro Skvarca	Antarctic Institute of Argentina
Lonnie G. Thompson*	Ohio State University, Byrd Polar Research Center
Jean-Claude Thouret	University of Grenoble, Institute of Alpine Geography (France)
1386-J—Glaciers of North America	
J. Platt Bradbury	U.S. Geological Survey
George H. Denton	University of Maine, Department of Geological Sciences
John England	University of Alberta, Department of Earth and Atmospheric Sciences (Canada)
George Falconer	Unaffiliated glaciologist (Sidney, British Columbia)
Claus Siebe Grabach	National Autonomous University of México, Institute of Geophysics
Hugo Delgado Granados	National Autonomous University of México, Institute of Geophysics
Calvin J. Heusser	Columbia University, Earth Institute
Roger LeB. Hooke	Unaffiliated glaciologist (Deer Island, Maine)
Tavi Murray	Swansea University, School of Geography (England)
W.S.B. Paterson	Paterson Geophysics, Inc. (Heriot Bay, British Columbia)
José Luís Macias Vázquez	National Autonomous University of México, Institute of Geophysics
1386-K—Glaciers of Alaska	
Anthony A. Arendt	University of Alaska Fairbanks, Geophysical Institute
C Suzanne Brown	U.S. Geological Survey
Parker E. Calkin	University of Colorado, Institute for Arctic and Alpine Research
Keith Echelmeyer	University of Alaska Fairbanks, Geophysical Institute
William D. Harrison	University of Alaska Fairbanks, Geophysical Institute
Robert M. Krimmel*	U.S. Geological Survey
Mark F. Meier	University of Colorado, Institute for Arctic and Alpine Research
Austin Post	U.S. Geological Survey
Dennis C. Trabant	U.S. Geological Survey

CONTENTS: Major Sections



ISBN 978-0-607-98287-9