Glaciers of North America–

GLACIERS OF ALASKA

By BRUCE F. MOLNIA

With sections on COLUMBIA AND HUBBARD TIDEWATER GLACIERS
By ROBERT M. KRIMMEL

THE 1986 AND 2002 TEMPORARY CLOSURES OF RUSSELL FIORD BY THE HUBBARD GLACIER
By BRUCE F. MOLNIA, DENNIS C. TRABANT, ROD S. MARCH, *and* ROBERT M. KRIMMEL

GEOSPATIAL INVENTORY AND ANALYSIS OF GLACIERS: A CASE STUDY FOR THE EASTERN ALASKA RANGE
By WILLIAM F. MANLEY

SATELLITE IMAGE ATLAS OF THE GLACIERS OF THE WORLD

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

U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 1386–K

About 5 percent (about 75,000 km^2) of Alaska is presently glacierized, including 11 mountain ranges, 1 large island, an island chain, and 1 archipelago. The total number of glaciers in Alaska is estimated at >100,000, including many active and former tidewater glaciers. Glaciers in every mountain range and island group are experiencing significant retreat, thinning, and (or) stagnation, especially those at lower elevations, a process that began by the middle of the 19th century. In southeastern Alaska and western Canada, 205 glaciers have a history of surging; in the same region, at least 53 present and 7 former large ice-dammed lakes have produced jökulhlaups (glacier-outburst floods). Ice-capped Alaska volcanoes also have the potential for jökulhlaups caused by subglacier volcanic and geothermal activity. Satellite remote sensing provides the only practical means of monitoring regional changes in glaciers in response to short- and long-term changes in the maritime and continental climates of Alaska. Geospatial analysis is used to define selected glaciological parameters in the eastern part of the Alaska Range.

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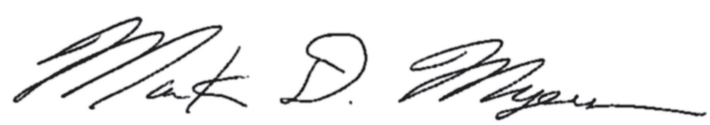
Foreword

On 23 July 1972, the first Earth Resources Technology Satellite (ERTS 1 or Landsat 1) was successfully placed in orbit. The success of Landsat inaugurated a new era in satisfying mankind's desire to better understand the dynamic world upon which we live. Space-based observations have become an essential means for monitoring global environmental changes.

The short- and long-term cumulative effects of processes that cause significant changes on the Earth's surface can be documented and studied by repetitive Landsat and other satellite images. Such images provide a permanent historical record of the surface of the planet; 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 1970's distribution of glaciers on the planet. As images become available from future satellites, the new data will be used to document global changes in glacier extent by reference to the baseline Landsat image record of the 1970's.

Although many geological processes take centuries or even millennia to 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 a worldwide impact and often are interrelated. Explosive volcanic eruptions, such as the 1991 Mount Pinatubo, Philippines, eruption, can produce dramatic 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 our ability to assess changes caused by these processes develops further, we will learn how to use indicators of global change, such as glacier variation, to manage more wisely the use of our finite land and water resources. This USGS Professional Paper series is an excellent example of the way in which we can use technology to provide needed earth-science information about our planet. 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 earth-science problems on a global basis.



Mark D. Myers,
Director,
U.S. Geological Survey

Preface

This chapter is the eighth chapter to be released in U.S. Geological Survey Professional Paper 1386, Satellite Image Atlas of Glaciers of the World, a series of 11 chapters. In each chapter, remotely sensed images, primarily from the Landsat 1, 2, and 3 series of spacecraft, are used to study the glacierized regions of our planet and to monitor glacier changes. Landsat images, acquired primarily during the middle to late 1970s, were used by an international team of glaciologists and other scientists to study various geographic regions or to discuss glaciological topics. In each geographic region, the present areal distribution of glaciers is compared, wherever possible, with historical information about their past extent. The atlas provides an accurate regional inventory of the areal extent of glacier ice on our planet during the 1970s as part of a growing international scientific effort to measure global environmental change on the Earth's surface.

This chapter is divided into three parts: Part I, Background and History; Part II, Glaciological Topics; and Part III, Regional Distribution of Alaska Glaciers. Glaciers in Alaska are located on 11 mountain ranges, 1 large island, an island chain, and 1 archipelago. The total number of glaciers is estimated to be >100,000, <700 of which are named.

The total glacierized area is about 75,000 km^2: Coast Mountains, ~10,500 km^2; Alexander Archipelago, <150 km^2; St. Elias Mountains, ~11,800 km^2; Chugach Mountains, ~21,600 km^2; Kenai Mountains, ~4,600 km^2; Kodiak Island, <15 km^2; Aleutian Range, ~1,250 km^2; Aleutian Islands, ~960 km^2; Wrangell Mountains, ~8,300 km^2; Talkeetna Mountains, ~800 km^2; Alaska Range, ~13,900 km^2; Wood River Mountains, <230 km^2; Kigluaik Mountains, <3 km^2; and Brooks Range, 723 km^2.

Since the middle of the 19th century, when the "Little Ice Age" began to wane, glaciers, especially those at lower elevations, have been retreating and thinning, although each of the glacierized areas has had a different response in terms of timing, magnitude, and complexity. Most glaciers at lower elevations (<1,500 m) are retreating, except for about a dozen tidewater and valley glaciers that are advancing. The melting of glacier ice in Alaska is a regional contributor to the continuing rise in eustatic (global) sea level.

In southeastern Alaska and western Canada >200 surge-type glaciers have been documented. Ice-dammed lakes and ice-capped volcanoes have been the source of glacier-outburst floods (jökulhlaups). Satellite and aerial remote sensing and geospatial analysis of maps and remote sensing data are used in this chapter for periodic monitoring and documenting changes in the position of termini and area of glaciers in the 14 glacierized areas of Alaska.

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. Chapter A is a general chapter containing introductory material on the Earth's cryosphere, including a discussion of the physical characteristics, classification, and global distribution of glaciers. The next 10 chapters, B through K, are arranged geographically and present glaciological information from Landsat and other sources of data on each of the geographic areas. Chapter B covers Antarctica; Chapter C, Greenland; Chapter D, Iceland; Chapter E, Continental Europe (except for the European part of the former Soviet Union), including the Alps, the Pyrenees, Norway, Sweden, Svalbard (Norway), and Jan Mayen (Norway); Chapter F, Asia, including the European part of the former Soviet Union, China (P.R.C.), India, Nepal, Bhutan, Afghanistan, and Pakistan; Chapter G, Turkey, Iran, and Africa; Chapter H, Irian Jaya (Indonesia) and New Zealand; Chapter I, South America; and Chapter J, North America (excluding Alaska); and Chapter K, Alaska.

The realization that one element of the Earth's cryosphere, its glaciers, was amenable to global inventorying and monitoring with Landsat images led to the decision, in late 1979, to prepare this Professional Paper, in which 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, a global benchmark or baseline could be established for determining the areal extent of glaciers during a relatively narrow time interval (1972 to 1982). This global "snapshot" of glacier extent could then be used for comparative analysis with previously published maps and aerial photographs and with new maps, satellite images, and aerial photographs in order to determine the areal fluctuation of glaciers in response to natural or culturally induced changes in the Earth's climate.

To accomplish this objective, optimum Landsat images of each of the glacierized regions of our planet were selected from the Landsat image data base at the EROS Data Center in Sioux Falls, S. Dak., 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. Between 1979 and 1981, these optimum images were distributed to an international team of more than 50 scientists who agreed to write a section of the Professional Paper concerning either a geographic area or a glaciological topic. 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 area and to compare their present areal distribution with historical information (for example, from published maps, reports, and photographs) about their past extent. Completion of this atlas will provide an accurate regional inventory of the areal extent of glaciers on our planet during the 1970s.

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

CONTENTS: Major Sections

ACRONYMS

AAAS	American Association for the Advancement of Science
AAR	accumulation area ratio
AHAP	Alaska High-Altitude Aerial Photography
AGS	American Geographical Society
amsl	above mean sea level
AMS	U.S. Army Map Service
ASTER	Advanced Spaceborne Thermal Emission and Reflection
BGN	Board on Geographic Names
BLM	U.S. Bureau of Land Management
B.P.	before present
C&GS	U.S. Coast and Geodetic Survey
CMMB	Central Medial Moraine Band
CTD	conductivity, temperature, and depth
DEM	digital elevation model
DLG	digital line graph
DMA	U.S. Defense Mapping Agency
DRG	digital raster graphic
EDC	EROS Data Center
ELA	equilibrium line altitude
ETM+	Enhanced Thematic Mapper Plus
EROS	Earth Resources Observation and Science
ERTS	Earth Resources Technology Satellite
GIS	Geographic Information System
GLIMS	Global Land Ice Measurements from Space
GNIS	Geographic Names Information System
GPS	Global Positioning System
HY	Hydrologic Year
IBC	International Boundary Commission
IGY	International Geophysical Year
IHD	International Hydrologic Decade
InSAR	Interferometric Synthetic Aperture Radar
INSTAAR	Institute of Arctic and Alpine Research
IPR	ice-penetrating radar
MODIS	Moderate Resolution Imaging Spectroradiometer
MSS	Multispectral Scanner System
NASA	National Aeronautics and Space Administration
NED	National Elevation Dataset
NGA	National Geospatial-Intelligence Agency
NGS	National Geographic Society
NIMA	National Imagery and Mapping Agency
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Survey
NPS	National Park Service
NSF	National Science Foundation
RBV	Return Beam Vidicon
RMSE	root mean square error
SAR	synthetic aperture radar
SLAR	side-looking airborne radar
TM	Thematic Mapper
UNESCO	United Nations Educational, Scientific and Cultural Organization
USC&GS	U.S. Coast and Geodetic Survey
USAF	United States Air Force
USFS	United States Forest Service
USGS	U.S. Geological Survey
USN	United States Navy
UTM	Universal Transverse Mercator

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