GLACIERS OF ASIA

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–F

Landsat images, other satellite images, and other data are used to discuss the geographic distribution of ice caps, outlet glaciers, valley glaciers and other glaciers in Asia, and glaciological hazards in the Himalaya

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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 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 and studied by repetitive Landsat and other satellite images. 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 1970s distribution of glaciers on our 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 10-year period 1972 to 1981.

Although many geological processes take centuries or even millenia 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 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 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 Professional Paper 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-System-science problems on a global basis.

Marcia K. McNutt
Director
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Preface

This chapter is the ninth 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 of the geographic area chapters, remotely sensed images, primarily from the Landsat 1, 2, and 3 series of spacecraft, are used to analyze the specific glacierized region of our planet under consideration and to monitor glacier changes. Landsat images, acquired primarily during the middle to late 1970s and early 1980s, were used by an international team of glaciologists and other scientists to study various geographic regions and (or) to discuss related glaciological topics. In each glacierized 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.

The chapter is divided into seven geographic parts and one topical part: Glaciers of the Former Soviet Union (F–1), Glaciers of China (F–2), Glaciers of Afghanistan (F–3), Glaciers of Pakistan (F–4), Glaciers of India (F–5), Glaciers of Nepal (F–6), Glaciers of Bhutan (F–7), and the Paleoenvironmental Record Preserved in Middle-Latitude, High-Mountain Glaciers (F–8). Each geographic section describes the glacier extent during the 1970s and 1980s, the benchmark time period (1972–1981) of this volume, but has been updated to include more recent information.

Glaciers of the Former Soviet Union are located in the Russian Arctic and various mountain ranges of Russia and the Republics of Georgia, Kyrgyzstan, Tajikistan, and Kazakstun. The Glacier Inventory of the USSR and the World Atlas of Ice and Snow Resources recorded a total of 28,881 glaciers covering an area of 78,938 square kilometers (km^2).

China includes many of the mountain-glacier systems of the world including the Himalaya, Karakorum, Tien Shan and Altay mountain ranges. The glaciers are widely scattered and cover an area of about 59,425 km^2. The mountain glaciers may be classified as maritime, subcontinental or extreme continental.

In Afghanistan, more than 3,000 small glaciers occur in the Hindu Kush and Pamir mountains. Most glaciers occur on north-facing slopes shaded by mountain peaks and on east and southeast slopes that are shaded by monsoon clouds. The glaciers provide vital water resources to the region and cover an area of about 2,700 km^2.

Glaciers of northern Pakistan are some of the largest and longest mid-latitude glaciers on Earth. They are located in the Hindu Kush, Himalaya, and Karakoram mountains and cover an area of about 15,000 km^2. Glaciers here are important for their role in providing water resources and their hazard potential.

The glaciers in India are located in the Himalaya and cover about 8,500 km^2. The Himalaya contains one of the largest reservoirs of snow and ice outside the polar regions. The glaciers are a major source of fresh water and supply meltwater to all the rivers in northern India, thereby affecting the quality of life of millions of people.

In Nepal, the glaciers are located in the Himalaya as individual glaciers; the glacierized area covers about 5,324 km^2. The region is the highest mountainous region on Earth and includes the Mt. Everest region.

Glaciers in the Bhutan Himalaya have a total area of about 1,317 km^2. Many recent glacier studies are focused on glacier lakes that have the potential of generating dangerous glacier lake outburst floods.

Research on the glaciers of the middle-latitude, high-mountain glaciers of Asia has also focused on the information contained in the ice cores from the glaciers. This information helps in the reconstruction of paleoclimatic records, and the computer modeling of global climate change.

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 provides a comprehensive, yet concise, 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 "Map/Poster of the Earth's Dynamic Cryosphere," and 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 arranged geographically and 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 (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, Afghanistan, Pakistan, India, Nepal, and Bhutan; 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, 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 could be established for determining the areal extent of glaciers during a relatively narrow time interval (1972 to 1981). 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 to determine the areal fluctuation of glaciers in response to natural or culturally induced changes in the Earth's climate.

To accomplish this objective, the editors selected optimum Landsat images of each of the glacierized regions of our planet from the Landsat image data base at the 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. 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. The total number of scientists who made contributions eventually reached 109. 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.

The atlas provides a regional inventory of the areal extent of glaciers on the planet during the 1970s, a period of time, in restrospect (2010), that was cooler climatically than the increasingly warmer period that followed at the end of the 20th century and has continued into the first decade of the 21st century.

Richard S. Williams, Jr.
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Editors

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CONTENTS: Major Sections