Satellite Image Atlas of Glaciers of the World

MIDDLE EAST and AFRICA

United States Geological Survey
Professional Paper 1386–G

An enlargement of a Landsat MSS color-composite image of Kilimanjaro and Mount Meru showing vegetation belts and the distribution of glaciers. See text page G59.

Cover design by Lynn Hulett.

Glaciers of the Middle East and Africa—

G–1. GLACIERS OF TURKEY
By AJUN KURTER

G–2. GLACIERS OF IRAN
By JANE G. FERRIGNO

G–3. GLACIERS OF AFRICA
By JAMES A.T. YOUNG *and* STEFAN HASTENRATH

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–G

Landsat images, in conjunction with aerial photographs, maps, and field measurements, were used to locate and describe the areal distribution of and changes in glaciers in Turkey, Iran, and Africa

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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 global change.

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 images. Such images provide a permanent historical record of the surface of our planet; they also make possible comparative two-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 current 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 image record of the 1970's.

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 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, thereby causing 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 more wisely manage 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-science problems on a global basis.

[Signature]

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Preface

This chapter, consisting of three independently authored subchapters, is the third 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 monitor glacier changes. Landsat images, acquired primarily during the middle to late 1970's, were used by an international team of glaciologists and other scientists to study various geographic areas or discuss glaciological topics. In each geographic area the present areal distribution of glaciers was compared, where 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 1970's as part of a growing international scientific effort to measure global change on the Earth's surface.

In Turkey, present-day glaciers are found in the higher elevations of the Eastern Black Sea Coastal Range, in the Middle and Southeastern Taurus Mountains, and on Mounts Erciyas, Süphan, and Ağrı. The total glacier area is estimated to be 22.9 km². The southeastern Taurus Mountains have the most glaciers. Modern maps, aerial photographs, and Landsat images are used to document the distribution of glaciers in Turkey, although the spatial resolution of the sensors limits the use of Landsat images to the largest glaciers.

In Iran, glaciers occur in the Elburz Mountains, the Zagros Mountains, and Kūhhā-ye Sabālan. The total glacier area is estimated to be 20 km². The largest concentration of glaciers is on the Takht-e Sulaiman massif of the Elburz Mountains. One of the glaciers, Sarchal, is about 7 km long. Five glaciers are present in the Zagros Mountains. Seven glaciers are located on Kūhhā-ye Sabālan. Because of the small size of the glaciers in Iran, Landsat images have only limited usefulness.

In Africa, glaciers are presently limited to two volcanoes, Mount Kenya in Kenya and Kilimanjaro in Tanzania, and one massif, the Ruwenzori, on the border between Uganda and Zaire. Mount Kenya has 11 cirque and valley glaciers totaling 0.7 km² in area. Kilimanjaro has 16 named glaciers and 3 ice fields in the Kibo caldera that total 5 km² in area. The total glacier area in Africa is 10.7 km². No Landsat data were acquired of the Ruwenzori because of persistent cloud cover. Landsat 3 return beam vidicon (RBV) camera images were acceptable for documenting glacier area on the two volcanoes, but vertical aerial photographs combined with field surveys remain the most effective means of monitoring areal changes in the glaciers of Africa. Availability of high-resolution satellite images or photographs would obviate the need for vertical aerial photographs.

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 eleven chapters designated by the letters A through K. Chapter A is a general chapter containing introductory material and a discussion of the physical characteristics, classification, and global distribution of glaciers. The next nine chapters, B through J, 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 Soviet Union), including the Alps, the Pyrenees, Norway, Sweden, Svalbard (Norway), and Jan Mayen (Norway); Chapter F, Asia, including the European part of the Soviet Union, China (P.R.C.), India, Nepal, 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. The final chapter, K, is a topically oriented chapter that presents related glaciological topics.

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 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 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, 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 author 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 1970's.

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

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