GLACIOLOGICAL DATA

REPORT GD-10

GLACIOLOGY IN CHINA

May 1981

Published by:
WORLD DATA CENTER A FOR GLACIOLOGY
[SNOW AND ICE]

Cooperative Institute for Research in Environmental Sciences
University of Colorado
Boulder, Colorado 80309 U.S.A.

Operated for:

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
Environmental Data and Information Service
Boulder, Colorado 80303 U.S.A.

DESCRIPTION OF WORLD DATA CENTERS[1]

WDC-A: Glaciology (Snow and Ice) is one of three international data centers serving the field of glaciology under the guidance of the International Council of Scientific Unions Panel of World Data Centers. It is part of the World Data Center System created by the scientific community in order to promote worldwide exchange and dissemination of geophysical information and data. WDC-A endeavors to be promptly responsive to inquiries from the scientific community, and to provide data and bibliographic services in exchange for copies of publications or data by the participating scientists.

1. The addresses of the three WDCs for Glaciology and of a related Permanent Service are:

World Data Center A
University of Colorado
Campus Box 449
Boulder, Colorado, 80309 U.S.A.

World Data Centre C
Scott Polar Research Institute
Lensfield Road
Cambridge, CB2 1ER, England

World Data Center B
Molodezhnaya 3
Moscow 117 296, USSR

Permanent Service on the Fluctuations of Glaciers - Department of Geography
Swiss Federal Institute of Technology
Sonneggstrasse 5
CH-8092 Zurich, Switzerland

2. Subject Matter

WDCs will collect, store, and disseminate information and data on Glaciology as follows:

Studies of snow and ice, including seasonal snow; glaciers; sea, river, or lake ice; seasonal or perennial ice in the ground; extraterrestrial ice and frost.

Material dealing with the occurrence, properties, processes, and effects of snow and ice, and techniques of observing and analyzing these occurrences, processes, properties, and effects, and ice physics.

Material concerning the effects of present day and snow and ice should be limited to those in which the information on ice itself, or the effect of snow and ice on the physical environment, make up an appreciable portion of the material.

Treatment of snow and ice masses of the historic or geologic past, or paleo-climatic chronologies will be limited to those containing data or techniques which are applicable to existing snow and ice.

3. Description and Form of Data Presentation

3.1 General. WDCs collect, store and are prepared to disseminate raw[+], analyzed, and published data, including photographs. WDC's can advise researchers and institutions on preferred formats for such data submissions. Data dealing with any subject matter listed in (2) above will be accepted. Researchers should be aware that the WDCs are prepared to organize and store data which may be too detailed or bulky for inclusion in published works. It is understood that such data which are submitted to the WDCs will be made available according to guidelines set down by the ICSU Panel on WDCs in this Guide to International Data Exchange. Such material will be available to researchers as copies from the WDC at cost, or if it is not practicable to copy the material, it can be consulted at the WDC. In all cases the person receiving the data will be expected to respect the usual rights, including acknowledgement, of the original investigator.

[1]International Council of Scientific Unions. Panel on World Data Centers. (1979) Guide to International Data Exchange Through the World Data Centres. 4th ed. Washington, D.C. 113 p.

+The lowest level of data useful to other prospective users.

This Guide for Glaciology was prepared by the International Commission on Snow and Ice (ICSI) and was approved by the International Association of Hydrological Sciences (IAHS) in 1978.

3.2 Fluctuations of Glaciers. The Permanent Service is responsible for receiving data on the fluctuations of glaciers. The types of data which should be sent to the Permanent Service are detailed in UNESCO/IASH (1969)*. These data should be sent through National Correspondents in time to be included in the regular reports of the Permanent Service every four years (1964-68, 1968-72, etc.). Publications of the Permanent Service are also available through the WDCs.

3.3 Inventory of Perennial Snow and Ice Masses. A Temporary Technical Secretariat (TTS) was recently established for the completion of this IHD project at the Swiss Federal Institute of Technology in Zurich. Relevant data, preferably in the desired format**, can be sent directly to the TTS or to the World Data Centers for forwarding to the TTS.

3.4 Other International Programs. The World Data Centers are equipped to expedite the exchange of data for ongoing projects such as those of the International Hydrological Project (especially the studies of combined heat, ice and water balances at selected glacier basins***), the International Antarctic Glaciological Project (IAGP), the Greenland Ice Sheet Project (GISP), etc., and for other developing projects in the field of snow and ice.

4. Transmission of Data to the Centers

In order that the WDCs may serve as data and information centers, researchers and institutions are encouraged:

4.1. To send WDCs raw+ or analyzed data in the form of tables, computer tapes, photographs, etc., and reprints of all published papers and public reports which contain glaciological data or data analysis as described under heading (2); one copy should be sent to each WDC or, alternatively, three copies to one WDC for distribution to the other WDCs.

4.2. To notify WDCs of changes in operations involving international glaciological projects, including termination of previously existing stations or major experiments, commencement of new experiments, and important changes in mode of operation.

---

*UNESCO/IASH (1969) Variations of Existing Glaciers. A Guide to International Practices for their Measurement.

**UNESCO/IASH (1970a) Perennial Ice and Snow Masses. A Guide for Compilation and Assemblage of Data for a World Inventory; and

Temporary Technical Secretariat for World Glacier Inventory. Instructions for Compilation and Assemblage of Data for a World Glacier Inventory.

***UNESCO/IASH (1970b) Combined Heat, Ice and Water Balances at Selected Glacier Basins. A Guide for Compilation and Assemblage of Data for Glacier Mass Balance Measurements; and

UNESCO/IASH (1973) Combined Heat, Ice and Water Balances at Selected Glacier Basins. Part II, Specifications, Standards and Data Exchange.

+The lowest level of data useful to other prospective users

FOREWORD

The renewal of scientific links with the People's Republic of China is re-awakening interest in information on the past and present environment of this vast area of eastern Asia. Several exchanges of scientists with expertise in glaciology or related fields have already taken place and in the near future we may anticipate direct collaborative research projects between western and Chinese scientists. To familiarize western scientists with current areas of Chinese activity in this field, and to identify older sources of information that may still be relevant, the Data Center invited Ms. Jane Bradley to prepare a bibliography of publications on glaciological studies in China and Tibet during her recent stay in Cambridge, England. This issue contains the results of her work in the libraries there and also a report prepared by Dr. Troy Péwé on glaciological research in China, following his recent visit to several Chinese institutes. Other communications in this issue report on pictorial representations of glaciers, and ice services provided by the Atmospheric Environment Service, Environment Canada.

Glaciological Data Report GD-11, to be issued in September, will contain the reports and recommendations of the November 1980 Snow Watch Workshop sponsored by the National Science Foundation. A subsequent issue will contain a bibliography on glacier hydrology prepared by the ICSI Working Group on Prediction of Glacier Runoff chaired by Dr. Gordon Young.

We thank our contributors for their submissions, and our staff for their efforts in preparing this publication.

R.G. Barry
Director
World Data Center-A for Glaciology [Snow and Ice]

Ann M. Brennan
Technical Editor

CONTENTS

GLACIOLOGY IN CHINA

Permafrost Research in China*

Troy L. Péwé
Arizona State University
Tempe, Arizona, U.S.A.

This report presents a short historical review of permafrost investigations in China and notes concerning permafrost in institutes and departments of academies, ministries, and universities.

Permafrost Investigations in China from informal discussions with Mr. Tong Boliang of the Institute of Glaciology and Cryopedology, Academia Sinica, Lanzhou, China.

There were no permafrost studies in China until after 1949. The first permafrost investigation was in 1950 in connection with railway construction in northeast China (Manchuria). No background information was available concerning frozen ground problems and the building of the railroads in permafrost terrain; therefore, engineers constructing railroads encountered many difficulties. Because of these problems, a study group on permafrost problems was established within the Ministry of Railways.

Also in the 1950's, a highway was constructed to Tibet and permafrost was encountered. The construction problems were not too severe because it was only a pioneer gravel road.

In the 1960's, there were additional surveys for railways in the northeast. Also at this time the surveying for railways into Tibet started. Permafrost then began to be investigated by scientists connected with the Academia Sinica. The railway project was purported to be the first large-scale permafrost study.

It was also in the 1960's that work in permafrost began to be expanded, especially in the Academia Sinica, with consideration of permafrost problems involving water supply and coal mining. There was a better understanding of such problems throughout the 1960's into the 1970's. As work with permafrost increased, the organization reponsible for permafrost studies in the Academia Sinica was the Institute of Geography. Problems of permafrost were also being studied in the Engineering and Construction Institute of the Academy.

Studies in permafrost also began to be considered by scientists at the universities, and in 1963-64, personnel at the University of Lanzhou began to do research in this field. Since 1963-64 the University of Lanzhou has had a permafrost course.

In the early 1970's, most permafrost information was needed in the mining and railway industries, as well as in general construction. Most of this information was needed for the area lying north of the Yellow River. In 1974, there began the second large survey for a railroad into Tibet. This survey is still actively underway. Since then, there has been a base camp, or what might be called a permafrost field station, on the Tibet Plateau under the aegis of the China Academy of Railway Sciences.

In regard to railways and general construction, permafrost work seems, at present, to be divided as follows; questions dealing with foundation and frost heaving, are primarily studied under the Construction Ministry; the study of railroads and associated structures on permafrost is coordinated under the Ministry of Railroads; permafrost work in the Academia Sinica at the Lanzhou Institute of Glaciology and Cryopedology undertakes more of the basic studies on the properties of frozen ground. Lanzhou provides basic engineering and scientific information to the two ministries mentioned earlier. Information on frost heaving and hydraulic problems is in great demand.

The first permafrost maps were published by the Lanzhou Institute at a scale of 1:1,000,000. Recently a strip map of permafrost conditions along the Qingzang Highway was published at a scale of 1:500,000. There is reported to be a map at 1:600,000 of part of the Plateau dealing with basic permafrost information for railroad construction.

Permafrost work is increasing in various ministries and institutes associated with the Academia Sinica as well as the universities. Since 1978, the Lanzhou Institute has been designated the Institute of Glaciology and Cryopedology. The first National Conference of Glaciology and Cryopedology met at Lanzhou.

* Reprinted with the author's permission from: China-Tibet Memorandum to the National Academy of Sciences, Polar Research Board, Committee on Permafrost, May-June 1980, 19 p.

Regional permafrost studies are now underway in the northeastern part of China as well as the Tibet Plateau. These studies consider basic information as well as the application of research for highway and railroad construction. Permafrost research is also going on in the Altai Mountains. It is reported that problems of permafrost in ground water are high on the list of research subjects in the Lanzhou Institute.

Since 1978, the Journal of Glaciology and Cryopedology, has been published in Lanzhou. The first issue was printed in 1978 and the second number to Volume I in 1979. English is increasingly used in the publication; in Nos. 1 and 2 of Volume 2, published in 1980, the table of contents is in English. In the Volume 2, No. 3, English abstracts are provided with the journal articles.

In summary, it can be stated that increased effort is being put into the scientific and engineering studies of perennially frozen ground in China. In the Lanzhou Institute of Glaciology and Cryopedology there are now more than 370 professional and support staff; of these, more than 70 are reported to be involved in permafrost work.

A. The Lanzhou Institute of Glaciology and Cryopedology, Academia Sinica

The Lanzhou Institute was developed primarily on the basis of an alpine ice and snow utilization team organized by Academia Sinica in 1958. Its first task was the investigation of mountain glaciers in northwestern China. In 1960 the research work of permafrost was added. In 1962, the organization was changed into the Division of Glaciology and Cryopedology, Institute of Geography, Academia Sinica. It investigated mountain glaciers in west China, the permafrost of the Qinghai-Xizang (Tibet) Plateau, and hydrology of arid regions in northwestern China. In 1964, the study of mud-rock flow was also begun. In 1965, the Division of Glaciology and Cryopedology amalgamated with the Division of Desert Research from Peking, forming the Institute of Glaciology, Cryopedology and Desert Research, Academia Sinica, which carried on scientific studies on glaciers, frozen ground, deserts, and mud-rock flow. In June 1978, the Division of Desert Research became an independent institute, and the remainder formed the Institute of Glaciology and Cryopedology. This Institute has seven research divisions: glaciology, cryopedology, mud-rock flow research, surveying and mapping, material analysis, remote sensing, and investigation technique. Additionally, the Seepage Mechanics Research Office is temporarily attached to the Insitute.

The principal areas of research are:

1. Glaciology. The Institute of Glaciology and Cryopedology mainly studies the distribution, variation, and natural resources of ice and snow in China. Since 1958, the areas investigated include the glaciers of the Qilian Shan, Tian Shan, Mt. Qomolangma (Mount Everest) and Mt. Xixiabangma of the Himalayas and other alpine regions of the Qinghai-Xizang (Tibet) Plateau. Research has also been done on preventive measures against avalanches and snow drift in the Tian Shan, and the mechanics of ice jamming on the Yellow River. Since 1974, research work has been done on the glacier variations in the Karakoram in order to repair damaged sections of the China-Pakistan Highway, and also in the Qilian Shan to effectively utilize the water resources for the promotion of agriculture in the Kansu Corridor. New achievements have been made on forecasting the advance and retreat of glaciers. In recent years, with the help of aerial photos and large scale topographic maps, and in accordance with the specified requirements of the International Glacier Inventory Program, nearly 3,000 glaciers in the Qilian Shan have been properly inventoried. Progress has been made in the fields of glacial hydrology, the relations between glaciers and climate, glacial sedimentation, Quaternary glaciation, and climatic variations.

2. Permafrost. Studies are proceeding on the formation, development, changing tendency, and the prevention of damages to permafrost under natural and artificial conditions along the Qinghai-Xizang highway, in several coal mining districts of the Qilian Shan, and also in areas in northeast China. In recent years, the Institute has taken up research work on the distribution, thermal properties, and the mechanics of permafrost along the Qinghai-Xizang Highway and prepared a report on fundamental parameters and other data to support modifications of railway design. Additionally, investigation of frozen ground through the Tian Shan has begun for the Southern Sinkiang Railway.

Frozen soil mechanics (including frozen soil rheology, frozen upheaval forces, frozen strength, thawing settlement), frozen soil heat (frozen soil heat conductivity, water migration, change in temperature field, etc.), ground ice, seasonal frozen soil, and other fields have also been studied. Recently, a map of permafrost distribution along the Qingzang Highway, at a scale of 1:500,000, has been compiled, adding to our understanding of the characteristics of permafrost on the Plateau.

3. Mud-rock Flow. The Institute studies glacial mud-rock flow and the characteristics, distribution, formation, development of, and preventive measures against, mud-rock flow. In recent years, scientists investigated the mud-rock flow along the Sichuan-Xizang Highway and in Dongchuan of Yunnan, Gansu, and the northwest provinces. Preventative projects have been suggested for the engineering works of various plants, mines, factories, and highway buildings.

4. Surveying and Mapping. Mapping by terrestrial stereophotogrammetry is employed in the study of glaciers, permafrost, and mud-rock flow. Maps of the Qomolangma (Mount Everest) region have been completed at a scale of 1:500,000. Other completed maps include the 1:60,000 maps of the Batura glacier region in the Karakoram, the 1:200,000 maps of Tomol Peak in the Tian Shan, as well as surveying and mapping work in several other districts.

5. Material Analysis. The material composition of sediments in cold regions and trace elements in snow and ice are analyzed in order to supply quantitative analytical data for the study of glaciology and cryopedology.

6. Remote Sensing and Telementry. In recent years, a quartz crystal thermometer was made and employed, and a radio telemetry system is beginning to be used. Satellite images and aerial photos are being applied to the analysis of changes in glaciers, snow, and permafrost, the estimation of snow and ice resources, and the forecast of snowmelt runoff.

B. China Academy of Railway Sciences

One of the major industries of China is the railway industry. A good network of railways extends through eastern and central China and is slowly progressing to the far northeast; plans are underway to extend into Tibet. All work connected with the railways is supervised by the Ministry of Railways. In 1950, the Railway Research Institute began; it had 50 employees at that time. By 1956, it had 560 employees. It has continued to grow very rapidly and is now a many faceted institute of the Ministry of Railways. This institute, now called the China Academy of Railway Sciences, has grown to have sixty departments in the Peking area. In addition, it has six railway departments outside of Peking, including one in Lanzhou.

The Academy of Railway Sciences has 6,500 employees in research and technology. The main studies are: (1) traffic, (2) construction, and (3) rolling stock. About one-third of the research done deals with construction, including roadbeds, bridges, and tunnels. There is a test railroad circle nine miles north of Peking where field research is undertaken.

The Academy of Railway Sciences probably has more engineers interested in the effect of permafrost on construction than any other organization in China. As a sign of this, it can be noted that the exchange program of permafrost scientists and engineers between China and Canada in 1975 was headed by Mr. Li Yu-sheng, who is vice president of the China Academy of Railway Sciences. He also hosted the Canadian delegation during its visit in China in 1977. Mr. Li led the delegation of Chinese scientists and engineers to the Third International Permafrost Conference in Edmonton in 1978.

C. The Geomorphology Group at the University of Peking

The University of Peking has about 6,000 students and is about 80 years old. The Department of Geography has 18 scientists. There are five geomorphologists in the Division of Physical Geography. Several of the scientists are interested in periglacial work and the most active person appears to be Associate Professor Tswei Chi-kiu, who works on the Tibet Plateau in the field of geomorphology and periglacial phenomena. Since 1975, some of the geomorphologists from the University have been working near Lhasa.

Some of the phenomena studied on the Plateau have been seasonal "pingos," which are probably frost blisters. Also, they have made observations and reports on ice segregations and stone stripes at elevations of 6,000 m. They study such phenomena as aufeis, solifluction, and inactive periglacial features, such as stone rings, which appear in central Tibet at 1,900 m. The geomorphologists further report that in northeast China, near the border with the USSR, inactive polygons occur at an elevation of 2,700 m. In northeast China when the vegetation is removed for construction there is slumping as the ice melts in the perennially frozen ground.

Chinese Snow and Ice Bibliography

Jane E. Bradley
18 Juniper Lane
Amherst, Massachusetts, U.S.A.

Introduction

This bibliography results primarily from a search for Chinese glaciological studies in the following libraries:

1. Scott Polar Research Institute, Cambridge, England

2. East Asian History of Science Library, Cambridge, England.

These two libraries were most useful because they contain catalogs of material organized by subject, which greatly facilitated the location of pertinent literature. Additional searches were made of the British Library located in the British Museum, London, and the Cambridge University Library. Although the British Library has a subject catalog on microfilm in their Department of Oriental Manuscripts, a survey yielded little in the way of relevant material. Also, little was obtained from the extensive University Library in Cambridge, due to the lack of subject categories. However, both libraries do have extensive holdings in Chinese geological and geographical journals and there is the potential for improving this bibliography by careful investigation of these sources. In addition, further sources may be unearthed from the reference lists of Chinese language articles cited in this bibliography, some of which were not available for examination by this author. For a detailed bibliography of Chinese periodicals in the British Isles see:

London. University. Contemporary China Institute (1975) A Bibliography of Chinese Newspapers and Periodicals in European Libraries. New York, Cambridge, Cambridge University Press, 1025 p.

British Museum (1965) Chinese Periodicals in British Libraries. London, British Museum, Handlist no. 2.

The Scott Polar Research Institute in Lensfield Road, Cambridge, concentrates on polar studies but also covers glacial studies in alpine regions of the world. The Library has a detailed and comprehensive subject card index which includes articles in journals relevant to the library. Their coverage of the field is quite extensive and accounts for approximately 70 percent of this bibliography.

The other major library source is the East Asian History of Science Library, Cambridge. This unique library has grown since 1942 around the collection of Dr. Joseph Needham, F.R.S., F.B.A., from sources both in China and the West. Dr. Needham and some twenty collaborators are working on a multivolume publication, Science and Civilization in China, a project covering all aspects of Chinese science through time. Volume 1 in the series was published in 1954 and Volume 5, part 5 has just appeared. This unique library generously allowed me to search through their boxes of reprints catalogued under subject headings. Thus, it was relatively simple to locate many useful references, particularly early works in the field by western scientists.

A computer search was also carried out through the Cambridge University Scientific Periodicals Library's computerized bibliographic retrieval system. However, this computer service only covered Geoarchive for the earth sciences, and although every attempt was made to cover all key words relating to glacial studies, the search produced few additional references for the period 1974-1979.

Citations were also added to this bibliography from materials held by the World Data Center-A for Glaciology [Snow and Ice]. Each document which is owned by WDC-A is marked with the "*" symbol. Photocopies of any of these documents can be provided upon request at $.10 per page over 25 pages, $5 minimum.

Although this bibliography is only a brief survey of available literature in the field of glaciology, it will perhaps be helpful to those wishing to make a detailed search of the field. It is perhaps strongest in early work in Chinese glacial studies.

A translation has been made into English of the titles of those works in Chinese, to give some idea of the contents of the material. Those unfamiliar with the various romanization systems for the Chinese language may be confused by the variety of spelling found in the bibliography. Although most libraries are beginning to follow the official romanization of the People's Republic of China, Pinyin, many early references use Wade-Giles, Yale, or other systems. Confusion may arise when encountering authors listed in several places by different romanizations: e.g. Hsing (Wade-Giles) may also be listed as Sying (Yale) or Xing (Pinyin). There are conversion charts available, a valuable one being:

Deeney, John J. (1975) Style Manual and Transliteration Tables for Mandarin. Taipei, Taiwan, Tamkang College of Arts and Science, Western Literature Research Institute. Monograph Series no. 1.

The bibliography has been divided into 10 categories, with citations repeated in each relevant category. An author index follows the bibliography. The 10 subject categories are:

A. Avalanches;

B. Climatology;

C. Freshwater ice;

D. General topics;

E. Glacial geology;

F. Glaciation;

G. Glaciers;

H. Instrumentation;

I. Permafrost or frozen ground;

J. Snow or other precipitation.

Acknowledgements

I am deeply grateful for the help and encouragement given me by Dr. Needham and his colleagues at the East Asian History of Science Library. Their kindness in providing me with a work space and valuable assistance in their busy library was as much appreciated as the benefit I gained personally from being in contact with their expertise in all Chinese matters. Everyone patiently answered my questions, pointed me in the right direction and corrected my errors.

I should also like to thank the Scott Polar Research Institute for kindly allowing me access to their files and for providing a pleasant and quiet work space. I especially thank the librarians for bringing to my attention new publications from the People's Republic of China as they were received at the Library.

I also wish to thank Professor Roger Barry, Director, World Data Center-A, for providing funds which enabled this work to be carried out, and Ann Brennan, for her encouragement and editorial assistance.

The mailing addresses of libraries mentioned in this bibliography are:

British Library, British Museum, Great Russell Street, London, England

Cambridge University Library, Cambridge, England

East Asian History of Science Library, 16 Brooklands Avenue, Cambridge, England

Scott Polar Research Institute, Lensfield Road, Cambridge, England CB2 1ER.

AVALANCHES

1
Moskalev, Y.D. (1967) Problems of the forecasts of snow avalanches in the Tien-Shan. (In: Schram, K.; Thams, J.C., eds., Internationale Tagung fur Alpine Meteorologie, 9th, Brig und Zermatt, 14-17 September 1966. Zurich, City-Druck AG, p. 51-59.)

2
*Qiu, Jiaqi; Hu, Ruji (1979) Avalanche happening in December 1966 in Western Tian Shan, China. Academia Sinica, Xinjiang Institute of Geography, 13p.

3
*Roch, A. (1954) Glaciers, snow and avalanches of Mount Everest. Journal of Glaciology, v.2(16), p.428-430.

4
*Shi, Yafeng; Wang, Wenying (1979) Researches on snow cover in China and the avalanche phenomena of the Batura Glacier in Pakistan. Academia Sinica, Lanzhou Institute of Glaciology and Cryopedology, 9p.

5
Chu, Ko-chen (1964) Li shi shi dai shi jie ch'i hou de bo dong. (Fluctuations of world climate during historical times.) Weather Monthly (Peking) 31, p.4. In Chinese.

6
Chu, Ko-chen (1973) Preliminary study on the climatic fluctuations during the last 5,000 years in China. Scientia Sinica, v.16(2), p.226-256.

7
De Terra, H.; Hutchinson, G.E. (1934) Evidence of recent climatic changes shown by Tibetan highland lakes. Geographical Journal, v.84, p.311-320.

8
Flohn, H (1959) Bemerkungen zur Klimatologie von Hochasien; Aktuelle Schneegrenze und Sommerklima, (Notes on the climatology of Asia, contemporary snow line and summer climate.) Akademie der Wissenschaften und der Literatur, Mainz. Mathematisch-Naturwissenschaftlichen Klasse. Abhandlungen, no. 14, p.1409-1431. In German.

9
Guo, Xu-dong (1974) Climatic changes in the Mount Jolmo Lungma region, southern Tibet, China during the Quaternary period. Scientia Geologica Sinica, no. 1, p.59-78. In Chinese with English summary.

10
Hsieh, Chiao-min (1976) Chu K'o-chen and China's climatic changes. Geographical Journal, v.142, p.248-56.

11
Hsu, Jen (1966) Climatic condition in north China during the time of Sinanthropus. Scientia Sinica, V.15, p. 410-414.

12
Huang, Pei-hua (1963) Chung kuo ti szu chi ch'i hoyen pien te ch'u pu t'an t'ao. (Preliminary study of weather evlution in the Quaternary of China.) K'o Hsueh T'ung Pao (Science Bulletin), no. 1, p.34-39. In Chinese.

14
*Lin, Chen-ti; Wu, Hsiang-ting (1977) 500 years of climatic change on the Ching-Hai Tibetan Plateau. K'o hsueh shieh yen, v.3? English translation by J. Bradley for WDC-A Glaciology (Snow and Ice), 1980.

15
Lu, Chiung (1943) Summary of postglacial climatic change. Kan Du Shu Tong Xun, v.79(80). In Chinese.

15
Ma, T.Y.H. (1940) On the causes of climatic change and the last Quaternary glaciation in China. Bulletin of the Geological Society of China, v.20, p.343-355.

16
Mon, Wen-tung (1930) On past climate of Nortn China. Historical Journal of China, v.2(3,4).

17
Norin, E, (1932) Quaternary climatic changes within the Tarim Basin. Geographical Review, v.22, p, 591-598.

18
Rigby, Malcolm (1961) Meteorology, hydrology and oceanography 1949-1960. (In: Gould, S.H., ed. Sciences in Communist China. American Association for the Advancement of Science, Publication no. 68, p.523-614.

19
Rutkovskaya, V.A. (1957) Climatic changes and climatic trends. Weather Monthly (Peking), 8, p.22-24. In Chinese.

20
Sarntheim, M. (1978) Sand deserts during glacial maximum and climatic optimum. Nature, v.272, p.43-46.

21
Shen, Wen-hsiung (1974) Changes in China's climate. China Pictorial, v.4, p.30-33. Also: American Meterological Society. Bulletin, v.55, p.1347-1350.

22
Shi, Yafeng; Wang, Jingtai (1979) Fluctuation of climate, glaciers and sea-level since the late Pleistocene in China. Academia Sinica, Lanzhou Institute of Glaciology and Cryopedology, 21 p. Also; International Union of Geodesy and Geophysics. General Assembly, 17th, Canberra 3-15 December 1979.' Abstracts, p.73.

24
Sun, Tien-ching (1962) Beobachtungen von quartaren Vereisungspuren in der Volksrepublik China. (Observation of Quaternary freezing in the People's Republic of China.) Bericht der geologischen Gessellschaft in der Deutschen Demokratischen Republik, v.6, p.181-192.

25
*Tang, Ying-jun (1980) Evidence of climatic fluctuation in Quaternary deposit involution layers. Journal of Glaciology and Cryopedology, v.2(1), p.41-43. In Chinese.

25
*Tang, Ying-jun (1980) Evidence of climatic fluctuation in Quaternary deposit involution layers. Journal of Glaciology and Cryopedology, v.2(1), p.41-43. In Chinese.

26
Tator, B.A. (1950) Climatic fluctuation, a suggested means for the development of lake terraces, Kunming Basin, China. American Journal of Science, v.148, p.498-507.

27
Tseng, Ming-hsuan; T'ong, Kuan-jung (1966) Mu-Tu-Da-Ge Shan qie-qian gan Bu-La-Ke bing chuan xiao rung ch'i de fu she yu re liang ping heng. (Energy balance and radiation during the ablation season on the Bu-La-ke Glacier, Mutudage Mountain.) (tentative translation). (In: Gan han qu, di li xue shu hui yi lun wen xuan ji. Collected works on a geographical conference on arid regions. Peking, Science Publications.)

28
Tu, Chang-wang (1937) China weather and world oscillation with applications to long-rangeforecasting of floods and droughts of China during the summer. National Research Institute of Meteorology. Memoirs, v.11(4). Also: Collected Scientific Papers, Meteorology, 1919-1949 (1954) Peking, Academia Sinica, p.349-392.

29
Wallace, James Allen (1965) Annotated Bibliography on the Climate of South China. Washington, D.C., U.S. Weather Bureau, 260p.

30
Wang, P.F. (1958) Problems met in research on climatic changes of past hundred years, II. Weather Monthly (Peking), 4, p.21-27.

31
Wang, Shaowu; Chao, Zung-tsyr (1979) Droughts and floods in the last 500 years in China. (In: International Conference on Climate and History, July 8-14. Climatic Research Unit, University of East Anglia. Abstracts. Norwich, U.K., p.64-65.)

32
Wissmann, H. von (1938) Klimate Chinas im Quartar. Geographische Zeitschrift, p.321-40.

33
Wu, Hsi-hao; Ch'ing, Yu-p'u; Yang, Ta-yuan (1963) Tui "Chungkuo ti szu chi ch'i ho yen pien te t'an t'ao" yi wen te t'ao lun. (Comment on the paper "Preliminary study of the weather evolution in the Quaternary in China.") K'o Hsueh T'ung Pao (Science Bulletin), no. 6, p.31-35. In Chinese.

34
Yang, Chien-chu (1958) Changes in weather conditions which have taken place in several parts of China over the years. Weather Monthly (Peking), 1, p.34-37.

35
Yang, Huai-jen; Ch'iu, Shu-chang (1965) Quaternary glaciation and the postglacial climatic fluctuations in the region of Urumchi Valley, Sinkiang. Acta Geologica Sinica, v.31(3), p.194-212.

36
*Academia Sinica. Institute of Geography (1973) Distribution of isotopes in some natural waters in the region north of Mt. Jolmo Lungma. Scientia Sinica, v.16(4), p.560-564.

37
Japan. Army. Tada Unit (1939) Showa 13 nendo hokushi Shokasen Keppyo gaiko. Dai 3 pen, eiteikakei. Sono ichi, mokyo chiho. (Freezing of rivers in north China in 1938. Report 3. Yungting Ho River System. Park I. Mongolia-Singkiang Province Area.) 67p. In Japanese.

38
Japan. Asiatic Institute. North China Liaison Section (1942) Dai 4-setsu, keppyo oyobi, kaihyo. (Freezing and thawing of the Lwan River, Hopeh, China.) 92 p. (In: Ranka Suiun Suiro narabin; suimon chosa hokokusho. Report on investigations of water transporation, watercourses and hydrology of the Lwan River, Chapter 4). In Japanese.

39
Japan. Kwantung Army (n.d.) Hyojo ni okeru sakusen no sanko. (Manual for operations on ice.) 54 p. In Japanese.

40
Kahoku otsu Kabushiki kaisha (Kahoku Transportation Co. Inc.) (1941) Meteorology in relation to North China rivers. (In: Kohoku otsu Kabushiki Kaisha. Hokushi Kasen Yoran. Mukden, p. 3-5.) In Japanse.

41
Kubo, Yoshimitsu (1958) Shizen keppyopan no seisei ni tsinte. (The growth of the natural ice-plate.) Seppyo, v.20(5), p.136-141. In Japanese with English summary.

42
Lanzhou, China. Hydrographic Station (1959) Shui nei ping ti shih yen yen chui pao hao. (Report of research on underwater ice.) Huang ho chien she (Yellow River Construction), no. 4, p.61-63. In Chinese.

43
*Li, Weixin (1980) Measurement of ice dielectric coefficient and its application in glaciological research. Journal of Glaciology and Cryopedology, v.2 (Special Issue), p.51-53. In Chinese.

44
Own, Sho-chow (1957) Ice-pillars and rime at the high mountain station on Chou Mountains, Fukien Province. Weather Monthly (Peking), 1, p.37.

45
Salemachila, I.I. (1957) Calculation of icing conditions on electric cables at various altitudes based on the surface data. Weather Monthly (Peking), 1, p.38-41.

46
*Sheng, Wenkun (1980) Application of simple chemical analysis of natural water in the analysis of ice and snow samples. Journal of Glaciology and Cryopedology, v.2 (Special issue). p.91-92. In Chinese.

47
Shu, Chao (1936) Freezing over of the port of Tientsin and the lower Haiho Valley during February 1936. Meteorology Magazine, (Nanking), v.12(4), p.195-200.

48
Zhang, Qing-lian; Yin, Zhao; Zhang, Xian-lu (1959) Distribution of isotopes in some natural waters of China. Science Record NS, v.3(10), p.495-498. In Chinese.

49
*Zhang, Xiangsong (1980) Recent research on snow and ice in the world. Journal of Glaciology and Cryopedology, v.2(1), p.54-58. In Chinese.

50
*Zhang, Xiangsong (1980) Recent research on snow and ice in the work (I). Journal of Glaciology and Cryopedology, v.2(2), p.48-52. In Chinese.

51
*Academia Sinica. Scientific Expedition to Tibet (1975) Report of Scientific Investigation in the Mt. Everest Region from 1966-1968: Modern Day Glaciers and Landforms (Glaciology and Geomorphology). Peking, Science Publications, 202p. In Chinese with English table of contents.

52
Alford, Donald (1965) Notes on high elevation research with selected bibliography. U.S. Army. Cold Regions Research and Engineering Laboratory. CRREL Special Report, no.78, 34p.

53
Bailey, F.M. (1924) Through Bhutan and southern Tibet. Geographical Journal, v.64(4), p.291-97.

54
Bla-ma bTsan-po (1962) Geography of Tibet according to the 'dZam-gling-rGyas-bShad. Rome. Istituto Italiano per il Medio ed Estremo Oriente, 286 p. (Serie Orientale Roma, no.25).

55
Brooks, C.E.P. (1954) Climatic changes of the past 1000 years. Experientia, v.10, p.153-158.

56
Burdsall, R.L.; Emmons, A.B. (1935) Men Against the Clouds; the conquest of Minya Konka. New York, Harper.

57
Ch'ang, Kuo-kan (1962) Critical notes on old Chinese gazetteers, Shanghai, 1962, (Bibliography of 2,000 works.) In Chinese.

58
Chao, Chih-hsin; Wang, Chih-yao (1958) Chung-kuo ti chih wen hsien mu lu. (Bibliography of Chinese geology.) Peking, Ti Chih Ch'u Pan She, 543 p.

59
Chao, E.C.T. (1961) Progress and outlook of geology. (In: Gould, S.H., ed. Sciences in Communist China. American Association for the Advancement of Science, no. 68, p.497-522.)

60
Chao, E.C.T. (1973) Contacts with earth scientists in the People's Republic of China. Science, v.179, p. 961-3.

61
Chao, Y.T. (1929) Geological notes in Szechuan. Bulletin of the Geological Society of China, v.8, p.137-149.

62
Chen, Cheng-siang; Au, Kam-nin (1975) Some recent developments in geoscience in China. Science Reports of the Tohoku University 7th Series (Geography), v.25 (1). Sendai, Japan,Tohoku University, Institute of Geography.

63
Cheng,Ch'i-p'u (1959) Yung chu tung chieh ti ch'u shui wen ti chih k'an ts'e kung tso chung ti chi tien ti hui. (Points to be considered during hydrogeological survey in permafrost regions.) Hsui Wen Ti Chih Kung Ch'eng Ti Chih (Hydrogeology and Engineering Geology), no.11, p.13-15. In Chinese.

64
Chi, Jung-sen (1936) Science Bibliography of China. Geology Section: Bibliography 1934-1935. Nanking, Academia Sinica, 57p.

65
Chi, Jung-sen (1942) Bibliography of Chinese geology for the years 1936-1940. Pehpei (sic), National Geological Survey of China, 147p.

66
Chinese scientists survey world's highest peak. (1968) China Reconstructs, May, p.20-21, 24-27.

67
Ch'iu, Shih chi (1965) Scientific and technological development. (In: Communist China, 1964, ed. by Union Research Institute. Hong Kong, Union Research Institute, v.1., p.172-210.)

68
Chiu, Shih-chi (1964) Nien ta lu ti k'o hsueh chi shu kung tso. (Science and technology in Mainland China). Tsu Kuo, v.14, p.23-33. In Chinese.

69
Chu, Liang (n.d.) Determination of the height of the Qomolangma Feng (Mt. Everest). Scientia Sinica. v.19(2), p.260-275.

70
Chu, Ko-chen (1959) Scientific expeditions undertaken by Academia Sinica in recent years. Scientia Sinica, v.8(9), p.887-909.

71
*Constitution of the Chinese Society of Glaciology and Cryopedology (1980) Journal of Glaciology and Cryopedology, v.2(4), p.77. In Chinese.

72
Geological Society of China (1947) Publications of the Geological Survey of China. Peking, 2 v.

73
*Glaciological research in China (1964) Journal of Glaciology, v.5(38), p.258.

74
Guibert, Andre (1944) Exploration in the Upper Tung Basin, Chinese Tibetan borderland. Geographical Review, v. 37, p.70-87.

75
Guo, Xu-dong (1976) Report on the Mount Qomolangma area scientific expedition 1966-1968. Quaternary Geology, Peking, p.63-78. In Chinese.
76
Hanson-Lowe, J. (1940) Journey along the Chinese-Tibetan border. Geographical Journal, v.95(5), p.357-367.
77
Hedin, S. (1909) Trans-Himalaya. V.2, New York, Macmillan, 439p.
78
Hedin, S. (1922) Southern Tibet. Stockholm, Lithographia Institut.
79
Hedin, S. (1940) Wandering Lake. London, Routledge, 293p.
80
Heim, A. (1933) Minya Gongkar: Forschungsreise ins Hochgebirge von Chinesisch Tibet. (Minya Gongkar: Exploration in the high mountains of Chinese Tibet.) Bern, Huber, 244p.
81
Horner, N.G. (1932) Lop-Nor: topographical and geological summary. Geografiska Annaler, v.14, p.297-312.
82
Hsiao, T'eng-lin (1759) Hsi-tsang chien-wen lu (Travels in Tibet.) Chapter 2, Located at the British Museum.
83
Hsin tien-hsia ming-shan sheng-ching chi. (Collected short works on the mountains of China.) (193?) Arranged by Provinces. 2 vols. Hui-wen-t'ang Shu-chu, Shanghai.
84
*Hsin-hua. (New China News) (1964) Glaciological research in China. Journal of Glaciology, v.5(38), p. 258.
85
Hsu, Ginn-tse (1958) Bibliography of the Tibetan Highlands and its Adjacent Districts. Peking, Science Press. Contains Western language sources primarily Russian.
86
Huc, Evariste Regis (1966) Wanderungen durch die Mongolei nach Tibet, 1844-1846. (Traveling through Mongolia toward Tibet.) Stuttgart, Steingruben Verlag, 386 p. In German.
87
Jen, Hua; Han, San-tang (1973) At the foot of Mt. Kaolan. China Pictorial, 8, p.24-27.
88
Kalmui Kova, V.G.; Ovdienko, I.K. (1957) Severo-zapadnuy Kitai. (Geography of Northwest China.) Moscow, 2, 2191p.
89
Kaulback, R. (1938) Journey in the Salween and Tsangpo Basins, southeastern Tibet. Geographical Journal, v.91(2), p.97-122.
90
Kazakova, M.N. (1969a) Northwest China: the Mongolian - Sinkiang region. (In: Physical Geography of China, New York, Frederich A. Praeger, v.2, p.193-245)
91
Kazakova, M.N. (1969b) Tsinghai-Tibetan region. (In: Physical Geography of China, New York, Frederich A. Praeger, v.2, p.246-77.)
92
Kikolski, Bohdan (1964) Contemporary research in physical geography in the Chinese People's Republic. Association of American Geographers. Annals, v.54, p.181-189.
93
*Kou, Youguan; Ding, Liangfu; Li, Wengzhou; Zhang, Yongling (1980) Glacial meteorology on Mt. Tuomuer. Journal of Glaciology and Cryopedology, v.2(4), p.11-14. In Chinese with English abstract.
94
Kurz, Marcel (1959) Chronique Himalayenne: l'age d'or 1940-55. (Himalayan Chronicle: the Golden Age, 1940-55.) Zurich, Foundation Suisse pour Explortions Alpines, 2 v.
95
Kuznetsov, I.V., et al., eds.(1955) Iz istorii nauki i tekhniki kitaia: sbornik statei. (Historical sketch of science and technology in China: a symposium) Akademia Nauk SSSR, 181p.
96
Li, Hsiao-fang (1947) Bibliography of geollogy and geography of Sinkiang. Nanking, National Geological Survey of China, 213p.
97
Li, Pu (1954) Scientists in Tibet. China Reconstructs, v.3(6), p.28-31.
98
*List of members of the Chinese Society of Glaciology and Cryopedology. (1980) Journal of Glaciology and Cryopedology, v.2(4), p.75. In Chinese.
99
*List of members of the Council of the Chinese Society of Glaciology and Cryo pedology (1980) Journal of Glaciology and Cryopedology, v.2(4), p.74. In Chinese.
100
*Liu, Jinhuang (1980) Application of pseudocolour in research in glaciology and cryopedology. Journal of Glaciology and Cryopedology, v.2 (Special issue), p.63-67. In Chinese.

101
Marinov, N.A. (1968) Merzlaya zona Azii. (The frozen zone of Asia.) Akademia Nauk SSSR. Seriya geograficheskaya. Izvestiya, no. 2, p.29-38.

102
National Geological Survey of China (1928) Catalog of the Library of the National Geological Survey of China. Peking, 89 p.

103
Needham, Joseph, (1954-) Science and Civilisation in China. Cambridge (England) University Press. v.1-6 completed.

104
Ozaki Kinemon (1944) Chugoku chishitsu chiri bunken mokuroku. (Bibliography of Chinese geology and geography.) Shanghai, Shanghai Science Institute, 68 p.

105
Pannell, C.W.; Welch, R. (1976) Recent satellite coverage of China. The China Geographer, v.3, p.31-33.

106
Price, M. Phillips (1968) A journey in the upper Yenesein basin, Outer Mongolia and Chinese Turkestan in 1910. Geographical Journal, v.134(2), p.181-193, p.244-45.

107
Rock, Joseph F. (1931) Konka Risumgongba, Holy Mountain of the Outlaws. National Geographic Magazine, v.60(1).

108
Rock, Joseph F. (1930) Glories of the Minya Konka. National Geographic Magazine, v.58(4).

109
Sheng, Benxing; Shi, Yafeng (1976) Report on the Mount Qomolongma Area Scientific Expedition 1966-1968. Quaternary Geology, Beijing, Science Press, p. 29-62. In Chinese.

110
Shi, Yafeng; Liu, Teng-sheng (1964) Preliminary report on Mount Shisma Pangma scientificexpedition, 1964. Kexue Tongbao, no.10, p.928-38. In Chinese.

111
Shi, Yafeng; Su, Zhen (1964) Researches on glaciology and hydrology of the Urumqi River. Peking, Science Press.

112
Siddiqi, M.I. (1962) Tibet today. Pakistan Geographical Review, v.17(2), p.25-36.

113
Stein, Aurel (1928) Innermost Asia. Oxford, v.1, p.459-460.

114
Stein, M.A. (1921) Serindia: a detailed report of exploration in Central Asia and Western-most China. Oxford, Clarendon Press, 5 v.

115
Stoddart, D.R. (1978) Geomorphology in China. Progress in Physical Geography, v.2(2), p.187-236.

116
Ting, Wen-chiang (1921) On Hsu Hsia-K'o: explorer and geographer. North China Review, v.3, p.325.

117
Trinkler, E. (1932) Geographische Forschungen im Westlichen Zentralasien und Karakoram-Himalaya. (Geographical research in West Central Asia and the Karakoram Himalaya.) Berlin, Dietrich Reimer and Ernest Vohsen, 133p. In German.

118
Tseng, T.C. (1946) Bibliography of Chinese Geology: Bibliography of Geology and Allied Sciences of Tibet and Regions to the West of Chinshachiang. Peking, National Geological Survey of China, 114 p.

119
Tseng, Ying-ching (1968) Chungkuo li shih yen chiu kung chu shu hsu lu [kao pen]. (Research tools for Chinese history: an annotated bibliography.) Hongkong, University of Hongkong, B.A. Thesis. In Chinese.

120
U.S. Library of Congress (1961) Scientific and technical journals in Japan and mainland China: a selected list. Washington, D.C., Library of Congress, Technology Division, 47p.

121
U.S. Library of Congress. Science and Technology Division. (1961) Chinese Scientific and Technical Serial Publications in Collections of the Library of Congress. Revised ed. Washington, D.C., Library of Congress, Science and Technical Division, Reference Department.

122
Visser, Ph. C. (1934) The Karakoram and Turkistan expedition of 1920-1930. Geographical Journal, v.84(4).

123
*Wang, Wenying; Chen, Xiaobai (1980) New stage in the development of measuring and testing technique in glaciology and cryopedology. Journal of Glaciology and Cryo pedology, v.2 (Special Issue), p.1-2. In Chinese.

124
*Wang, Wenying; Cheng, Jianming (1980) Terrestrial stereophotogrammetric surveying and mapping in the region of Mt. Qomolangma, the Batura Glacier in the Karakoram. Journal of Glaciology and Cryopedology, v.2(4), p.22-28. In Chinese with English abstract.

125
Ward, F.K. (1916) Glacial phenomena on the Yun-nan Tibet frontier. Geographical Journal v.48(1), p.55-68.

126
Ward, F.K. (1923) From the Yangtze to the Irrawaddy. Geographical Journal, v.62(1), p. 6-20.

127
Ward, F.K. (1923) Mystery rivers of Tibet. London, Seeley Service.

128
Ward, F.K. (1926) Exploration in south-eastern Tibet. Geographical Journal, v.67(2), p.97-123.

129
Ward, F.K. (1934) Himalaya east of the Tsangpo. Geographical Journal, v.84(5), p.369-97.

130
Wylie, Turrell V. (1958) Geography of Tibet according to the Dzamgling-rgyas-bshad. Ph.D. Thesis, University of Washington. Ann Arbor, University Microfilms, 327p.

131
*Xu, Qinqi (1980) Introduction of a theory-Ice Ages controlled by variations of the Earth's orbit. Journal of Glaciology and Cryopedology, v.2(2), p.53-57. In Chinese.

132
*Yu, Jimin; Chen, Xuede; Wang, Changling (1980) Remote measuring and auto-recording of ground temperature. Journal of Glaciology and Cryopedology, v.2 (Special issue), p.7-9. In Chinese.

133
*Zhang, Xiangsong (1980) Recent research on snow and ice in the work (I). Journal o Glaciology and Cryopedology, v.2(2), p.48-52. In Chinese.

134
*Academia Sinica. Scientific Expedition to Tibet (1975) Report of Scientific Investigation in the Mt. Everest Region from 1966-1968: Modern Day Glaciers and Landforms (Glaciology and Geomorphology). Peking, Science Publications.

135
Acharyya, S.K. (1973) Late Palaeozoic glaciation versus volcanic activity along the Himalayan chain with special reference to the eastern Himalaya. Himalayan Geology (Delhi), v.3, p.209-230.

136
Andersson, J.G. (1923) Essays on the Cenozoic of northern China. Memoirs of the Geological Survey of China, A3, p.1-752.

137
Barbour, George B. (1925) Loess of China. The China Journal of Science and Arts, v.IV(8 and 9), p.454-463, 509-517.

138
Barbour, George B. (1931) Taiku deposits and the problem of Pleistocene climates. Bulletin of the Geological Society of China, v.10, p.71-104.

139
Barbour, George B. (1934) Analysis of Lushan glaciation problem. Bulletin of the Geological Society of China, v.13, p.647-656.

140
Barbour, George B. (1935) Recent observations on the loess of north China. Geographical Journal, v.86, p.54-64.

141
Chang, H.T. (1922) On the history of geological sciences in China. Bulletin of the Geological Society of China, v.1, p.4-7.

142
Chang, Ta (1963) Geology of China: Communist China. Washington, D.C., U.S. Department of Commerce, Office of Technical Services, Joint Publications Research Service.

143
Chao, Chanko-ping (1958) Periglacial sediments on Yung-an in Fu-tsan province. K'o Hsueh T'ung Pao (Science Bulletin), v.18, p.569-570. In Chinese.

144
Chao, Chih-hsin; Wang, Chih-yao (1958) Chung-kuo ti chih wen hsien mu lu. (Bibliography of Chinese geology.) Peking, Ti Chih Ch'u Pan She, 543p.

145
Chi, Jung-sen (1942) Bibliography of Chinese geology for the years 1936-1940. Pehpei (sic), National Geological Survey of China, 147p.

146
China. Jilin Province. Geological Bureau (1975) Preliminary observations on vestiges of glaciation found at the base of middle Carboniferous rocks in the southern part of Jilin Province. Acta Geologica Sinica, no. 2, p.194-203. In Chinese with English summary.

147
Chinese Geographical Society. Geomorphology Committee (1965) Chung-kuo ti li hsueh hui ti mao hsueh shu t'ao lun hui. (Collected works of the 1965 Geomorphology meeting of the Chinese Geographical Conference.) Peking, Science Press, 170 p.

148
Chinese Geographical Society. Geomorphology Committee. (1967) Collected works of the 1965 Geomorphology meeting •f the Chinese Geographical Conference. Translation of Chinese Geographical Society. Geomorphology Committee. (1965). Washington, D.C., U.S. Joint Publication Research Service, 424p.

149
Ching, Tsai-jui (1965) Relics of the Quaternary glaciation and the classification of glaciation epochs of the plateau area of western Hupei. Acta Geologica Sinica, v.45, p.237-42. In Chinese.

150
Cooke, H.B.S.; Lowe, C. vanR.; Wells, L.H. (1941) Geology and early man. Nature, v.147,p.45-49

151
Geological Society of China (1947) Publications of the Geological Survey of China, Peking, 2 v.

152
Gorbunov, A.P. (1969) Region periglaciaire du Tian-Chan. Biuletyn Peryglacjalny, no. 19, p.151-174.

153
Gregory, J.W.; Gregory, C.J. (1925) The geology and physical geography of Chinese Tibet. Philosophical Transactions of the Royal Society of London. Series B, no. 213, p.171-298.

154
Guo, Xu-dong (1974) Climatic changes in the Mount Jolmo Lungma region, southern Tibet, China during the Quaternary period. Scientia Geologica Sinica, no. 1, p.59-78. In Chinese with English summary.

155
Hanson-Lowe, J. (1936) Theoretical reflections on the geomorphology of China from the viewpoint of glacio-eustatism. Bulletin of the Geological Society of China, v.15, p.119-129.

156
*Hanson-Lowe, J. (1947) Notes on the Pleistocene glaciation of the South Chinese-Tibetan Borderland. Geographical Review, v.37(1), p.70-87.

157
Harland, W.B. (1945) On the physiographic history of western Szechuan with special reference to the ice age in the Red Basin. Journal of the Western China Border Research Society. Series B, 15, p.1-19.

158
Heim, A. (1930) Structure of the sacred Omei-Shan, Szechuan. Bulletin of the Geological Society of China, v.9, p.59-58

159
Heim, A.; Gansser, August (1939) Central Himalaya, Geological Observations of the Swiss Expedition, 1936. Zurich, Gebruder Fretz, 245p. (Schweizerische Gesellschaft. Denkschriften, Bd. 73, Abh. 1).

160
Hoynagi, Mutsumi (1966) Glacial problems in China (a general review). Journal of Geography, Tokyo, v.75(3), p.33-43; v.75(4), p. 26-41. In Japanese with English Summary.

161
Huang, Pei-hua (1960) Lun yunnan chih ti mao fayu wenti. (A discussion of the problems concerning the geomorphological evolution of Yunnan Province.) Quaternary Research, Peking, v.2(1-2). In Chinese.

162
Huang, Pei-hua (1963) Kuan yu ch'ang chiang yi nan ti ch'u ping ch'uan ye chi wen ti. (On the relic glaciers in the area south of the Yangtze River.) K'o Hsueh T'ung Pao (Science Bulletin), no. 10, p.29-33. In Chinese.

163
Huang, T.K. (1967) Main characteristics of the geologic structure of China; preliminary conclusions. St. Louis, Mo., U.S. Aeronautical Chart and Information Center, ACIC Technical translation, ACIC-TC-1262, 75 p. NTIS: AD-664 846 Translated from Acta Geologica Sinica, v. 4(1), p. 1-37 (1960).

164
Huang, Ti-fan; Yang, Chich-chao (1964) New glacial relics in the middle and downstream areas of the Yang-Tze River. K'o Hsueh T'ung-Pao. (Science Bulletin), no. 6, p. 544-547.

165
*Jen, Mei-ngo (1958) Glaciation of Yu-Lung Shan, Yunnan, China. Erdkunde, v.12(4), p.308-313. Also: Annales de Geographie, v.59, p.50-56. In French.

166
Jennings, J.N. (1976) Quaternary stratigraphy (of China). Australian Quaternary Newsletter, 1, p.10-21.

167
*Ji, Zi Xiu (1980) Modern periglacial process in the central part of Tian Shan. Journal of Glaciology and Cryopedology, v.2(3), p.1-11. In Chinese with English abstract.

168
Kalvoda, J. (1973) Geomorphological problems of the Mount Everest area. Himalayan Geology (Delhi), v.3, p.311-319.

169
Klaer, Wendelin (1962) Periglaziale Hohenstufe in den Gebirgen Vorderasiens. (Periglacial altitude levels in the mountains of Asia Minor.) Zeitschrift fur Geomorphologie, v.6(1), p.17-32. In German.

170
Kozarski, S. (1961) Fossil congelifluction covers in the northern part of the Lushan (central China). Biuletyn peryglacjalny, no. 10, p.195-207.

171
Kozarski, S. (1963) Problem of Pleistocene glaciations in the mountains of east China. Zeitschrift fur Geomorphologie, v.7(1), p.49-70.

172
Kuo, W.K.; Yeh, C.C. (1964) Preliminary note on Quaternary glaciation in northeastern Yunnan. Bulletin of the Geological Society of China, 24, p. 115-24.

173
Lee, J.S. (1933) Quaternary glaciation in the Yangtze valley. Bulletin of the Geological Society of China, v.13, p.15-62.

174
Lee, J.S. (1934) Data relating to the study of the problem of glaciation in the lower Yangtze valley. Bulletin of the Geological Society of China, v.13, p.395-432.

175
Lee, J.S. (1936) Confirmatory evidence of Pleistocene glaciation from the Huang-Shan, southern Anhui. Bulletin of the Geological Society of China, v.16, p.279-90.

176
Lee, J.S. (1939) Geology of China. London, Murby, 528 p.

177
Lee, J.S. (1947) Vestiges of corrie glaciation on the Kweichow plateau. Bulletin of the Geological Society of China, v.27, p.35-53.

178
Li, C.; Wu, Y.S. (1940) Preliminary note on Quaternary glaciation in western Hupeh. Bulletin of the Geological Society of China, v.20, p.15-22.

179
Li, Ching-yuan Y. (1952) Geological activities in Asia. Economic Geology, v.49, p.193-201.

180
Li, Hung-lien (1965) The geological and geomorphological actions of mudrock glaciers in the mountain district on the southeastern part of Tibet. (In: Collected Works of the 1965 Geomorphological Meeting of the Chinese Geographical Conference. Washington, DC. U.S. Joint Publication Research Service, p.388-400.)

181
Li, Y.; Pan, C.; Tsao, C.; Hu, C. (1973) Further notes on Quaternary glaciations in China. Acta Geologica Sinica (Peking), 1, p.94-101.

182
Liu, En-lan (1943) Geography of Lifan. Journal of the Western China Border Research Society, (B), 14,1.

183
Liu, Zhe-ouen; Liu, Zhen-zhong; Wang, Fu-bao (1962) Comparison of the glacial development in the Quaternary period near Everest. The Teng Keh Li peak and the united peaks of the Chi Lien mountain. Acta Geographica Sinica, v.28, p.19-33.

184
*Miller, Maynard M. (1965) Mount Everest and the Mahalangur Himal, 1963. Explorers Journal, v.43(3), p.130-148.

185
*Miller, Maynard M.; Leventhal, J.S.; Libby, W.F. (1965) Tritium in Mt. Everest ice - annual glacier accumulation and climatology at great equatorial altitudes. Journal of Geophysical Research, v.70(16), p.3885-88.

186
Norin, E. (1946) Geological explorations in western Tibet. Reports from the Scientific Expedition to the north-western provinces of China under the leadership of Dr. Sven Hedin. The Sino-Swedish Expedition. Publication 29, III. Geology, 7, 214 p.

187
Pearson, R.J. (1973) Radiocarbon dates from China. Antiquity, v.47, p.141-143.

188
Sheng, Benxing; Shi, Yafeng (1976) Report on the Mount Qomolongma Area Scientific Expedition 1966-1968. Quaternary Geology, Beijing, Science Press, p. 29-62. In Chinese.

189
Shi, Yafeng; Li, Chi-chun; Cheng, Hsing (1979) Quaternary China. Geographical Magazine, v.51(9), p.636-643.

190
Smalley, I.J. (1966) Properties of glacial loess and the formation of loess deposits. Journal of Sedimentary Petrology, v.36, p.669-676.

191
Stoddart, D.R. (1978) Geomorphology in China. Progress in Physical Geography, v.2(2), p.187-236.

192
Sun, T.C. (1944) Glacial features in northwestern Kuangsi. Bulletin of the Geological Society of China, v.24, p.105-113.

193
Sun, Tien-ching (1962) Beobachtungen von quartaren Vereisungspuren in der Volksrepublik China. (Observation of Quaternary freezing in the People's Republic of Chin.) Bericht der geologischen Gessellschaft in der Deutschen Demokratischen Republik, v.6, p.181-192.

194
Syrnev, I.P. (1971) Characteristics and correlation of Quaternary sediments in the middleand lower reaches of the Yangtze River Basin. Akademiia nauk SSSR. Izvestiia. Seriia geograficneskaia, v.4, p.118-124.

195
T'ai, Ch'ien-chien (1972) Hsi Tsang Nielamutan fa hsien te shih ch'i. (Stone age development in Nie-la-mu-tan, Tibet.) Kao Gu, 3. In Chinese.

196
*Tang, Ying-jun (1980) Evidence of climatic fluctuation in Quaternary deposit involution layers. Journal of Glaciology and Cryopedology, v.2(1), p.41-43. In Chinese.

197
Tator, B.A. (1950) Climatic fluctuation, a suggested means for the development of lake terraces, Kunming Basin, China. American Journal of Science, v.148, p.498-507.

198
Teilhard de Chardin, P. (1935) Geological observation in the Turfan area. Geografiska Annaler, v.17, p.446-452.

199
Thorp, J.; Dye, D.S. (1936) Chengtu clays - deposits of possibly loessial origin in western and northwestern Szechuan Basin. Bulletin of the Geological Society of China, v.15, p.225-242.

200
Ting, S. (1947) Notes on geomorphology in the Ili district, Sinkiang. Journal of the Geographical Society of China, v.14. In Chinese with English summary.

201
Trinkler, E. (1930) Ice age on the Tibetan plateau and in adjacent regions. Geographical Journal, v.75, p. 225-232.

202
Ts'ao, Chao-yuan, et al. (1963) Kuan yu chung kuo ping ch'i he chien ping ch'i wen t'i.(On the question of glacial and interglacial stages in China.) K'o Hsueh T'ung Pao (Science Bulletin), no. 3, p.29-30. In Chinese.

203
Tseng, T.C. (1946) Bibliography of Chinese Geology: Bibliography of Geology and Allied Sciences of Tibet and Regions to the West of Chinshachiang. Peking, National Geological Survey of China, 114 p.

204
Tsui, Chich-tsui (1961) On the problem of Pleistocene ice-cover patterns in West China. Acta Geologica Sinica, v.44(2), p.229-45. In Chinese with English summary.

205
Wang, Yung-yen; Hsueh Hsiang-hsi; Ho, Ju-chang; Chang Kuo-wei (1966) Division of the Quaternary strata in the loess district of north Shansi and east Kansu. Acta Geologica Sinica, v.46, p.102-117.

206
Wissmann, H. von (1938) Loess-making and ice ages in China. Journal of the Geographical Society of China, v.5,p.3-6.

207
Wissmann, H. von (1959) Rezente und quartar Verglatscherung des Yulungschan. (Present day glaciation and former ice cover in Yulungshan mountains in Yunnan Provice.) Mitteilungen der Osterreichischen Geographischen Gessellschaft, v.101(2), p.165-82. In German.

208
Yang, Huairen, et al. (1958) Quaternary glacial and peri-glacial deposits in the lower Yangtze River Valley. Quaternary Research, v.1(1), p.240.

209
Yen, Ch'in-shang; Hsu, Shih-yuan; Jen, Ping-hui (1964) Chu i pu K'ai chan wo kuping ch'uan ping yuan fang mian yen chiu ti chi ko wen ti. (Some problems of promoting studies of glaciers and glacialmargins in China.) Acta Geologica Sinica, v.30(2), p.174-181. In Chinese.

210
Yuan, P.L. (1948) Geology of Dsungaria, Part I. National Tsing Huan University. Science Reports. Series C, v.1(3).

211
Zheng, Benxing; Shi, Yafeng (1976) Inquiry into the Quaternary period in the Mt. Qomolungma region. (In: Report on the 1966-1968 Scientific Expedition to the Mt. Qomolangma Region: Quaternary Geology, Peking, Science Publications, p.29-62.)

GLACIATION

212
Acharyya, S.K. (1973) Late Palaeozoic glaciation versus volcanic activity along the Himalayan chain with special reference to the eastern Himalaya. Himalayan Geology (Delhi), v.3, p.209-230.

213
Andersson, J.G. (1923) Essays on the Cenozoic of northern China. Memoirs of the Geological Survey of China, A3, p.1-752.

214
Barbour, George B. (1944) Ice Age in West China. Geographical Review, v.34(3), p.490-91.

215
China. Jilin Province. Geological Bureau (1975) Preliminary observations on vestiges of glaciation found at the base of middle Carboniferous rocks in the southern part of Jilin Province. Acta Geologica Sinica, no. 2, p.194-203. In Chinese with English summary.

216
Ching, Tsai-jui (1965) Relics of the Quaternary glaciation and the classification of glaciation epochs of the plateau area of western Hupei. Acta Geologica Sinica, v.45, p.237-42. In Chinese.

217
*Cui, Zhijiu (1980) On the periglacial mark in permafrost areas and the relation between glaciation and periglaciation. Journal of Glaciology and Cryopedology, v.2(2), p.1-6 In Chinese.

218
*Guo, Peng-fei (1980) Discussion of Quaternary Ice Age in the Middle and East sections of the Qilian Shan. Journal of Glaciology and Cryopedology, v.2(1), p.6-16. In Chinese.

219
*Hanson-Lowe, J. (1947) Notes on the Pleistocene glaciation of the South Chinese - Tibetan Borderland. Geographical Review, v.37(1), p.70-87.

220
Heim, A. (1936) Glaciation and solifluction on Minya Gongkar. Geographical Journal v.87(5), p.444-54.

221
Kozarski, S. (1963) Problem of Pleistocene glaciations in the mountains of east China. Zeitschrift fur Geomorphologie, v.7(1), p.49-70.

222
Kuo, W.K.; Yeh, C.C. (1964) Preliminary note on Quaternary glaciation in northeastern Yunnan. Bulletin of the Geological Society of China, 24, p. 115-24.

223
Lee, J.S. (1933) Quaternary glaciation in the Yangtze valley. Bulletin of the Geological Society of China, v.13, p.15-62.

224
Lee, J.S. (1934) Data relating to the study of the problem of glaciation in the lower Yangtze valley. Bulletin of the Geological Society of China, v.13,

225
Lee, J.S. (1936) Confirmatory evidence of Pleistocene glaciation from the Huang-Shan, southern Anhui. Bulletin of the Geological Society of China, v.16, p.279-90.

226
Lee, J.S. (1947) Vestiges of corrie glaciation on the Kweichow plateau. Bulletin of the Geological Society of China, v.27, p.35-53.

227
*Li, Bingyuan; Zhang, Qingsong (1980) Some points on the division of Quaternary glaciation in Southern Xizang. Journal of Glaciology and Cryopedology, v.2(3), p.52-55. In Chinese.

228
Li, C.; Wu, Y.S. (1940) Preliminary note on Quaternary glaciation in western Hupeh. Bulletin of the Geological Society of China, v.20, p.15-22.

229
Li, Y.; Pan, C.; Tsao, C.; Hu, C. (1973) Further notes on Quaternary glaciations in China. Acta Geologica Sinica (Peking), 1, p.94-101.

230
Ma, T.Y.H. (1940) On the causes of climatic change and the last Quaternary glaciation in China. Bulletin of the Geological Society of China, v.20, p.343-355.

231
*Miller, Maynard M.; Leventhal, J.S.; Libby, W.F. (1965) Tritium in Mt. Everest ice - annual glacier accumulation and climatology at great equatorial altitudes. Journal of Geophysical Research, v.70(16), p.3885-88.

232
*Murzayeva, V.E. (1978) Posledneye oledeneniye zarubezhnoy Azii. (The last glaciation of non-Soviet Asia.) Materialy Glyatsiologischeskikh Issledovaniy. Khronika, Obsuzhdeniya, no. 34, p.84-93. In Russian with English summary.

233
Richardson, H.L. (1943) Ice age in west China. Journal of the Western China Border Research Society, (B), 14, 1.

234
Sun Tien-ching; Yang, Huan-jen (1961) Great ice age glaciation in China. Acta Geologica Sinica, v.41, p.234-244. In Chinese.

235
Trinkler, E. (1930) Ice age on the Tibetan plateau and in adjacent regions. Geographical Journal, v.75, p. 225-232.

236
Tsao, Chao-yuan, et al. (1963) Kuan yu chung kuo ping ch'i he chien ping ch'i wen t'i. (On the question of glacial and interglacial stages in China.) K'o Hsueh T'ung Pao (Science Bulletin), no. 3, p.29-30. In Chinese.

237
Tsui, Chich-tsui (1961) On the problem of Pleistocene ice-cover patterns in West China. Acta Geologica Sinica, v.44(2), p.229-45. In Chinese with English summary.

238
Wang, Ming-ye; Chung, Mein-ping (1965) Remnants of Quaternary glaciation on the Tibetan Plateau. Acta Geologica Sinica, v.31(1), p.62-63. In Chinese with English summary.

239
Ward, F.K. (1922) Glaciation of Chinese Tibet. Geographical Journal, v.59, p.363-369.

240
Weng, Wen-po; Lee, J.S. (1946) Preliminary study on the Quaternary glaciation of the Nanshan. Bulletin of the Geological Society of China, v.26, p.163-171.

241
Wissmann, H. von (1937) Quartare Vergletscherung in China. (Quaternary glaciation in China.) Zeitschrift der Gesellschaft fur Erdkunde zu Berlin, p.241-62. Also: Bulletin of the Geological Society of China, v.17(2), p.145-168.

242
Wissmann, H. von (1938) Loess-making and ice ages in China. Journal of the Geographical Society of China, v.5,p.3-6.

243
Wissmann, H. von (1959) Rezente und quartare Verglatscherung des Yulungschan. (Present day glaciation and former ice cover in Yulungshan mountains in Yunnan Provice.) Mitteilungen der Osterreichischen Geographischen Gessellschaft, v.101(2), p.165-82. In German.

244
*Xu, Qinqi (1980) Introduction of a theory-Ice Ages controlled by variations of the Earth's orbit. Journal of Glaciology and Cryopedology, v.2(2), p.53-57. In Chinese.

245
*Yan, Qieshang; Xu, Shuiyan (1980) On the problem of further investigation of the Pleistocene glaciation of eastern China. Journal of Glaciology and Cryopedology, v.2(4), p.52-57. In Chinese.

246
Yang, Huai-jen; Ch'iu, Shu-chang (1965) Quaternary glaciation and the postglacial climatic fluctuations in the region of Urumchi Valley, Sinkiang. Acta Geologica Sinica, v.31(3), p.194-212.

247
*Zheng, Benxing (1980) Recent advances of the study of Quaternary glaciation in Qing-Zang Plateau. Journal of Glaciology and Cryopedology, v.2(2), p.15-18. In Chinese.

248
Academia Sinica. Lanzhou Institute Glaciology, Cryopedology and Desert Research. Glaciology Division (1975) Basic features of the glaciers in Mt. Jolmo Lungma area in southern Tibet, China. Scientia Sinica, 18, p.106-30.

249
*Academia Sinica. Lanzhou Institute of Glaciology and Cryopedology (1979) Batura Glacier in the Karakoram Mountains and its variations. Scientia Sinica, v.22(8), p.958-974.

250
Academia Sinica. Lanzhou Institute of Glaciology and Cryopedology (1980) Glaciers in China. Distributed by Guozishudian, P.O. Box 399, Beijing, China.

251
*Academia Sinica. Lanzhou Institute of Glaciology and Cryopedology (1980) New statistics on the area of glaciers in China. Journal of Glaciology and Cryopedology, v.2(2), p.7-10. In Chinese.

252
Academia Sinica. Research Institute of Geography (1959) T'ien Shan ping hsueh tso yuan k'ao ch'a. (Ice and snow survey of Tien Shan.) K'o Hsueh T'ung Pao (Science Bulletin), no. 19, p.659. In Chinese.

253
*Academia Sinica. Scientific Expedition to Tibet (1975) Report of Scientific Investigation in the Mt. Everest Region from 1966-1968: Modern Day Glaciers and Landforms (Glaciology and Geomorphology). Peking, Science Publications.

254
American Geographical Society (1958) Geographical Study of Mountain Glaciation in the Northern Hemisphere. Part 6 Western Arctic and Eastern Asia. New York, American Geographical Society, 54p.

255
Ashburner, John E.; Edmundson, Henry N.; Newby, Paul, R.T. (1967) Cambridge Hindu-Kush Expedition, 1966. Pembroke College, Cambridge, U.K.

256
Bailey, F.M. (1924) Through Bhutan and southern Tibet. Geographical Journal, v.64(4), p.291-97.

257
*Batura glacier in the Karakoram mountains and its variations (1979) Scientia Sinica, v.22(8), p.958-74.

258
Beletskii, E.A. (1958) V gorath Zapadnogo Kitaia. (In the mountains of western China.) Izvestiya Vsesoyuznogo Geograficheskogo Obshchestva, v.90, p.14-24. In Russian.

259
*Chen, Jianming (1980) Measurement of the variation of a glacial surface by a repeated terrestrial stereophotographic method. Journal of Glaciology and Cryo pedology, v.2(3), p.29-36. In Chinese with English abstract.

260
China. Karakoram Highway Engineering Headquarters. Batura Glacier Investigation Group (1976) Investigation report on the Batura Glacier in the Karakoram Mountains, the Islamic Republic of Pakistan (1974-1975). Peking, 123 p.

261
Chinese scientists survey world's highest peak. (1968) China Reconstructs, May, p.20-21, 24-27.

262
Chinese study Tibet's glaciers (1977) New Science (London), p.224.

263
Chiu, Chih-chiu (1958) Kung-Ke Shan hsien tai ping ch'uan te ch'u pu kuan ch'a. (Preliminary investigation of the modern glaciers of Kung-Ke Shan.) Ti Li Hsueh Pao (Acta Geographica Sinica) v.24(3), p.318-343. In Chinese.

264
Chiu, Chih-chiu (1960) Mu-shih-t'a-ko-kung-ko-er ping ch'uan ti mou hsueh t'e tien chi ch'i kai fa li yung ti t'iao chien. (Some characteristics and conditions for utilization and development of the Muztagh-Kungur Glaciers.) Ti Li Hsueh Pao (Acta Geographica Sinica), v.26(1), p.35-44. In Chinese. English translation by C.C. Pinther for the American Geographical Society, 1967.

265
*Distribution of isotopes in some natural waters in the region north of Mt. Jolmo Lungma. (1973) Scientia Sinica, v.16(4), p.560-564.

266
*Dolgushin, L.D. (1959) Sovremennoe oledenenie Nan'-Shania (Tsilen'-Shania) (Contemporary glacierization of Nan Shan (Kilien Shan).) Akademiia Nauk SSSR. Izvestiya. Seriya Geograficheskaya, no. 6, p.33-43. In Russian.

248
Academia Sinica. Lanzhou Institute Glaciology, Cryopedology and Desert Research. Glaciology Division (1975) Basic features of the glaciers in Mt. Jolmo Lungma area in southern Tibet, China. Scientia Sinica, 18, p.106-30.

249
*Academia Sinica. Lanzhou Institute of Glaciology and Cryopedology (1979) Batura Glacier in the Karakoram Mountains and its variations. Scientia Sinica, v.22(8), p.958-974.

250
Academia Sinica. Lanzhou Institute of Glaciology and Cryopedology (1980) Glaciers in China. Distributed by Guozishudian, P.O. Box 399, Beijing, China.

251
*Academia Sinica. Lanzhou Institute of Glaciology and Cryopedology (1980) New statistics on the area of glaciers in China. Journal of Glaciology and Cryopedology, v.2(2), p.7-10. In Chinese.

252
Academia Sinica. Research Institute of Geography (1959) T'ien Shan ping hsueh tso yuan k'ao ch'a. (Ice and snow survey of Tien Shan.) K'o Hsueh T'ung Pao (Science Bulletin), no. 19, p.659. In Chinese.

253
*Academia Sinica. Scientific Expedition to Tibet (1975) Report of Scientific Investigation in the Mt. Everest Region from 1966-1968: Modern Day Glaciers and Landforms (Glaciology and Geomorphology). Peking, Science Publications.

254
American Geographical Society (1958) Geographical Study of Mountain Glaciation in the Northern Hemisphere. Part 6 Western Arctic and Eastern Asia. New York, American Geographical Society, 54p.

255
Ashburner, John E.; Edmundson, Henry N.; Newby, Paul, R.T. (1967) Cambridge Hindu-Kush Expedition, 1966. Pembroke College, Cambridge, U.K.

256
Bailey, F.M. (1924) Through Bhutan and southern Tibet. Geographical Journal, v.64(4), p.291-97.

257
*Batura glacier in the Karakoram mountains and its variations (1979) Scientia Sinica, v.22(8), p.958-74.

258
Beletskii, E.A. (1958) V gorath Zapadnogo Kitaia. (In the mountains of western China.) Izvestiya Vsesoyuznogo Geograficheskogo Obshchestva, v.90, p.14-24. In Russian.

259
*Chen, Jianming (1980) Measurement of the variation of a glacial surface by a repeated terrestrial stereophotographic method. Journal of Glaciology and Cryo pedology, v.2(3), p.29-36. In Chinese with English abstract.

260
China. Karakoram Highway Engineering Headquarters. Batura Glacier Investigation Group (1976) Investigation report on the Batura Glacier in the Karakoram Mountains, the Islamic Republic of Pakistan (1974-1975). Peking, 123 p.

261
Chinese scientists survey world's highest peak. (1968) China Reconstructs, May, p.20-21, 24-27.

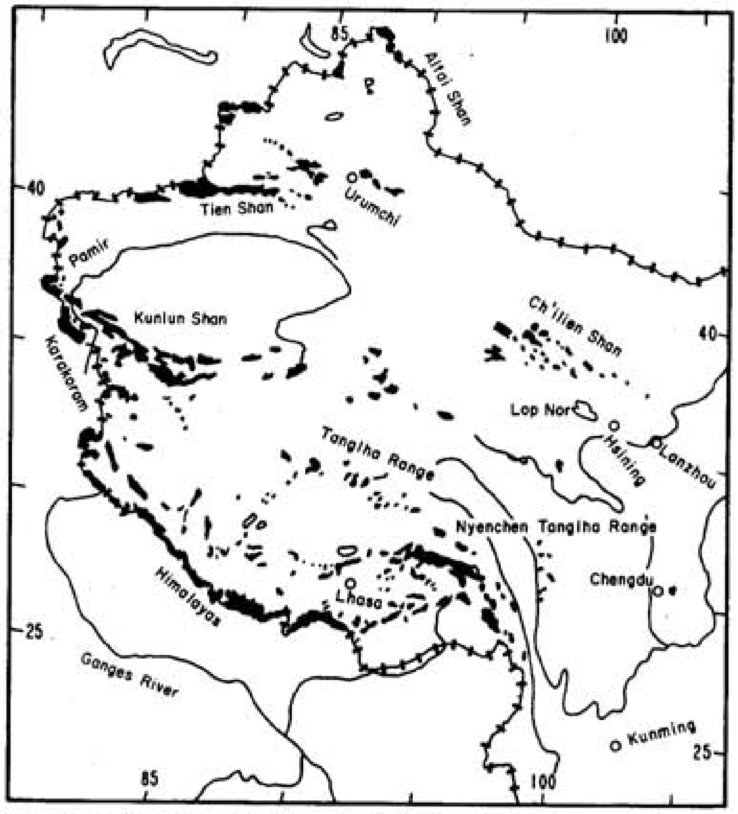
262
Chinese study Tibet's glaciers (1977) New Science (London), p.224.

263
Chiu, Chih-chiu (1958) Kung-Ke Shan hsien tai ping ch'uan te ch'u pu kuan ch'a. (Preliminary investigation of the modern glaciers of Kung-Ke Shan.) Ti Li Hsueh Pao (Acta Geographica Sinica) v.24(3), p.318-343. In Chinese.

264
Chiu, Chih-chiu (1960) Mu-shih-t'a-ko-kung-ko-er ping ch'uan ti mou hsueh t'e tien chi ch'i kai fa li yung ti t'iao chien. (Some characteristics and conditions for utilization and development of the Muztagh-Kungur Glaciers.) Ti Li Hsueh Pao (Acta Geographica Sinica), v.26(1), p.35-44. In Chinese. English translation by C.C. Pinther for the American Geographical Society, 1967.

265
*Distribution of isotopes in some natural waters in the region north of Mt. Jolmo Lungma. (1973) Scientia Sinica, v.16(4), p.560-564.

266
*Dolgushin, L.D. (1959) Sovremennoe oledenenie Nan'-Shania (Tsilen'-Shania) (Contemporary glacierization of Nan Shan (Kilien Shan).) Akademiia Nauk SSSR. Izvestiya. Seriya Geograficheskaya, no. 6, p.33-43. In Russian.



Distribution of existing glaciers in China. (Adapted from Journal of Glaciology and Cryopedology, v. 2(2), p. 8.)

267
Dolgushin, L.D. (1961) Main particularities of glaciation of Central Asia according to the latest data. (In: General Assembly of Helsinki, 1960. International Association of Scientific Hydrology. IAHS-AISH Publication no. 54. Gentbrugge, Belgium, p.348-58.)

268
Fei-tao-luo-wei-qi, B.A. (Fedorovich, B.A.?) (1960) The problem of frequency and type of glaciations in the Tien Shan's, western China. Quarternaria Sinica v.3(1-2). In Chinese.

269
Finsterwalder, R.; Schneider, E. (1958) Zur Karte des Chomolongma-Mount Everest 1:25,000. Zeitschrift fur Vermassungswesen, v. 83(4), p.123-36.

270
Freeberne, Michael (1965) Glacial meltwater resources in China. Geographical Journal, V.131 (pt. 1), p.57-60.

271
Gellert, J.F. (1966) Neue chinesische Hochgebirgs und Gletzcherforschung in Innerasien. (Recent Chinese mountain and glacier studies in central Asia.) Petermanns geographische Mitteilungen, v.110(3), p.198-199. In German.

272
Gregory, J.W.; Gregory, C.J. (1923) To the alps of Chinese Tibet. London, Seeley Service.

273
*Gu, Zhongwei (1980) Advances in radio-echo sounding of glaciers in foreign countries. Journal of Glaciology and Cryopedology, v.2 (Special issue), p.93-96. In Chinese.

274
Hedin, S. (1894) Forsuchungen uber die physische Geographie des Hochlandes von Pamir im Fruhjahr 1894. (Investigations of the physical geography of the Pamirs in the spring of 1894.) Zeitschrift Geschichte Erdkunde, v.29, p.289-346. In German.

275
Hedin, S. (1895) Die gletscher des Mus-tag-ata. (The glaciers of Mugtagh Ata.) Zeitschrift Geschichte Erdkunde, v.30, p.94-134. In German

276
Hedin, S. (1909) Trans-Himalaya. V.2, New York, Macmillan, 439p.

277
Hedin, S. (1922) Southern Tibet. Stockholm, Lithographia Institut.

278
*Hsieh, Tze-chu; Fei, Ching-shen (1980) Recent research on the distribution and fluctuations of the glaciers in Chilien Shan. (In: World Glacier Inventory. Proceedings of the Riederalp Workshop, 17-22 September 1978. IAHS-AISH Publication no. 126, p.117-20.)

279
Hsieh, Tzu-chu, et al. (1975) Basic features of the glaciers of the Mt. Jolmo Lungma region, southern part of the Tibet autonomous region, China. Scientia Sinica, v.18(1), p.106-30.

280
Huang, Mao-huan (1964) Hsi-Hsia-Pang-Ma ti ping hsueh shih chieh. (Snow and ice on Mt. Hsi-Hsia-Pang-Ma.) K'o Hsueh Ta Chung (Popular Science), no. 9, p.340-341. In Chinese.

281
Huang, Pei-hua (1963) Kuan yu ch'ang chiang yi nan ti ch'u ping ch'uan ye chi wen ti. (On the relic glaciers in the area south of the Yangtze River.) K'o Hsueh T'ung Pao (Science Bulletin), no. 10, p.29-33. In Chinese.

282
*Huang, Yizhi; Gu, Zhongwei; Wan, Tianqi; Gao, Yuanjin (1980) Experiment on radio-echo sounding of a mountain glacier. Journal of Glaciology and Cryodpedology, v.2(3), In p.37-39. In Chinese with English abstract.

283
Jen, Ping-hui (1963) Kao shen ping shueh li yung hsueh shu hui yi (Conference on utilization of snow and ice on high mountains.) K'o Hsueh T'ung Pao, (Science Bulletin) no. 7, p.71-72. In Chinese.

284
*Kang, Ersi; Zhu, Shousen; Huang, Mingmin (1980) Some results of the research on glacial hydrology in the region of Mt. Tuomuer. Journal of Glaciology and Cryopedology, v.2(4), p.18-21. In Chinese with English abstract.

285
Kaulback, R. (1938) Journey in the Salween and Tsangpo Basins, southeastern Tibet. Geographical Journal, v.91(2), p.97-122.

286
Kazakova, M.N. (1969a) Northwest China: the Mongolian-Sinkiang region. (In: Physical Geography of China, New York, Frederich A. Praeger, v.2, p.193-245)

287
Kazakova, M.N. (1969b) Tsinghai-Tibetan region. (In: Physical Geography of China, New York, Frederich A. Praeger, v.2, p.246-77.)

288
*Kick W. (1978) Eisgeschwindigkeitsmessungen an Gletschern Hochasiens: Geschichte-Technik-Ergebnisse. (Ice velocity measurements in glaciers of high Asia: History-technique-results.) Zeitschrift fur Gletscherkunde und Glazialgeologie, v.13 (1-2), p.7-22. In German.

289
*Kick, W. (1962) Variations of some central Asiatic glaciers. (In: Symposium on variation of the regimen of existing glaciers. General Assembly of Obergurgl, Austria. International Association of Scientific Hydrology. Publication no. 55. p. 223-229.)

290
Kick, W. (1966) Measuring and mapping of glacier variations. Canadian Journal of Earth Sciences, v.3(6), p. 775-81.

291
*Kikolski, Bohdan (1959) Wstepne wyniki chinskich badan glacjologicznych. (First results of the Chinese glaciological survey.) Przeglad Geograficzny, v.31(3-4) p. 683-91. In Polish with English summary.

292
*Kou, Youguan; Ding, Liangfu; Li, Wengzhou; Zhang, Yongling (1980) Glacial meteorology on Mt. Tuomuer. Journal of Glaciology and Cryopedology, v.2(4), p.11-14. In Chinese with English abstract.

293
Lehr, P.; Horvath, E., comps. (1975) Glaciers of China. (In: Field, W.O. ed. Mountain Glaciers of the Northern Hemisphere, v.1. U.S. Army. Cold Regions Research and Engineering Laboratory, p.449-75.)

294
*Li, Chi-chun; Cheng, Pen-hsing (1980) Recent research on glaciers on the Chinghai Tibet Plateau. (In: World Glacier Inventory. Proceedings of the Riederalp Workshop, 17-22 September 1978. IAHS-AISH Publication no. 126, p.121-127.

295
*Li, Jijun (1980) Recent advances in the study of existing glaciers in Qing-Zang Plateau. Journal of Glaciology and Cryopedology, v.2(2), p.11-14. In Chinese.

296
Liu, En-lan (1943) Geography of Lifan. Journal of the Western China Border Research Society, (B), 14,1.

297
*Makarevich, K.G.; Suslov, V.F. (1976) Contemporary and historical fluctuations of the glaciers in Soviet and foreign parts of central Asia. (In: International Geographical Conference, 23rd, Moscow, July-August 1976. Proceedings. Vol. 2, p.304-307.)

298
*Mayewski, Paul A.; Jeschke, Peter A. (1979) Himalayan and trans-Himalayan glacier fluctuations since A.D. 1812. Journal of Arctic and Alpine Research, v.11(3), p.267-87.

299
*Mercer, John H. (1963) Glacier variations in the Karakoram. Glaciological Notes (New York), no. 14, p.19-33.

300
*Method of radiation and heat balance and its application in investigation of glacier and permafrost. (1980) Journal of Glaciology and Cryopedology, v.2 (Special Issue), p.32-33. In Chinese.

301
Morrison, Charles, C.; Van Summern, Jane; McCauley, Camilla (1958) Geographic study of mountain glaciation in the northern hemisphere. Part 7a. Central Asian mountain system. Part 7b. Central Asian mountain system. New York, American Geographical Society, Department of Exploration and Field Research.

302
Muller, Fritz (1958) Eight months of glacier and soil research in the Everest region. Mountain World, 1958-1959, p.191-208.

303
Odell, N.E. (1925) Observation on rocks and glaciers on Mount Everest. Geographical Journal, v.66(4), p.66.

304
*Odell, N.E. (1941) Ablation at high altitudes and under high solar incidence. American Journal of Science, v.239, p.379-82.

305
Pai, Chung-ai; Hsieh, Wei-jung (1965) Tian Shan Wulumuqi he yuan gong hao bing chuan xiao rong qi jian kai guo bing mian shang de re liang bing heng. (The energy balance during the ablation season of the "Gonghao" Glacier at the source of the Wulumuqi River, Tian Shan) (In: Tian Shan Wulumuqi he bing chuan yu shui wen yan jiu. (Glaciology and hydrology of glaciers on the Wulumuqi River Tian Shan. Peking, Science Publications.) In Chinese.

306
Petrov, M.P. (1964) Vostochnyi Tian Shan kak fiziko-geograficheskii rubezh. (Eastern Tian Shan as a physical geographcial boundary.) Leningrad. Universitet. Vestnik, no. 6, p.124-138.

307
*Ren, Bing-hui (1980) Basic data on the main glaciers of China. Journal of Glaciology and Cropedology, v.2(1), p.60-61. In Chinese.

308
*Roch, A. (1954) Glaciers, snow and avalanches of Mount Everest. Journal of Glaciology, v.2(16), p.428-430.

309
Schneider, Hans-Jochen (1969) Minapin-Gletscher und Menschen im NW-Karakorum (Erlauterungen zur Expeditionskarte 1:50,000); Die Erde, v.100(2-4), p.266-286. In German.

310
Sheng, Benxing; Shi, Yafeng (1976) Report on the Mount Qomolongma Area Scientific Expedition 1966-1968. Quaternary Geology, Beijing, Science Press, p.29-62. In Chinese.

311
Shi, Yafeng (1959) Ch'i-lien shan hsien tai ping cn'uan tzu yuan chi ch'i li yung wen t'i.(Resources of modern glaciers in the Kilien mountains and their utilization.) K'o Hsueh T'ung Pao (Science Bulletin) no. 3, p.73-76. In Chinese.

312
Shi, Yafeng (1959) Let the high altitude glaciers serve the arid climatic regions of the northwest. (In: Forward-Leaping Geographic Scholarship of China, Academia Sinica, Institute of Geography. Chapter 6.)

313
*Shi, Yafeng (1960) Glaciers al servicio de la agricultura en China popular. (Glaciers in tne service of agriculture in Communist China.) Revista Geografica de Chile, no. 19, p.44-50. In Spanish.

314
*Shi, Yafeng (1964) Chinese research on glaciology, permafrost and arid land hydrography in the past five years. Washington, D.C., Office of Technical Services, JPRS 25,016.

315
Shi, Yafeng (1964) Wu nien lai te Chung-kuo ping ch'uan hsueh, tung t'u nsueh yu kan lan ch'u shui wen yen chiu. (Cninese research on glaciology, permafrost and arid land hydrography in the past five years.) K'o Hsueh T'ung Pao, (Science Bulletin), no. 3, p.218-225. In Chinese.

316
*Shi, Yafeng; Hsieh, Tze-chu; Cheng, Pen-hsing; Li, Chi-chun (1980) Distribution, features and variations of glaciers in China. (In: World Glacier Inventory. Proceedings of the Riederalp Workshop, 11-22 September 1978. IAHS-AISH Publication no.126, p.111-16.

317
Shi, Yafeng; Wang, Jingtai (1979) Fluctuation of climate, glaciers and sea-level since the late Pleistocene in China. Academia Sinica, Lanzhou Institute of Glaciology and Cryopedology, 21 p. Also: International Union of Geodesy and Geophysics. General Assembly, 17th, Canberra 3-15 December 1979. Abstracts, p.73.

318
Shi, Yafeng; Zie Zi-chu (1964) Chungkuo xian dai bing chuan de ji ben te cheng. (Basic characteristics of existing glaciers in China.) Acta Geographica Sinica, v.30(3), p.182-213. In Chinese.

319
Shih, S.Y. (1963) Study of contemporary glaciation of Chinese Tienshan mountains. Acta Geographica Sinica, v.29(4), p.310-328.

320
Siddiqi, M.I. (1962) Tibet today. Pakistan Geographical Review, v.17(2), p.25-36.

321
Stein, M.A. (1921) Serindia: a detailed report of exploration in Central Asia and Western-most China. Oxford, Clarendon Press, 5 v.

322
Su, C. (1973) Modern glaciers in Mount Everest region. Ke Xue Zhi yen, Peking, v.4, p. 26-27. In Chinese.

323
*Sun, Zuozhi; Chen, Jianming (1980) Measuring of glacier variations by repeated terrestrial stereophotogrammetric method Journal of Glaciology and Cryopedology, v.2 (Special issue), p.54-56. In Chinese.

324
*Times, London (1961) Plan to use glaciers for irrigation in China. Journal of Glaciology, v. 3(30), p. 1157.

325
Trinkler, E. (1932) Geographische Forschungen im Westlichen Zentralasien und Karakoram-Himalaya. (Geographical research in West Central Asia and the Karakoram Himalaya.) Berlin, Dietrich Reimer and Ernest Vohsen, 133p. In German.

326
Tseng, Ming-hsuan; T'ong, Kuan-jung (1966) Mu-Tu-Da-Ge Shan qie-qian gan Bu-La-Ke bing chuan xiao rung ch'i de fu she yu re liang ping heng. (Energy balance and radiation during the ablation season on the Bu-La-ke Glacier, Mutudage Mountain.) (tentative translation). (In: Gan han qu, di li xue shu hui yi lun wen xuan ji. Collected works on a geographical conference on arid regions, Science Publications.)

327
Ts'ui, Chih-chiu (1958) Gong-Ga Shan Xian-dai bing-chuan de chu-bu guan-cha. (Initial observations of the glaciology on Mount Gong-Ga) Journal of the Geographical Society of China, v.24(3). In Chinese.

328
Ts'ui, Chih-chiu (1960) Mu-Tu-Da-Ge yi Gong-Ge-Qian bing chuan de "ji"(?) xie te dian ji chi kai fa li yong de tiao jian. (Yigongge qian Glacier, Mutudage (Mt.): its basic characteristics and factors for its use and development.) Journal of the Geographical Society of China, v.26(1).

329
Wang, Chung-long (1966) Engergy balance during the ablation season on the KungHao Glacier.of the Shin Kuan riverhead, eastern Qi-Lian. (In: Collected works of the Conference on Geography of Arid Regions, Peking, Science Publications.) In Chinese.

330
*Wang, Jiyou, Luo, Xiangrui (1980) Application of microwave range finding in the surveying of glaciers and permafrost on Qingzang Plateau. Journal of Glaciology and Cryopedology, v.2 (Special issue), p.56-60. In Chinese.

331
*Wang, Liangwei; Zhu, Guocai; Qian, Songlin; Wang, Wanlin (1980) Systems of data transferand measurement in radio telemetry station on glacier. Journal of Glaciology and Cryopedology, v.2 (Special issue), p.3-7. In Chinese.

332
Wang, Lilun; Zhang, Wenying; Su, Zhen (1980) Primary results of the study of modern glaciers in the region of Mt. Tuomuer. Journal of Glaciology and Cryopedology, v.2(4), p.15-17. In Chinese with English abstract.

333
*Wang, Ping; Luo, Hongzhen (1980) Trace element content in snow and ice samples ofwest Qiongtailan glacier, Mt. Tuomuer. Journal of Glaciology and Cryopedology, v.2 (Special issue), p.77-79. In Chinese.

334
*Wang, Rui; Tang, Lingyu (1980) Preliminary application of pollen analysis method to the research of annual layer of glaciers. Journal of Glaciology and Cryopedology, v.2 (Special issue), p.87-90. In Chinese.

335
*Wang, Wenying; Cheng, Jianming (1980) Terrestrial stereophotogrammetric surveying and mapping in the region of Mt. Qomolangma, the Batura Glacier in the Karakoram. Journal of Glaciology and Cryopedology, v.2(4), p.22-28. In Chinese with English abstract.

336
*Wang, Wenying; Huang, Mao-huan (1980) Recent situation of Baltbare surging glacier, Pakistan. Journal of Glaciology and Cryopedology, v.2(1), p.26-31. In Chinese.

337
*Wang, Zhongxiang (1980) Method of observing and determining the mass balance of continental glaciers. Journal of Glaciology and Cryopedology, v.2 (Special issue), p.48-51. In Chinese.

338
Ward, F.K. (1916) Glacial phenomena on the Yun-nan Tibet frontier. Geographical Journal, v.48(1), p.55-68.

339
Ward, F.K. (1922) Glaciation of Chinese Tibet. Geographical Journal, v.59, p.363-369.

340
Ward, F.K. (1923) From the Yangtze to the Irrawaddy. Geographical Journal, v.62(1), p. 6-20.

341
Ward, F.K. (1926) Exploration in south-eastern Tibet. Geographical Journal, v.67(2), p.97-123.

342
Ward, F.K. (1934) Himalaya east of the Tsangpo. Geographical Journal, v.84(5), p.369-97.

343
Wei, Wang (1960) Glaciers to serve production. Peking Review, v.3(9), p.18-19.

344
Wissmann, H. von (1959) Heutige Vergletscherung und Schneegrenze in Hochasien. (Contemporary glaciation and the snow line in Asia.) Akademie der Wissenschaften und der Literatur in Mainz. Mathematisch-Naturwissenschaftlichen Klasse. Abhandlungen, no.14, p.1103-1407.

345
Wissmann, H. von (1959) Rezente und quartare Vergletscherung des Yulungschan. (Present day glaciation and former ice cover in Yulungshan mountains in Yunnan Provice.) Mitteilungen der Osterreichischen Geographischen Gessellschaft, v.101(2), p.165-82. In German.

346
*Wu, Huanzhong (1980) Application of remote sensing data in glacial mapping work. Journal of Glaciology and Cryopedology, v.2 (Special issue), p.60-61. In Chinese.

347
*Wushiki, Hisao (1976) Chugoku ni okerunhimaraya-hyoga no kenkyu. (Chinese research on the Himalayan glaciers.) Seppyo, v.38(1), p.32-51.

348
Xie Zichu; Su, Zhen (1975) Distribution, type, size and number of glaciers in the Mt. Everest Region. (In: Report on the 1966-68 Scientific Expedition to the Mt. Qomolangma Region: Glaciology and Geomorphology, Peking, p.1-14.) In Chinese.

349
*Xie, Zichu (1980) Mass balance of glaciers and its relationship with characteristics of glaciers. Journal of Glaciology and Cryopedology, v.2(4), p.1-10. In Chinese with English abstract.

350
Yen, Ch'in-shang; Hsu, Shih-yuan; Jen, Ping-hui (1964) Chu i pu K'ai chan wo kuo ping ch'uan ping yuan fang mian yen chiu ti chi ko wen ti. (Some problems of promoting studies of glaciers and glacial margins in China.) Acta Geographica Sinica, v.30(2), p.174-181. In Chinese.

351
*Yin, Shizong (1980) Experiment in the preparation of glacier distribution map (scale 1:1M)of Xizang plateau with MSS images. Journal of Glaciology and Cryopedology, v.2(Special issue), p.67-70. In Chinese.

352
Zabirov, R.D. (1960) Pamir bing chuan tso yong. (Glacial activity in the Pamirs.) Peking, Science Publications, 188p. In Chinese.

353
*Zabirov, R.D.; Knizhnikov, IU. (1962) Fototeodolitnaia s'emka lednikov Tian-Shania v period MGG. (Phototheoditic survey of the Tien Shan glaciers during the I.G.Y.) Frunze, Akademia Nauk Kirgizskoi SSSR, 100p. In Russian with English summary.

354
*Zhang, Xiangsong (1980) Recent variations o the Insukati Glacier and adjacent glacier in the Karakoram Mountains. Journal of Glaciology and Cryopedology, v.2(3), p.12-16. In Chinese with English abstract.

355
Zheng, Benxing; Shi, Yafeng (1975) Changes in glaciers in the Mt. Qomolangma region. (In: Report on the 1966-1968 Scientific Expedition to the Mt. Qomolangma region: Glaciology and Geomorphology, Peking. Science Publications.)

356
*He, Jie; Zheng, Qipu (1980) Application of thermal resistor in measuring temperature of frozen soil. Journal of Glaciology and Cryopedology, v.2 (Special issue), p.20-23. In Chinese.

357
*Li, Weixin; Liu, Haisheng (1980) Designing and making of snow densitometer. Journal of Glaciology and Cryopedology, v.2 (Special issue), p.30-31. In Chinese.

358
*Wang, Liangwei; Zhu, Guocai; Qian, Songlin; Wang, Wanlin (1980) Systems of data transfer and measurement in radio telemetry station on glacier. Journal of Glaciology and Cryopedology, v.2 (Special issue), p.3-7. In Chinese.

359
*Wang, Wenying; Chen, Xiaobai (1980) New stage in the development of measuring and testing technique in glaciology and cryopedology. Journal of Glaciology and Cryopedology, v.2 (Special Issue), p.1-2. In Chinese.

360
*Yu, Jimin; Chen, Xuede; Wang, Changling (1980) Remote measuring and auto-recording of ground temperature. Journal of Glaciology and Cryopedology, v.2 (Special issue), p.7-9. In Chinese.

361
*Zhou, Fuchun; Chen, Dawei (1980) Measurement of permafrost table by portable seismograph. Journal of Glaciology and Cryopedology, v.2 (Special issue), p.9-12. In Chinese.

362
*Zhu, Guocai; Ji, Jianmiao (1980) Quartz crystal thermometer and its application in prmafrost drilling holes. Journal of Glaciology and Cryopedology, v.2 (Special issue), p.18-20. In Chinese.

363
*Zhu, Guocai; Zhang, Fuyuan (1980) Underground thermal current meter and its application in permafrost. Journal of Glaciology and Cryopedology, v.2, (Special issue), p.15-18. In Chinese.

364
*An, Zhongyuan (1980) Formation and evolution of permanent ice mound on Qing-Zang Plateau. Journal of Glaciology and Cryopedology, v.2(2), p.25-30. In Chinese.

365
*Chen, Xiaobai (1980) Observations of frost heave and frost heaving force in the Jiangcan District, Qiliang Shan. Journal of Glaciology and Cryopedology, v.2(2), p.36-40. In Chinese.

366
Cheng, Kuo-tung; Tung, Po-liang; Lo, Hsueh-bo (1978) Experimental research on embankment in an area with massive ground ice. (In: International Conference on Permafrost, 3rd, Proceedings, v.2, p.199-221.)

367
Chou, Yu-wu; Tu, Yung-huang (1963) Ching ts'ang kao yuan tung t'u ch'u pu kao ch'a. (Preliminary studies on frozen earth on the Tsinghai-Tibetan Plateau.) K'o Hsueh Tung Pao (Science Bulletin), no. 2, p.60-53. In Chinese

368
*Cui, Zhijiu (1980) On the periglacial mark in permafrost areas and the relation between glaciation and periglaciation. Journal of Glaciology and Cryopedology, v.2(2), p.1-6 In Chinese.

369
*Ding, Jingkang; Lou, Anjin (1980) Method of determining the horizontal frost heave force in situ. Journal of Glaciology and Cryopedology, v.2 (Special issue), p.33-36. In Chinese.

370
Fu, Pao-p'o (1958) Kuan yu chi suan k'o nengtsue ta tung chieh shen tu chi k'o neng tsue ti tu wen t'i. (On the computation of the probable maximum freezing depth and minimum soil temperature.) Acta Meteorologica Sinica, v.29(2), p.63-72. In Chinese.

371
*Fu, Rong; Zhang, Jinsheng; Hou, Zhongjie (1980) Preliminary research on ultrasonic measurement of frozen soil and ice. Journal of Glaciology and Cryopedology, v.2 (Special issue), p.44-48. In Chinese.

372
*He, Jie; Zheng, Qipu (1980) Application of thermal resistor in measuring temperature of frozen soil. Journal of Glaciology and Cryopedology, v.2 (Special issue), p.20-23. In Chinese.

273
*He, Yixian (1980) Numerical interpretation of resistivity sounding data in permafrost regions. Journal of Glaciology and Cryopedology, v.2 (Special issue), p.37-39. In Chinese.

374
Heim, A. (1936) Glaciation and solifluction on Minya Gongkar. Geographical Journal v.87(5), p.444-54.

375
*Li, Lie; Xing, Zemin (1980) Characteristics of underground ice in the District of Fenghuo Shan along the Qing-Zang Highway. Journal of Glaciology and Cryopedology, v.2(2), p.31-35. In Chinese.

376
Lin, Feng-t'ung (1959) Ta Hsiao Hsing-anling yung chiu tung t'u ti ch'u chao ti hsia chui ching yen. (Experiences in searching for underground water in the permafrost areas of Ta-hsiao-An Ridge.) Shui Wen Ti Chih King Ch'eng Ti Chih (Hydrogeology and Engineering Geology), no. 6, p.37-40. In Chinese.

377
*Lin, Feng-tong (1980) On selection and evaluation of the sources of water supply in the permafrost regions in Ta-Xiao Xing An Ling. Journal of Glaciology and Cryopedology, v.2(1), p.32-36. In Chinese.

378
Marinov, N.A. (1968) Merzlaya zona Azii. (The frozen zone of Asia.) Akademia Nauk SSSR. Seriya geograficheskaya. Izvestiya, no. 2, p.29-38.

379
*Method of radiation and heat balance and its application in investigation of glacier and permafrost. (1980) Journal of Glaciology and Cryopedology, v.2 (Special issue), p.32-33. In Chinese.

380
Murzaev, E.M. (1955) Severo-vostochnyi Kit'ai. (Northeastern China.) Moscow, Izdatelstvo Akademia Nauk SSSR, 251p. In Russian.

381
Pan, Chun-mu; Hsia, T'ieh-ten (1958) Yung chiu tung chieh ti ch'u ti hung ch'eng ti chieh wen t'i. (Problems of engineering geology in permafrost areas.) Quaternaria Sinica, v.1(1), p.272-276. In Chinese.

382
*Qiu, Guoqing (1980) On the engineering geological survey in the alpine permafrost regions of West China. Journal of Glaciology and Cryopedology, v.2(3), p.17-23. In Chinese with English abstract.

383
*Shi, Yafeng (1964) Chinese research on glaciology, permafrost and arid land hydrography in the past five years. Washington, D.C., Office of Technical Services, JPRS 25,016.

384
Shi, Yafeng (1964) Wu nien lai te Chung-kuo ping ch'uan hsueh, tung t'u hsueh yu kan lan ch'u shui wen yen chiu. (Chinese research on blaciology, permafrost and arid land hydrography in the past five years.) K'o Hsueh T'ung Pao, (Science Bulletin), no. 3, p.218-225. In Chinese.

385
Sugaya, Juji (1956) Congelation structure and frost-heaving ratio at Assan, Manchuria. Canada, Defence Science Information Serivce, 17p.

386
*Wang, Jiyou; Luo, Xiangrui (1980) Application of microwave range finding in the surveying of glaciers and permafrost on Qingzang Plateau. Journal of Glaciology and Cryopedology, v.2 (Special issue), p.56-60. In Chinese.

387
*Xing, Zemin; Wu, Xiaoling; Qu, Ronghang (1980) Determination of ancient permafrost table, based on the variation of the content of clay minerals. Journal of Glaciology and Cryopedology, v.2 (Special issue), p.39-44. In Chinese.

388
*Zheng, Qipu (1980) Hydrogeological characteristics of permafrost and cold regions in Dahinganling. Journal of Glaciology and Cryopedology, v.2(4), p.44-51. In Chinese with English abstract.

389
*Zhou, Fuchun; Chen, Dawei (1980) Measurement of permafrost table by portable seismograph. Journal of Glaciology and Cryopedology, v.2 (Special issue), p.9-12. In Chinese.

390
*Zhu, Guocai; Ji, Jianmiao (1980) Quartz crystal thermometer and its application in permafrost drilling holes. Journal of Glaciology and Cryopedology, v.2 (Special issue), p.18-20. In Chinese.

391
*Zhu, Guocai; Zhang, Fuyuan (1980) Underground thermal current meter and its application in permafrost. Journal of Glaciology and Cryopedology, v.2 (Special issue), p.15-18. In Chinese.

392
*Zhu, Yangfu (1980) Freezing-thaw regularity of railway bed in the permafrost region o the Qinghai-Xizang Plateau. Journal of Glaciology and Cryopedology, v.2(4), p.38-43. In Chinese with English abstract.

394
*Zhuo, Chan-qing (1980) Introduction to the achievements of the study on the bases and foundations of frozen ground in China. Journal of Glaciology and Cryopedology, v.2(1), p.1-5. In Chinese.

394
Academia Sinica. Research Institute of Geography (1959) T'ien Shan ping hsueh tzu yuan k'ao ch'a. (Ice and snow survey of Tien Shan.) K'o Hsueh T'ung Pao (Science Bulletin), no.19, p.659. In Chinese.

395
*Bai, Zhongyuan; Wang, Zhonglong (1979) Moving features of snow drift in the region of Tian Shan in China. Academia Sinica, Lanzhou Institute of Glaciology and Cryopedology, 23p.

396
Chen, C.L. (1958) Problems of frost supplementary forecast of individual stations. Weather Monthly (Peking), 10, p.15-17.

397
Chen, Jih-nung (1966) On the Szechuan-Tibet highway. China Reconstructs, v.15(3), p.40-44.

398
Chen, Su (1973) Keeping the road open in snow. China Reconstructs, v.22(1), p.16-18.

399
Ching, (1957) Discussion of the snowy shower, Chengtu, 8th August 1956. Weather Monthly (Peking), 8, p.31.

400
Chou, H. (1959) Distinctive result obtained by primitive method on the prevention of sleet damage at Ho-chien hsien in Hung-Nan. Scientia, (Peking), 1, p.30-31. In Chinese.

401
Chu, C.K. (1959) Forecasting of early frost in the northern region. Weather Monthly (Peking), 101, p.9. In Chinese.

402
*Distribution of isotopes in some natural waters in the region north of Mt. Jolmo Lungma (1973) Scientia Sinica, v.16(4), p.560-564.

403
Flohn, H (1959) Bemerkungen zur Klimatologie von Hochasien; Aktuelle Schneegrenze und Sommerklima. (Notes on the climatology of Asia, contemporary snow line and summer climate.) Akademie der Wissenschaften und der Literatur, Mainz. Mathematisch-Naturwissenschaftlichen Klasse. Abhandlungen, no. 14, p.1409-1431. In German.

404
Hedin, S. (1894) Forsuchungen uber die physische Geographie des Hochlandes von Pamir im Fruhjahr 1894. (Investigations of the physical geography of the Pamirs in the spring of 1894.) Zeitschrift Geschichte Erdkunde, v.29, p.289-346. In German.

405
Honan Province. China Shin-Ping Station. (1959) On sleet which fell April 28. Weather Monthly (Peking), 99, p.43.

406
Hoynagi, Mutsumi (1966) Geographical problems concerning the old Silk Road region in theTarim Basin. Geographical Reports of Tokyo Metropolitan University, no. 4, 32p.

407
Hsing, Shu-peng (1957) On the phenomenon of frozen snow and rime occurring at the same time. Weather Monthly (Peking), 1, p.37-38.

408
Huang, Mao-huan (1964) Hsi-Hsia-Pang-Ma ti ping hsueh shih chieh. (Snow and ice on Mt. Hsi-Hsia-Pang-Ma.) K'o Hsueh Ta Chung (Popular Science), no. 9, p.340-341. In Chinese.

409
Hwang, Kuang-piao (1956) Taiwan Chih shuang hsueh. (Snow and hoarfrost in Taiwan.) Ch'i hsiang Hsueh Pao (Meteorological Bulletin. v. 2(4), p. 17-18. In Chinese.

410
Investigating the snow resources of the Qilian Mountains (1979) China Pictorial (English edition), no.368, p.43.

411
Jen, Ping-hui (1963) Kao shen ping shueh li yung hsueh shu hui yi (Conference on utilization of snow and ice on high mountains.) K'o Hsueh T'ung Pao, (Science Bulletin) no. 7,p.71-72. In Chinese.

412
Lauscher, Friedrich (1978) Schnee in China. (Snow in China.) Wetter und Leben, v.30(3), p.148-64. In German with English summary.

413
*Li, Weixin; Liu, Haisheng (1980) Designing and making of snow densitometer. Journal of Glaciology and Cryopedology, v.2 (Special issue), p.30-31. In Chinese.

414
Remarks on the method of snow density determination by means of snow sondes (1958) Weather Monthly, (Peking), v.11, p.34-35. In Chinese.

415
Shen, C.T. (1959) Early forecasting of frost in 1958 in the Amur region. Weather Monthly, (Peking) 101, p.17.

416
*Sheng, Wenkun (1980) Application of simple chemical analysis of natural water in the analysis of ice and snow samples. Journal of Glaciology and Cryopedology, v.2 (Special issue). p.91-92. In Chinese.

417
*Shi, Yafeng; Wang, Wenying (1979) Researches on snow cover in China and the avalanche phenomena of the Batura Glacier in Pakistan. Academia Sinica, Lanzhou Institute of Glaciology and Cryopedology, 9p.

418
Tang, Y.H. (1959) Application of Mihailov's formula for the forecasting of frost damage. Weather Monthly (Peking), 101, p.12

419
Ting, S.C. (1957) Frost and minimum temperature in Chengteh, Johol. Weather Monthly (Peking), 8, p.33-35.

420
Wiens, Harold, J. (1967) Regional and seasonal water supply in the Tarim Basin and its relation to cultivated land potential. Assciation of American Geographers Annals, v.57,p.350-366.

421
Wissmann, H. von (1959) Heutige Vergletscherung und Schneegrenze in Hochasien. (Contemporary glaciation and the snow line in Asia.) Akademie der Wissenschaften und der Literatur in Mainz. Mathematisch-Naturwissenschaftlichen Klasse. Abhandlungen, no.14, p.1103-1407.

422
*Workman, William Hunter (1909) Study of nieve penitente in Himalaya. Zeitschrift fur Gletscherkunde, v.3, p.241-270.

423
Wu, L. (1958) Problems and their solutions of observation of temperature, humdity an wind speed and direction at high mountain stations during winter icing conditions. Weather Monthly (Peking), 10, p.36-39.

424
Zhang, Peiyuan; Gong, Gaofa (1980) Ancient precipitation records in China. World Meteorological Organization. WMO Bulletin v.29(1), p.7-10.

425
*Zhang, Xiangsong (1980) Recent research on snow and ice in the world. Journal of Glaciology and Cryopedology, v.2(1), p.54-58. In Chinese.

AUTHOR INDEX

COMMUNICATIONS

Pictorial Records of Glaciers

Charlene Wright Locke
World Data Center A for Glaciology (Snow and Ice)
University of Colorado
Boulder, Colorado, U.S.A.

INTRODUCTION

"One picture is worth a thousand words." In the study of glaciers - their fluctuations, behavior, and peculiarities - pictures are of the utmost importance. Glaciers, as agents of environmental modification, monitors of climatic change, and sources of fresh water, as well as being objects of wonder and inspiration, have been subjects for study for many centuries. By using pictures of glaciers, whether a drawing, photograph, air photograph, or satellite image, we can learn many things about glaciers and climatic fluctuations. We have no way of knowing whether a scientist or an artist was the first to study a glacier, but from the first accurate depictions of a glacier, the scientist has been helped by having a record of the state of a glacier at a certain time.

Nearly 15 million km^2 (approximately 10 percent) of the land surface of the world is presently covered by ice (Flint, 1971). As our world becomes smaller through ever-expanding communication and transport networks and an exploding world population, the role of glaciers and glacierized areas for human use is certain to increase. These glacierized areas, although mainly remote from present population centers, could be increasingly significant for human activities for a number of reasons, primarily water supply. Approximately 75 percent of all fresh water on the earth is in the form of glacier ice (Meier, 1976).

It is also important to remember that glaciers are subject to drastic changes. Geologically a mere 14,000 to 20,000 years ago, glaciers covered more than 44 million km^2 (approximately 29 percent) of the land surface (Flint, 1971). As population increases and glacier fluctuations become more important, accurate inventories and maps of glacier distribution as well as the monitoring of their behavior and peculiarities become more important. Studies of glaciers over the last few centuries have been greatly helped by documentary and pictorial records, e.g., Messerli et al. (1978) for the Alps.

Geologists and geographers use many methods (such as moraine records, boulder weathering, and lichenometry) to study glacier fluctuations. These methods, however, only date maximum extent of the ice. Other techniques of Quaternary paleoenvironmental analysis, such as palynology and dendroclimatology, offer continuous records and high resolution. They are, however, only proxy records for glacial fluctuations, and thus may be inaccurate in detail. In contrast, a pictorial record shows the actual extent of the glacier, whether at a maximum, minimum, or intermediate position. Obvious disadvantages in the use of pictures for studying historical glacier fluctuations are the relatively short period of time and limited geographic coverage (mainly populated areas such as the Alps and some coastal areas such as Glacier Bay, Alaska) for which pictures are available; their advantages are discussed below. The study and monitoring of current glacier behavior is also greatly aided by pictorial studies ranging from large-scale terrestrial photographs to intermediate-scale air photographs to small-scale satellite imagery. It is always helpful to remember that a picture may be interpreted at a later date, or compared with later information, regardless of whether the significance was realized at the time the picture was taken (Harrison, 1954).

The purpose of this paper is to discuss several types of picture and their role in the study of glaciers. Brief descriptions are given of the glacier photograph collections of the American Geographical Society/W.O. Field and the U.S. Geological Survey (Tacoma)/A.S. Post and R. Krimmel/L.Mayo, which are being indexed at the World Data Center-A for Glaciology and which are believed to be the largest combined set of United States glacier photographs.

TYPE OF PICTURES

There are four main types of glacier pictures: drawings, terrestrial photographs, air photographs, and satellite imagery. All share the common characteristic of recording the features of a glacier at a point in time. Beyond that they differ in nearly all respects - scale, accuracy, point of view, and temporal coverage; yet each has significant advantages as well as drawbacks.

A. Drawings

Some of the earliest pictorial records of glaciers date from the 17th and 18th centuries (Merian, 1642 and Altmann, 1751 in Le Roy Ladurie, 1971), a time when many parts of the world were undergoing a marked climatic cooling and the majority of glaciers were advancing. This so-called Little Ice Age (A.D. 1500-1920; Sugden and John, 1976, p. 114-120) had a considerable impact on human civilization, so it is not surprising to find drawings of many glaciers at relatively advanced positions during this time. The 16th through 19th centuries were also a time of great geographical exploration, so we find glacier references (sketches, maps, and text) in many expedition journals (e.g., Saussure, 1779; Laperouse, 1789; Reid, 1890 and 1892). These earliest drawings are a valuable record of glacier fluctuations because once a picture exists, all subsequent pictures can be compared to it in order to define advances and retreats.

The major disadvantage of using drawings in the study of glaciers is the possibility that the picture is not accurately drawn. For example, a watercolor painting would be less likely to show details than would, say, an engraving. However, if the drawing is compared with a photograph or with the actual site, one would most likely be able to gauge the general accuracy of the drawing by comparison of rock outcrops, ridge lines, stream valleys, and the like. Le Roy Ladurie (1971) states that early pictorial work provides evidence for the comparison of glacier termini then and now. Rarely is any data available on the thickness of the glacier upvalley. However, Ladurie gives a fine example of marked changes in thickness on the Montenvers Glacier by comparing an engraving made in 1781 with a 1966 photograph taken from approximately the same site.

The ability to distort reality in drawings can be an advantage. Where comparatively subtle features (such as flow features) are present, but will not show up well on conventional photographic images, they can be enhanced by a skilled artist.

Drawings are quite similar to terrestrial photographs. The primary advantage of drawings is in their having the longest length of record of all the types of glacier pictures; their disadvantage is in uncertainty of accuracy in all details.

B. Photographs

Photographs give us many advantages over simple observations, including the ability to stop action. All surficial features on and around the glacier are recorded simultaneously, including those which are considered unimportant at the time, but are later determined to be significant. Photographs also allow a broadened spectral sensitivity. Film can "see" and record over a wavelength range approximately twice as broad as that of the human eye (0.3-0.9 μm vs 0.4-0.7 μm; Lillesand and Kiefer, 1979), thus invisible ultraviolet and reflected infrared energy can be detected and recorded in the form of a visible image. Photographs may bring out detailed depositional and erosional patterns not noticed by an observer at the site because the film can emphasize color values and relief that are not very apparent otherwise (Veatch, 1969). By viewing photographs under magnification or using a telephoto lens, it is possible to see more detail than with the unaided eye. Most importantly, with proper ground reference data, it is possible to obtain measurements of positions, distances, directions, areas, heights, volumes, and slopes from a photograph.

1. Terrestrial Photographs

A terrestrial photograph is one taken from the earth's surface, whether on rock, water, or the ice itself. Cameras date back to the early 19th century, and glaciers did appear as photographic subjects towards the end of that century. In North America, a number of scientists and explorers, H.F. Reid, G.K. Gilbert, and I.C. Russell among them, photographed glaciers in the 1880's and 1890's. Most of these photographs, like the drawings before them, recorded glacier termini. One of the earliest collections of glacier photographs, covering the Alaska/Canada border, is that from the surveys done by the International Boundary Commission beginning in 1893 (International Boundary Commission, 1918, 1952). Most of the boundary photographs were taken from adjacent peaks and so have different vantage points than most early photographs, thus revealing cirques and accumulation areas. These photographs have much in common with air photography.

One of the longest continuous glacier research projects in which terrestrial photographs play a key role is the work of W.O. Field and others in Alaska (see Field, 1979). He has been studying, photographing, and recording glacier behavior at intervals of a few years for more than 50 years, mainly in the Glacier Bay region but also in other parts of the St. Elias, Chugach, Kenai, Wrangell, and Coast Mountains, and the Alaska Range. Photographic stations which had been established years earlier by other scientists were used whenever possible, so exact duplication of photographs was possible over the maximum period of time.

With nearly 100 years of photographs available for study including his own field work, Field has a remarkable record of glacier behavior and fluctuations. He has used photographs to document surging glaciers and to interpret the catastrophic recession of tidewater glaciers (Field, 1969, 1979). His work is a very successful combination of historical and recent terrestrial photographs, and more recently air photographs, with detailed field work.

Another detailed long-term photographic study was that of F.M. Veatch, who annually photographed the Nisqually Glacier on Mt. Rainier for 24 years (1942-1966). A network of about 20 stations was set up on the ground in order to systematically cover nearly the full length of the glacier. When possible, stations were established at sites from which still earlier photographs had been taken. A number of photographs taken sporadically from 1884 to 1941 were used for comparative purposes, as were engineering surveys. Because of the Nisqually Glacier's accessibility by highway, its variety of features, the availability of data from previous investigators, concurrent topographical and profile survey data, and weather observations at the Paradise Ranger Station located less than one mile from the glacier, it is ideally suited for this sort of study.

Veatch's paper (1969) presents results from his study in such a manner that the potential for similar studies is apparent. Quantitatively, changes in ice thickness and lateral ice margins, and the longitudinal slope of the ice surface were measured. The elevation of the snow line and firn edge were measured in late summer each year. Qualitatively, the characteristics of the terminus, whether actively bulging and crevassing, indicating expansion, or more gently sloping and less crevassed, indicating retreat or stagnation, are a key to the glacier's dynamic state. Annual photographs do not necessarily reveal all movements of the terminus, but do show the yearly trends. Also interpreted were debris cover and distribution (including sources of debris) and moraine patterns. Characteristics of the glacier surface, especially crevasses, were studied and used to determine subsurface conditions such as direction and rate of movement and location of subglacial obstructions. Erosion and deposition in the area around the glacier were studied along with effects of outburst floods.

A repetitive photographic program, which is relatively quick and inexpensive, can graphically portray the visible changes inherent in a dynamic glacier system (Veatch, 1969). A terrestrial photography program has the advantages of low logistical costs and relatively inexpensive equipment, and the need for only minimal photogrammetric training or experience.

2. Air Photographs

As soon as it was realized that cameras positioned above the ground could provide photographs so that one could see the earth's surface in its spatial context with all features recorded simultaneously, the technique of air photography was born. The first known air photograph was taken from a balloon in 1853. This method was followed by cameras mounted on kites, 1882, and by airplane technology in 1909 (Lillesand and Kiefer, 1979). The photography of glaciers from the air began in Alaska in 1929 when the U.S. Navy began reconnaissance flights. One of the earliest studies using annual glacier air photography was begun in the late 1940's/early 1950's by the American Geographical Society on the Juneau Icefield (Field and Miller, 1950). Other major long-term reconnaissance studies have been those of Hubley (1956), in western Washington, and Austin Post, who began photographing glaciers in the early 1960's for the University of Washington and has continued his annual flights until the present for the U.S. Geological Survey. Post's photographs have been the basis of a number of glacier studies and cover a large percentage of the glaciers in the western United States, including Alaska, and western Canada.

"Glacier reconnaissance in North America depends largely on aerial photography" (LaChapelle, 1962). With air photographs, precise quantitative data on a limited number of glaciers is replaced by less detailed, mainly qualitative data from large numbers of glaciers over a nearly limitless geographical area. It is especially advantageous to be able to observe large areas in a short period of time, such as late in the ablation season. To obtain a valid consensus of glacier activity over a large area, Meier and Post (1962) found that it was more important to have a large statistical sample of glaciers, which would only be practical using an air photogrph survey, than it was to have detailed informtion from a few glaciers. Air photogrphy is relatively efficient in time, personnel, and cost (Meier and Post, 1962), although it does require a larger investment than terrestrial studies.

There are two types of air photographs. Verticals are similar to planimetric maps and are made with the camera axis directed as vertically as possible. Obliques cover much larger areas than verticals and are made with the camera axis inclined. High obliques include an image of the horizon, while low obliques do not. Obliques are not generally used for mapping because their scales change greatly from foreground to background (Compton, 1962).

Many types of data can be obtained from air photographs. Qualitatively, air photographs show the extent of the ice and the position of the terminus and give clues to the glacier's health and activity. The latter are shown by: 1) effects of ice motion, such as amount of crevassing, character and profile of the terminus, and evidence of kinematic waves; 2) surficial characteristics, such as type of terrain surrounding glacier margins and amount of ablation moraine; and 3) evidence of the mass budget, such as the elevation of the snowline and lower limit of superimposed ice, the character of the line between snow and ice, thickness of annual accumulation horizons, degree to which crevasses are obscured by snow, and the status of semi-permanent snow patches (LaChapelle, 1962; Meier and Post, 1962). Quantitative data can be obtained from air photographs when some amount of past or current information is available from ground observation. Using air photographs, Meier and Post (1962) extended their regime studies on several different types of glaciers in various locations to determine net mass budgets of the glaciers in western North America. LaChapelle (1962) also proposed methods for determining glacier mass budgets using the position of the annual firm limit, determined from air photographs, combined with an accurate topographic map and approximate regional values of the steady-state budget gradient.

An important use of air photographs is in the inventorying of the world's glaciers. One of the objectives of the International Hydrological Decade (1965-1974) was to assemble inventories of perennial ice and snow masses. The work was actively continued through the UNESCO Temporary Technical Secretariat for a World Glacier Inventory by F. Muller at Zurich until his untimely death in 1980 (International Association of Hydrological Sciences, 1980). The morphometric data included in these inventories will have direct use as soon as the techniques of glacier response prediction have been further refined (Sugden and John, 1976). The first American contribution to this international glacier census effort is an inventory of glaciers in the North Cascades, Washington (Post et al., 1971). This inventory was mainly accomplished using a combination of large-scale topographic maps and air photographs taken when little snow remained. The highly successful Canadian Glacier Inventory followed a similar technique.

C. Satellite Imagery

"Probably no combination of two technologies has generated more interest and application over a wider range of disciplines than the merger of remote sensing and space exploration" (Lillesand and Kiefer, 1979). The potential for relating environmental phenomena to the figure of the earth is unequalled in conventional air photography. A time-lapse view of many dynamic aspects of our environment can be obtained.

Specific programs aimed at imaging of the earth's surface began as an offshoot of the program of meteorological satellites (TIROS, Nimbus, ITOS, or NOAA), which provide data for monitoring snow and ice features over large areas of the earth (Gloersen and Salomonson, 1975). Enthusiasm for the monitoring of snow and ice grew as more detailed imagery was obtained from numerous manned spacecraft missions. Breakthroughs in the study of snow and ice using satellites came with the development of the Earth Resources Technology Satellites (ERTS) and the Nimbus-5 spacecraft.

In 1972, 1975, and 1978, ERTS/Landsat satellites were launched. They were designed to acquire data on resources of the earth's land masses on a systematic, repetitive, medium resolution, multispectral basis (Lillesand and Kiefer, 1979). The two Landsat satellites (Landsat-1 failed in 1978) pass within 9° of the poles, make 14 orbits of the earth each day, and obtain coverage of the earth approximately 20 times per year. Data are recorded on videotape rather than photographic film.

The four-channel multispectral scanner (MSS) covers four broad wavelength bands, ranging from 0.5 μm to 0.7 μm in the visible spectrum and 0.7 μm to 1.1 μm in the reflected infrared. Landsat-3 carries an additional band responding to thermal infrared radiation (10.4 μm to 12.6 μm; Landsat Data Users Handbook, 1979). Various methods of color enhancement or multispectral analysis, such as use of pattern recognition techniques, can be used because of the different channels. The other remote sensing system onboard Landsat, the return beam vidicon system (RBV), has more cartographic fidelity than the MSS system because it images an entire scene instantaneously. However, not as many RBV data are available because the RBV on Landsat-1 malfunctioned and was shut down after producing only 1690 scenes and on Landsat-2 only occasional RBV imagery is obtained. Black and white products and false-color composites ranging in scale from 1:250,000 to 1:3,369,000 are available from the EROS Data Center, Sioux Falls, South Dakota.

With satellite imagery, an entire icecap or glacier system can be studied at one time instead of using disparate and often temporally separate pictures. The potential for monitoring glacier behavior, as it relates to climatic changes, sources of water supply, and catastrophic events, is enormous. Systematic repetitive coverage permits monitoring of surging glaciers, changes in runoff, and variations in size and location of glacier-margin lakes, as well as variations in extent of glaciers (Williams, 1976). Satellite data can be related to recorded field data, such as those on runoff variations and terminus oscillations, with clear practical and economic implications (Sugden and John, 1976).

Due to scale and resolution differences, satellite images should be regarded as an additional source of information rather than a replacement for air photographs. As an example of differences in scale, more than 1600 conventional air photographs (1:20,000 scale) with no overlap would be required to cover the area of a single Landsat frame. Effective resolution is 79 m on Landsat multispectral scanner images. The problem of small scale is lessened by the fact that glaciers present a good contrast with the surrounding terrain, especially in the summer months. Features such as lateral, medial, and terminal moraines, as well as glacier-margin lakes, braided stream patterns on outwash, and sediment plumes of glacial rock flour in lakes or marine waters are all usually large enough to be resolved at such small scales (Williams, 1976). Some subtle features extending many kilometers on the ground are visible on the imagery and would not be noticed on large scale air or terrestrial photography.

Problems with satellites arise from cloud cover, sun angle, and operational hiatuses. For pictures imaged under conditions of low sun angle, however, surface irregularities on glaciers are especially pronounced because of enhancement of shadows. Krimmel and Meier (1975) found previously undetected subtle changes in slope that could be reflecting the subglacial topography or dynamic flow features on large glaciers that were imaged under conditions of low sun angle. Satellite images have other definite advantages over other types of pictures in the study of glaciers, such as the periodic coverage of remote areas and continuous coverage under conditions that may restrict or prohibit conventional air photography flights. Landsat images provide a virtually distortion-free orthographic view which greatly aids transference of data on to maps.

Satellite imagery presents an excellent tool for systematically monitoring large numbers of glaciers. Post et al. (1976) and Meier (1976) have used satellite imagery to study and monitor the behavior of selected surging glaciers in Alaska. Surging glaciers can advance over large areas and in so doing can dam up a large quantity of water and then suddenly release it causing devastating floods downstream. It is particularly important, then, to monitor some aspects of glacier behavior such as ice velocity, especially for glaciers which may directly affect people. It is far quicker and more efficient to produce maps and displacement data on large surging glaciers using satellite images than it is to use conventional air photographs or ground surveys (Post et al., 1976). In addition to inferred ice velocity from measurements of the changing positions of moraine loops over several months, glacial surge features shown on the imagery were the presence of shock wave, increasing relief along valley walls, spreading of zones of intense crevassing and deformation of medial moraines.

Studies have also been done (Meier, 1975; Ostrem, 1975) using satellite images to monitor seasonal snow cover, especially as applied to the determination of glacier mass balance. Uses for this data include providing information on annual runoff and expected deviations from normals, which will allow for predictions of flooding and drought, as well as determining capabilities of hydroelectric power generation and sources of water supply.

In the future, we can hope for great improvements in remote sensing from satellites for glacier studies with such things as improved sensors which will aid in spatial, temporal, and spectral resolution. As more data become available from satellites, the need for machine processing of imagery will become more important in order to perform measurements on the imagery with sufficient rapidity and accuracy. Equally important is the improvement of archival procedures. With each Landsat satellite generating images at a rate of 144 per hour, the need for constantly improving computerized access to data is obvious.

Examples of Types of Pictures

Examples of the four main types of glacier pictures are shown for the Muir Glacier in Glacier Bay, Alaska (Figs. 1-6). Glacier Bay, which extends some 105 km from Icy Strait into the Alsek and Fairweather Ranges, is an area of widely varied glacier behavior with the most outstanding feature being the rapid disappearance of glacial ice.

The coast of southern Alaska has a long historical record. Detailed explorations were undertaken by Vancouver in 1794. From notes of his explorations, it appears that Glacier Bay was nonexistent at this time, except for a small indentation of 10 miles or so before the bay was blocked by the terminus of a great glacier that was 20 km wide and 1200 m thick (Bohn, 1967; Field, 1979). This glacier has largely disappeared and its remnants are those glaciers at the heads of Glacier Bay's numerous inlets.

The first scientist to venture into Glacier Bay itself was John Muir. In 1879 he made detailed observations of many glaciers, including what is now called the Muir Glacier. H.F. Reid did the first topographic surveys of Glacier Bay (Reid, 1890, 1892), followed by additional mapping by the International Boundary Commission in 1894 and from 1907 to 1912 (International Boundary Commission, 1918, 1952). In 1899, the Harriman Alaska Expedition visited Glacier Bay. This large party included many leading scientists including Muir, Burroughs, Dall, Gilbert, Gannett, Merriam, and Keeler, and studies were undertaken on the biology as well as geology and glaciology of the region. Photographs were taken by A. Curtis. For a number of years after the great earthquake of September 1899, Glacier Bay was choked with ice due to increasingly rapid recession making access very difficult.

Much recent work has been done in Glacier Bay. Notable contributions included the integrated glaciological, geological, and ecologicl studies developed by R.P. Goldthwait and the Institute of Polar Studies at Ohio State University (Goldthwait, 1967), D.B. Lawrence's ecological studies (Lawrence, 1958), W.O. Field and the American Geographical Society's

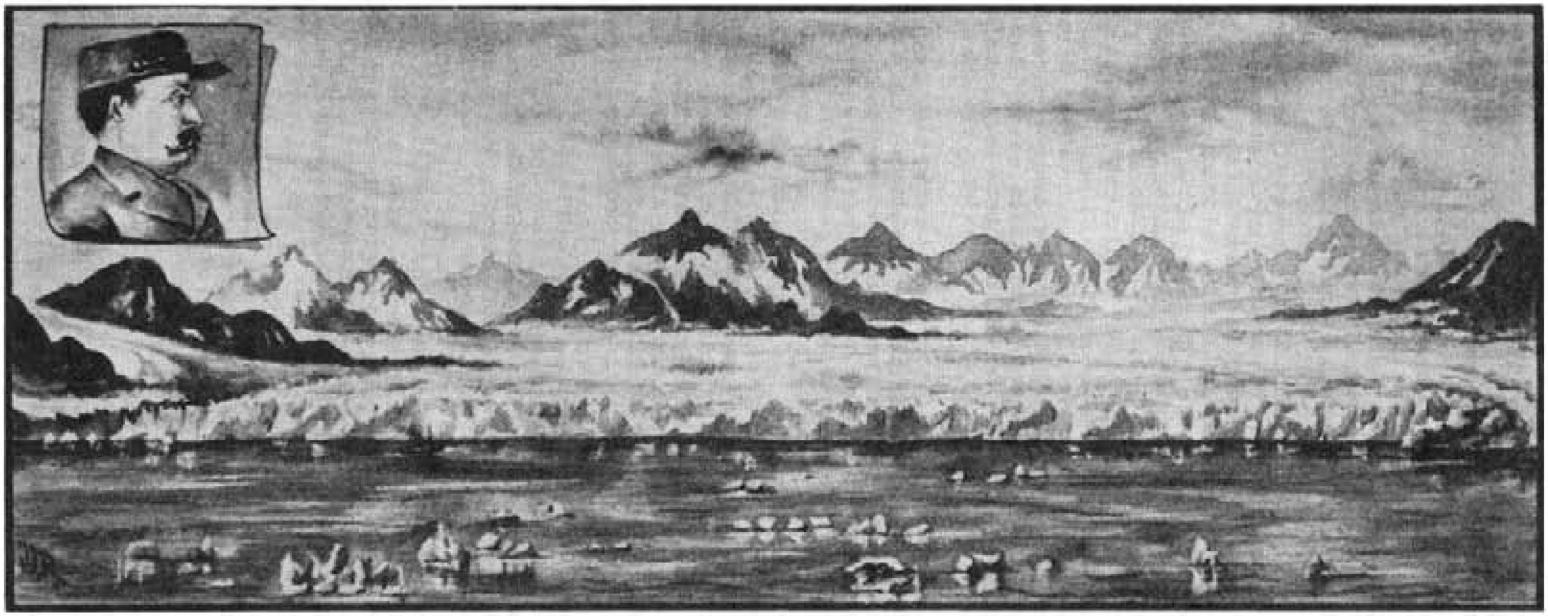


Figure 1. A pen and ink wash by Theodore J. Richardson (1891) showing a 180° panorama of the Muir Glacier. The inset is Captain James Carroll of the steamer *Queen*.

Figure 2. A terrestrial photograph taken by Frank LaRoche (1893). AGS collection at the WDC-A: Glaciology, University of Colorado, Boulder, Colorado.

Figure 3. An oblique air photograph taken by the U.S. Navy (1929). AGS collection at the WDC-A: Glaciology, University of Colorado, Boulder, Colorado.

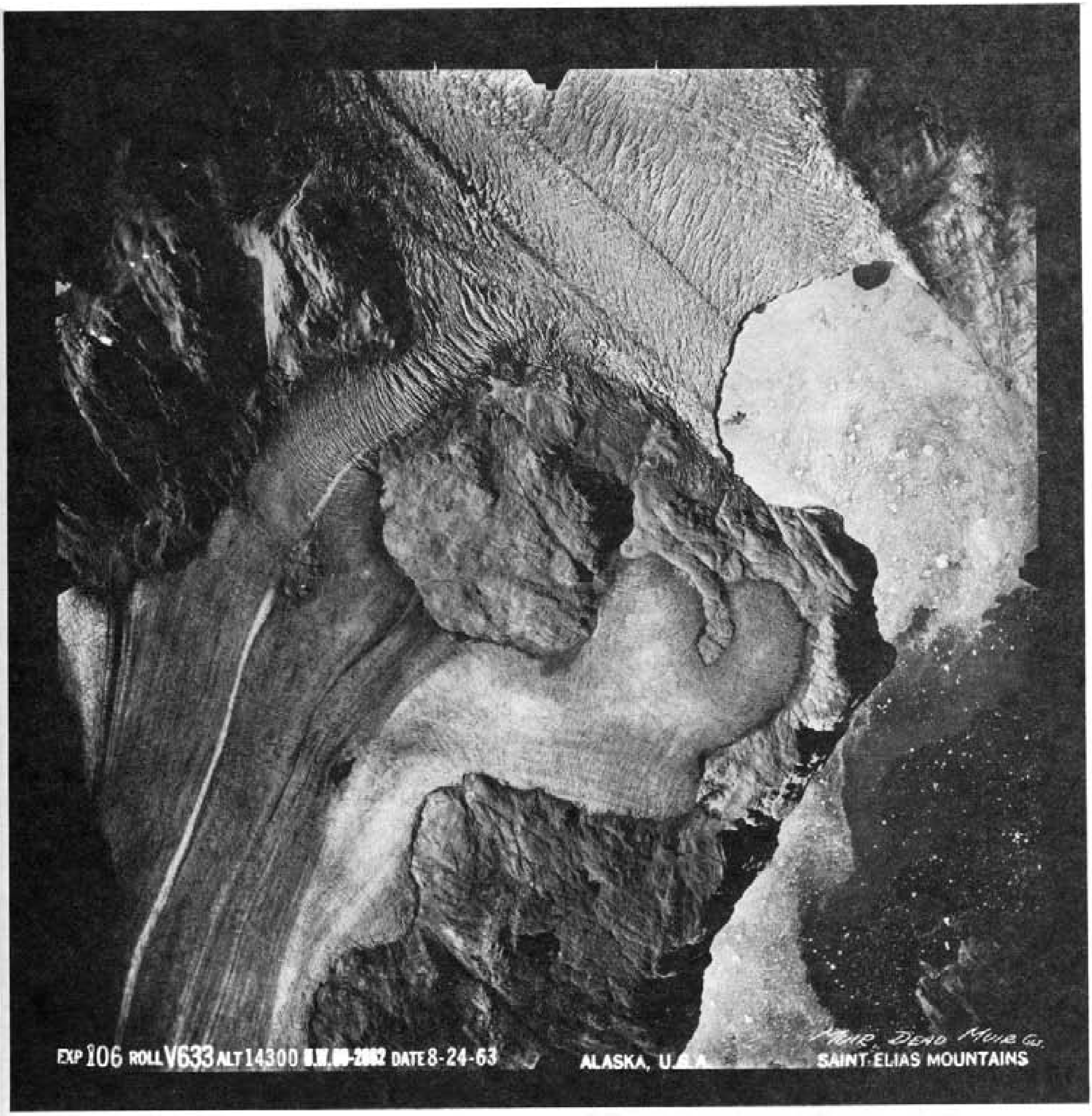


Figure 4. A vertical air photograph taken by A.S. Post (1963), at an altitude of 4359m (14,300 ft.). USGS/Post collection at USGS, Tacoma, Washington.

Figure 5. A Landsat image of Glacier Bay (1977). Scale is 1:3,369,000. The arrow points to the terminus of the Muir Glacier.

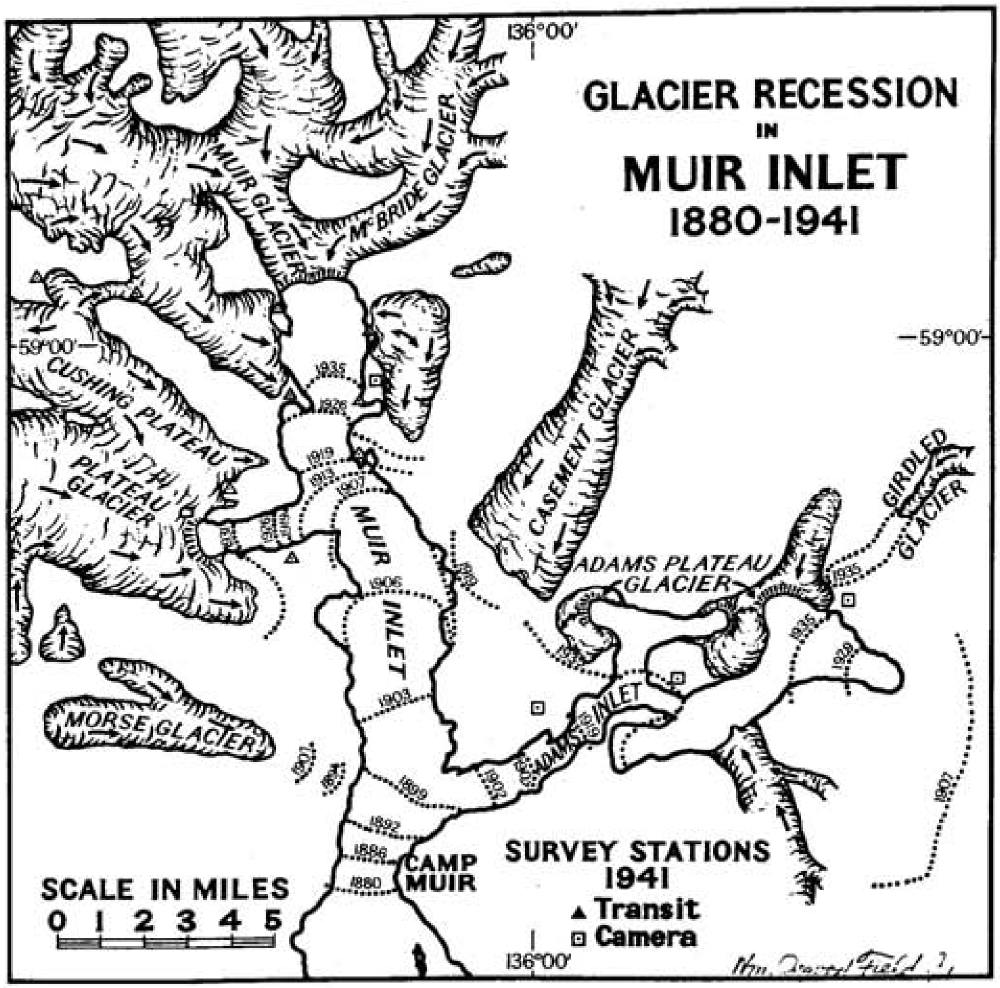


Figure 6. Map of glacier recession in Muir Inlet, 1880-1941, by William O. Field, Jr.

continuing work on glacier variations (Field, 1926, 1947, 1975, 1979) and A.S. Post's high quality air photographic surveys and interpretive studies (Post and LaChapelle, 1971; Post, 1969).

Muir Inlet is the principal drainage basin on the east side of Glacier Bay. The Muir Glacier now at the head of the inlet, has been retreating, catastrophically at times, since before Vancouver's arrival in 1794 (at that time the Muir Glacier was a tributary of the great glacier that occupied all of Glacier Bay). Field (1979) has estimated that average annual recession rates of the Muir Glacier exceed 400 m.

Because of the large numbers of tourists since the 1880's who have visited the Muir Glacier, the area's status as a National Monument, and the many scientists who have studied the glacier, a detailed pictorial record exists of its recession. The record ranges from drawings made in the early 1880's through photographs taken as early as the late 1880's and air photographs beginning in 1929, to satellite imagery from the early 1970's. It is an ideal glacier for further study using present and historical pictures as keys to the past as well as to future glacier behavior.

SUMMARY

The four basic types of pictures provide different types of useful data. Drawings, while not as accurate as a photograph, provide the earlist pictorial basis for later comparison of glacier changes. Drawings took a long time to do and required a skilled person to make them, but drawings are the only type of picture in which mechanical failure is not a major problem.

Terrestrial photographs also have a long historical record, at least in certain parts of the world. As far as detail and perspective, they are quite similar to many drawings, however, accuracy is not questioned. Expense of equipment, while being more than for drawing, is considerbly less than it would be for air photography. Depending on the glacier location, however, terrestrial photography may be more expensive in the long run because of difficulty of access. Terrestrial photographs are usually one aspect of more detailed quantitative field work, such as surveying or sampling, possibly within more than one discipline. These photographs, then, often provide ground truth, such as on mass balance, that can be used with, and are necessary for, remote sensing applications.

Conventional air photography provides mainly qualitative data on large numbers of glaciers in a relatively short period of time in virtually any geographic location. The scale of air photographs varies from relatively small to relatively large. The length of record of air photographs is fairly short for most glaciers, but because the technique is so efficient in time and space, the number of available photographs is quite large. In inaccessible regions, air photography provides the first glimpse of many of the world's glaciers. In the study of glaciers, weather is often a limiting factor, even in the summer. Visibility problems occur often with air photography surveys. In addition, photographic missions are usually flown at selected times, rather than systematically, and to selected localities, rather than randomly. Although the efficiency of the given study is increased, the generation of a broad-based data bank suffers.

Satellite imagery has the shortest historical record, but there are now probably more glacier satellite images than any other type of glacier picture. The main advantage with satellite images is their frequent systematic coverage of the world's glaciers on a multispectral basis, with the additional capability for machine analyzing. Disadvantages are mainly in the small scale of the imagery, obstruction by cloud cover, and other problems with resolution. There is always the possibility of mechanical failure.

No other type of pictorial data can be described as "best" or can really stand alone in the study of glaciers (Table 1). Often the data obtained from a remotely-sensed picture will need terrestrial data to substantiate it, and terrestrial data will often be aided by the overall view provided by a remotely sensed picture. A systems approach combining an integration of remotely sensed and geobased observations is probably the most useful for most studies.

Table 1: Types of Pictures - Advantages and Disadvantages[1]

	Length of Record	True Scale[2]	Area Covered[3]	Expense of Equipment	Ease of Access to Subject of Picture	Ease of Repetition	Possibility of Year-long Monitoring	Spectral Sensitivity
Drawings	+++	+	-	+++	+ to ---	+ to ---	---	-
Terrestrial Photographs	++	+	-	++ to -	+ to ---	+ to ---	---	+
Air Photographs	+	+ to -	- to +	-	++	++	++	+
Satellite Imagery	-	---	+++	---	+++	+++	+++	++

[1] best to worst
+++ to ---

[2] large scale defined as "+", although it is not necessarily an advantage.

[3] large area defined as "+", although it is not necessarily an advantage.

FUTURE WORK

The future for long-term studies of glacier behavior is bright. Technological improvements in satellite imagery will yield resolution comparable to that of air photographs at a fraction of the cost per image. Access to these images in the future, as at present, will be made possible by computerized data retrieval systems (EROS Data Center, Sioux Falls, SD).

The World Data Center-A for Glaciology is currently cataloguing the American Geographical Society/W.O. Field collection and that of the U.S. Geological Survey/A.S. Post. The former consists of approximately 40,000 drawings, terrestrial and air photographs, mostly from Alaska, taken since the 1880's. The latter consists of about 80,000 air photographs taken between 1962 and the present, and mainly covers northwestern North America. When cataloguing and programming are complete, critical information such as place, date, type of picture, and the name of the individual who or institution that has the picture will be available on a user request basis from the World Data Center-A for Glaciology, University of Colorado, Boulder, CO. Additional information on the WDC-A collections, methods used for cataloguing the pictures and the computerized data retrieval system will be forthcoming as the project progresses. Currently most of the U.S. Geological Survey/A.S. Post collection has been catalogued, and approximately 7 percent of that data has been computerized. Approximately 25 percent of the American Geological Society/W.O. Field collection has been catalogued and archived at the WDC-A. The WDC-A would like as complete a pictorial record of glaciers as possible, and is therefore interested in archiving and/or cataloguing other glacier picture collections.

BIBLIOGRAPHY

Altmann, J.G. (1751) Versuch einer historischen Beschreibung der helvetischen Eisbergen. Zurich.

Bohn, D. (1967) Glacier Bay: The Land and the Silence. San Francisco, Sierra Club, 158 p.

Compton, R.R. (1962) Manual of Field Geology. New York, John Wiley and Sons, 378 p.

Cooper, W.S. (1937) The problem of Glacier Bay Alaska: a study of glacier variations. Geographical Review, v. 27, p. 37-62.

Cooper, W.S. (1956) A contribution to the history of the Glacier Bay National Monument. University of Minnesota, Department of Botany.

Ferrigno, J.S.; Williams, R.S. (In preparation) Satellite image atlas of glaciers. U.S. Geological Survey. Professional paper.

Field W.O. (1926) The Fairweather Range: mountaineering and glacier studies. Appalachia, v. 16, p. 460-472.

Field, W.O. (1947) Glacier recession in Muir Inlet, Glacier Bay, Alaska. Geographical Review, v. 37, p. 369-399.

Field, W.O.; Miller, M.M. (1950) The Juneau Ice Field Research Project. Geographical Review, v. 40, p. 179-190.

Field, W.O. (1969) Current observations on three surges in Glacier Bay, Alaska, 1965-1968. Canadian Journal of Earth Science, v. 6, p. 831-839.

Field, W.O., ed. (1975) Mountain Glaciers of the Northern Hemisphere, 2 v. plus Atlas. U.S. Army. Cold Regions Research and Engineering Laboratory.

Field, W.O. (1979) Observations of glacier variations in Glacier Bay National Monument. (In: Proceedings of the First Conference on Scientific Research in the National Parks, New Orleans, Nov. 9-12, 1976. Edited by Robert M. Linn. U.S. Department of the Interior. National Park Service. Transactions and Proceedings series, no. 5, 1979, p. 803-808.)

Flint, R.F. (1971) Glacial and Quaternary Geology. New York, John Wiley and Sons, 892 p.

Gloersen, P.; Salomonson, V.V. (1975) Satellites - new global observing techniques for ice and snow. Journal of Glaciology, v. 15(73), p. 373-390.

Goldthwait, R.P. (1967) Evidence from Alaskan glaciers of major climatic changes. (In: Royal Meteorological Society. Proceedings of the International Symposium on World Climate from 8000 to 0 BC, p. 40-53.)

Harrison, A.E. (1954) Glacier studies with a camera. Sierra Club Bulletin, v. 39(6), p. 60-65.

Hubley, R.C. (1956) Glaciers of the Washington Cascade and Olympic Mountains; their present activity and its relation to local climatic trends. Journal of Glaciology, v. 2(19), p. 669-674.

International Association of Hydrological Sciences (1980) World Glacier Inventory. Proceedings of the Workshop held at Riederalp, Switzerland, 17-22 September 1978. IAHS AISH Publication, no. 126, 351 p.

International Boundary Commission (1918) Joint Report Upon the Survey and Demarcation of the International Boundary between the United States and Canada along the 141st Meridian from the Arctic Ocean to Mt. St. Elias. Washington, D.C., Department of State, 305 p. plus maps.

International Boundary Commission (1952) Joint Report Upon the Survey and Demarcation of the Boundary between Canada and the United States from Tongass Passage to Mt. St. Elias. Washington,D.C., Department of State, 365 p.

Krimmel, R.M.; Meier, M.F. (1975) Glacier applications of ERTS images. Journal of Glaciology, v. 15(73), p. 391-402.

LaChapelle, E. (1962) Assessing glacier mass budgets by reconnaissance aerial photography. Journal of Glaciology, v. 4(33), p. 290-296.

Landsat Data Users Handbook (1979) U.S. Geological Survey, U.S. Department of the Interior.

Laperouse, J.F. (1799) A Voyage 'round the world; translation from the French. London, 3 volumes and folio.

Lawrence, D.B. (1958) Glaciers and vegetation in southern Alaska. American Scientist, v. 46, p. 89-122.

LeRoy Ladurie, E. (1971) Times of Feast, Times of Famine: a history of climate since the year 1000. New York, Doubleday and Co., 426 p.

Lillesand, T.M.; Kiefer, R.W. (1979) Remote Sensing and Image Interpretation. New York, John Wiley and Sons, 612 p.

Meier, M.F.; Post, A.S. (1962) Recent variations in mass net budgets of glaciers in western North America. (In: International Association of Scientific Hydrology. Obergurgl Symposium, IASH/AISH Publication no. 58, p. 63-77.)

Meier, M.F. (1975) Application of remote-sensing techniques to the study of seasonal snow cover. Journal of Glaciology, v. 15(73), p. 251-265.

Meier, M.F. (1976) Monitoring the motion of surging glaciers in the Mt. McKinley massif, Alaska. (In: ERTS-1, A New Window on our Planet, R.S. Williams and W.D. Carter, eds., U.S. Geological Survey. Professional Paper, no. 929, p. 185-187.)

Merian, M. (1642) Topographia helvetiae, n.p.

Messerli, B.; Messerli, P.; Pfister, C.; Zumbuhl, H.J. (1978) Fluctuations of climate and glaciers in the Bernese Oberland, Switzerland, and their geoecological significance, 1600-1975. Arctic and Alpine Research, v. 10(2), p. 247-260.

Ostrem, G. (1975) ERTS data in glaciology - an effort to monitor glacier mass balance from satellite imagery. Journal of Glaciology, v. 15(73), p. 403-415.

Post, A.S. (1969) Distribution of surging glaciers in western North America. Journal of Glaciology,v. 8(53), p. 229-240.

Post, A.S.; LaChapelle, E. (1971) Glacier Ice. Seattle, The Mountaineers. 110 p.

Post, A.S.; Richardson, D.; Tangborn, W.V.; Rosselot, F.L. (1971) Inventory of glaciers in the North Cascades, Washington. U.S. Geological Survey. Professional Paper, no. 705-A.

Post, A.S.; Meier, M.F.; Mayo, L.R. (1976) Measuring the motion of the Lowell and Tweedsmuir surging glaciers of British Columbia, Canada. (In: ERTS-1, A New Window on our Planet, R.S. Williams and W.D. Carter, eds., U.S. Geological Survey. Professional Paper, no. 929, p. 180-184.)

Reid, H.F. (1890 and 1892) Notebooks and journals of expeditions of 1890 and 1892. Manuscript and transcript at World Data Center-A, Glaciology, University of Colorado, Boulder, CO.

Reid, H.F. (1892) Studies of Muir Glacier, Alaska. National Geographic Magazine, v. 4, p. 19-84.

Saussure, H.B. de (1779-1796) Voyages dans les Alpes. Neuchatel, Louis Fauche-Borel, 4 volumes.

Sugden, D.E.; John, B.S. (1976) Glaciers and Landscape. New York, John Wiley and Sons, 376 p.

Veatch, F.M. (1969) Analysis of a 24-year photographic record of Nisqually Glacier, Mt. Rainier National Park, Washington. U.S. Geological Survey. Professional Paper, no. 631, 52 p.

Williams, R.S. (1976) Vatnajokull Icecap, Iceland. (In: ERTS-1, A New Window on our Planet, R.S. Williams and W.S. Carter, eds. U.S. Geological Survey. Professional Paper, no. 929, p. 188-193.

WDC-A for Glaciology Photo Index File
An Update

In 1964 the Project Office for Glaciology (Water Resources Division, United State Geological Survey) began administration of the annual aerial photosurvey of snowline and glacier fluctuations of North Pacific Coast and interior Alaskan glaciers. The resulting photographic collection, herein designated the Post collection, consists of approximately 80-100,000 negatives of glaciers, snowlines, and other glacial features photographed since 1960, primarily by Austin Post and secondarily by R. Krimmel and L. Mayo.

In October 1976, the World Data Center-A for Glaciology [Snow and Ice] (WDC) transferred from the USGS to NOAA/EDIS in Boulder, Colorado. At that time, the WDC suggested a glacier photo indexing program in conjunction with the USGS in order to facilitate user access to these photographs and to update an existing but limited photo index in the Project Office for Glaciology.

In early 1978, the WDC designed a set of descriptive identifiers for all types of glacier photographs, with the collaboration of Austin Post and other glaciologists. The outcome was a universal index format and coding form which has been used for indexing the Post collection as well as other historical glacier photographs archived at the WDC. Information contained on the index form for each glacier most often includes the following: glacier name, location, International Hydrological Decade number (when available), glacier features, photo/camera type, and photographer.

A second set of historical glacier photographs has been assembled by W.O. Field and the American Geographical Society and is gradually being transferred for archival at the WDC. The Field collection contains approximately 40,000 terrestrial and aerial photographic prints of glaciers, many dating back to the early 1900's and before. These photographs are also being indexed by the WDC, using the same format as the Post collection.

A computer data base was developed at the WDC in 1978 and some of the completed index forms have been entered into this file. A CDC-derived report-writing and data-sorting software package (OUTFOL) allowed creation of multiple keyed index listings and off-line searches for photographs of specific glaciers or ones which show specific features.

More recently the Glacier Photo Index file has been redesigned for implementation on a Univac computer using the DMS1100 software package. Ultimately the entire computerized index file will reside in the Data Archive Management and User Service system (DAMUS) of NOAA/EDIS. The new system will allow efficient on-line searches by combination of glacier name, geographic location, and other index keys. The expected implementation of the new software system is 1 October 1981.

Current Status of Indexing

Approximately 80 percent of the Post collection has been indexed as of January 1981, and approximately 10 percent of the items are entered into the data file. However, data entry operations were suspended in early 1980, due to lack of funds. We expect data entry to restart in June or July of 1981, when additional funding becomes available. Expected completion of photo indexing and data entry is June 1984.

Canadian Ice Services

David Mudry
Chief, Ice Climatology and Applications Division
Ice Branch, Atmospheric Environment Service
Ottawa, Ontario, Canada

This paper presents an overview of the ice services provide by the Atmospheric Environment Service (AES) as well as detailed information about Canadian data collection for the Great Lakes.

I. AES, Ice Branch

The Ice Branch of AES provides an ice observing service, ice forecasting and advisory service, and an ice climatological and applications service. The Branch has been in existence since the late 1950's and has amassed a large volume of data and professional expertise. In 1979, a mini-computer was installed in the Ice Forecasting Central in Ottawa, and an ice research specialist was added to the headquarters unit in Downsview, Ontario.

The functions carried by, and the services provided by, each unit are as follows:

A. Ice Reconaissance

Using two long-range four-engine aircraft, a comprehensive ice reconnaissance program is carried out throughout the year, concentrating on the Gulf of St. Lawrence, the St. Lawrence Seaway and Great Lakes, east Newfoundland and southern Labrador waters, including Lake Melville in winter, with periodic reconnaissance missions to the Arctic to acquire baseline data. In summer, with southern waters clear of sea and lake ice, the Hudson Bay and Arctic areas are observed regularly.

The aircraft are equipped with a number of sensors which can enhance the visual reports of trained ice observers. The laser profilometer provides data on pressure ridges on the ice surface beneath the aircraft. The infrared line scanner can map the distribution of apparent surface temperatures during ice formation by recording the upward heat flux as a function of ice thickness over a narrow swath width. Both sensors are sensitive to cloud/fog beneath the aircraft. They work best from relatively low altitudes. The airborne radiation thermometer can provide sea surface temperature when corrected for atmospheric conditions, or if ground truthing is available, with cloud and altitude restrictions as above. The sideways looking airborne radar on one of the aircraft has the capability to "observe", and record on film, ice conditions during darkness and through undercast. Subject to its normal operational missions, the aircraft may be available for support of some commercial activities. Both aircraft are equipped with a camera array for photographing the ice surface. They also have radio facsimile transmitters to pass ice charts to ships and to stations equipped to record them. Most of the sensor and camera data as well as the ice charts can be made available. A sensor to record ice thickness from a fixed wing aircraft is not yet available.

Parameters recorded on ice reconnaissance missions include: ice edge positions, leads and cracks, ice concentrations and some floe size data, ice pressure features, surface melt, and snow cover.

B. Ice Forecasting and Advisory Services

The ice forecasting program coordinates the data recorded during the aircraft flights with satellite imagery (TIROS/NOAA and LANDSAT) received in near real-time to develop composite charts of current ice conditions. From these charts and forecast meteorological parameters, plain-language ice forecasts are prepared for both commercial navigation support and for coastal fishing operations in Atlantic Canada waters during the winter. In summer, charts and forecasts for support of shipping and other operations in Hudson Bay and Arctic waters are prepared and disseminated. When they are commercially active in winter, charts and forecasts are also prepared for the Great Lakes.

This paper supplements Glaciological Data, Report GD-9, Great Lakes Ice.

Specifically the following forecasts, bulletins, and charts are issued:

1. For commercial shipping and offshore activities

   a. Gulf of St. Lawrence--winter season--daily
   b. East Newfoundland--winter season--daily
   c. Great Lakes--winter season--daily when shipping active
   d. Hudson Bay--summer--daily until ice clears
   e. Baffin Bay--summer-daily ice edge
   f. Western Arctic--summer--daily during navigation season

2. For fishermen

   a. Nova Scotia (Cape Breton and Eastern Shore)--winter--daily
   b. Northumberland Strait area--spring--daily until clear
   c. Newfoundland coasts--winter/spring--daily

3. Special Forecasts/Bulletins

   a. Gulf St. Lawrence/Newfoundland winter outlook--annual--December
   b. Arctic summer outlook--annual--June
   c. Beaufort Sea Freeze-up--weekly--September to November
   d. St. Lawrence Seaway Freeze-up--periodic through December
   e. St. Lawrence Seaway Break-up--periodic February and March
   f. 30-day forecasts--operational areas--twice monthly
   g. Others--on request

4. Ice Charts-current conditions
   In operationally active areas--daily--radio facsimile broadcast

5. Ice Charts-composite

   1-3 per week depending on area--mail distribution
   (Areas covered are: Eastern seaboard, Hudson Bay and approaches, Eastern Arctic, Western Arctic, Great Lakes.)

The forecasts provide the positions of ice edges, ice concentration ranges, ice types as functions of the ice thickness, some data on pressure within the pack, and on ice growth or decay state. They will also include a forecast of expected ice drift.

The ice charts are analyses of ice conditions including all current data from ice reconnaissance flights, from analyzed satellite imagery, and from ship and shore reports. In addition to the parameters in the forecasts, the charts will also show details on floe sizes, some data on ice topography, and the areas of old ice.

A variety of information is also available by telephone, telex, telecopier, and mail.

C. Ice Climatology

Ice climatological services include archiving all Canadian ice data, publishing area summaries and analyses of these data, undertaking special studies, lectures, and training in ice-related topics, reviewing ice-related publications or ice-sensitive plans, as well as generating atlases of ice conditions for Canadian waters.

Archived data include: original observations, satellite imagery, historical ice charts, original remote sensing records from the laser profilometer, infrared line scanner, sideways looking airborne radar, and camera data. Some data are light-sensitive and cannot be reproduced, but are available for inspection. Other data exist in a variety of forms from paper copies to film strips to magnetic tapes, and copies can be made available.

Information services include normal and extreme positions of ice edges, average ice concentrations, average concentrations of ice types, seasonal patterns of ice advance and retreat, variability of the amount of old ice in operational areas, etc. Work has begun on statistics on pressure ridges. Freezing-degree day and melting-degree day accumulations relative to the changing ice seasons are also archived. Other types of analyses can be done on a request basis.

Ice thickness measurements (weekly) exist for many coastal stations. Most Arctic data go back to the 1950's; visual observations are since the late 1950's; daily, weekly, and monthly mean pressure charts are for the same periods. Satellite imagery is available since the early 1970's in the "quicklook" form.

Limited research and consultation services are available. A program of ice atlas production for Canadian waters has begun, with an Arctic atlas and an Eastern Canadian Seaboard atlas nearing publication.

Data for Northern Hemisphere ice conditions outside Canadian waters exists in varying forms and for differing historical periods; however, the history for the Soviet Arctic coastline is very general.

D. Remote Sensing

A broad spectrum of expertise in remote sensing instrumentation, data acquisition, data analysis and application has been developed within AES, and this expertise is available for consultation and guidance by data users, and for planning projects.

E. Iceberg Information

During the summer navigation season, the Ice Forecasting Central provides a daily broadcast iceberg bulletin for shipping through the Strait of Belle Isle giving the eastern and western limits of icebergs and the approximate number of bergs present. The bulletin is based on aerial reconnaissance and ship reports during May and June, but only ship reports thereafter.

On all aerial reconnaissance flights, the number of icebergs within the visual range are counted and recorded, but exact positions are not recorded. Hence, considerable statistical data on iceberg population exist from Newfoundland to the eastern Arctic, but it is in no way a complete iceberg census. Satellite imagery cannot provide a complete picture for iceberg population at this time.

F. International Data Exchange

The Ice Forecasting Central maintains a data exchange program with the United States in the Great Lakes and Alaska areas; and with Denmark in the Davis Strait-Greenland area. Through exchanges with the Baltic countries they also have data on ice conditions in the Baltic Sea and adjoining water bodies. These data are archived in the Ice Climatology Division.

II. Canadian Data Collection for the Great Lakes

The following is a brief summary of activities specific to the Great Lakes and the types of data collected:

Satellite Imagery
- NOAA - 1973-79 (Prints only)
- TIROS "N" - 1979-80 (Prints Only)
- ERTS/LANDSAT - 1973-80 (Prints)
  - 1974-80 (Fiche)

Ice Reconnaissance
- (1964 - Present)

a. Aerial - mostly visual interpretation, mostly Canadian side of Lakes plotted on charts 18" X 22" (scale 1:2M to 1979, 1:1M thereafter)
- A few flights include A.R.T. and laser data but in general, very little remotely sensed data is available for the Great Lakes.
- For the period 1964-71 these observations have been reproduced in booklet format on a one book per year basis.

b. Ice Breaker - 1964 - Present
- Canadian visual only. These observations are plotted on the same base charts as used for aerial ice reconnaissance.

Daily Current Charts
- (1972 - Present)
- These are operationally produced composite ice charts which incorporate all available information from freeze-up to break-up on a 7-day-a-week basis. The chart scale is 1.2M

Microfilm
- 35mm in maximum 100 ft. rolls. (1960-1975)
  All aerial ice reconnaissance, ship observations, and daily current charts appear on microfilm in chronological order.

Weekly Composite Charts
- (1972 - Present)
  These are operationally produced charts of scale approximately 1:5M which depict ice conditions on a particular day of each week from freeze-up to break-up.

Ice Thickness Data - Weekly measurements of ice thickness and data of freeze-up/break-up are available for the following selected areas during the corresponding period:

Thunder Bay, Ontario	1963-78
Sault Ste. Marie, Onatrio	1963-78
South Baymouth, Ontario	1962-78
Iroquois, Ontario	1963-72
Cornwall, Ontario	1963-71
Welland, Ontario	1963-78

In some areas there is more than one observing site. Other areas for which there is some data available have not been mentioned due to the discontinuous nature of the data. All available ice thickness data from selected Canadian stations are reprinted in booklets on a yearly basis.

Freezing/Melting Degree Data - Daily freezing and melting degree accumulation records are available for eight meteorological reporting stations situated around the Great Lakes:

Thunder Bay	1972 - Present
Gore Bay	1973 - "
Sault Ste. Marie	1973 - "
Wiarton	1973 - "
Windsor	1973 - "
Simcoe	1953 - "
Toronto	1953 - "
Trenton	1953 - "
Montreal	1953 - "

Statistics of yearly accumulations, their normals and extremes are also available. All data are presently in hard copy form.

Pressure Charts - 1000 millibar 1:20M scale - mean daily, weekly, and monthly analyses from 1970 to present. (Hard copy and microfilm (35mm))

Mean Sea Level pressure charts - 1955-1969 (hard copy only)

Essentially all our historical archives are in hard-copy format. That which can be reproduced is available to the user at our cost of reproduction, handling, and mailing.

NOTES

Meetings

WDC-A Radio Glaciology Workshop

A Radio Glaciology Workshop, organized by the World Data Center-A for Glaciology [Snow and Ice], will be held on 4-5 September 1981, in conjunction with the Third International Symposium on Antarctic Glaciology in Columbus, Ohio.

The Workshop will focus on two areas of radio glaciology: data acquisition and processing, and data archiving and distribution. Topics to be considered in the first category include: hardware specifications relating to data quality and quantity; the merits of analog and digital output modes; and post-processing techniques including: 'cleaning', analog compression, A/D conversion, and digital signal processing. A quantitative evaluation of the accuracy of positioning techniques will also be considered. Finally, there will be a review of interpretation problems associated with different display modes.

The second focus of the Workshop will address the development of an archiving and distribution policy for radio glaciology data. Topics for consideration include: defining the needs, concerns, and constraints of the radio glaciology community regarding the availability of data, the variety of data products, and the potential for standardization and quality control in a data management environment. Consideration will also be given to data management plans for new data acquistion systems, such as those on satellites.

The Workshop will produce a working document summarizing the key scientific, technical, and data management needs relating to radio glaciology data acquistion, processing, archiving, and distribution.

For details of the Workshop and preregistration contact:

P.K. MacKinnon
World Data Center-A for Glaciology
University of Colorado
Campus Box 449
Boulder, Colorado 80309

Phone: (303) 492-5171
FTS 320-5311

Second Symposium on Applied Glaciology

The International Glaciological Society will hold a Second Symposium on Applied Glaciology in New Hampshire, USA in 1982; the first symposium on this subject was held in 1976 in Cambridge, U.K. Registration will take place on Sunday 22 August, and sessions will be from Monday 23 to Friday 27 August.

Topics

The Symposium will be concerned with the following topics:

1. engineering problems associated with river, lake, and sea ice;
2. engineering problems associated with ground ice, icebergs, and glaciers;
3. properties and behaviour of snow, ice, and ice cover;
4. snow removal, control, and processing;
5. avalanche control and snow pressure;
6. ice accretion;
7. modelling techniques in applied glaciology.

Papers

The Papers Committee will be happy to consider any paper that provides new information on the above topics. Details about the submission of summaries and final papers will be given in the Second Circular, to be published in the summer of 1981. Dates for submission are firm ones and must be adhered to.

Publication

The Proceedings of the Symposium will be published in the Annals of Glaciology. Papers will be refereed according to the Society's usual standards before being accepted for publication.

Organization

The main organization is undertaken at the Society's Headquarters office in Cambridge, U.K., while the local organization will be effected by our members in Hanover, with the help of staff of the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL). We hope to arrange visits to the Laboratory during the week of the Symposium. Local tours will be arranged for people accompanying the participants. The Society's Annual Dinner will be held during the week.

Further Information

The Second Circular will give information about accommodation, general programme, preparation of summaries, and final papers.

Requests for copies of the Second Circular should be addressed to the:

Secretary General
International Glaciological Society
Lensfield Road
Cambridge CB2 1ER
England

Organizing Committee

A.J. Gow (Chairman)
B.S. Yamashita
W.F. Weeks
H. Richardson (Secretary General, IGS)

DATA ANNOUNCEMENT

81-GLA-02

ARCTIC OCEAN BUOY DATA

Processed digital data sets of the Arctic Ocean drifting buoy program are now available through the World Data Center-A (WDC-A) for Glaciology [Snow and Ice], Boulder, Colorado. These data were collected as part of the United States contribution to the First GARP Global Experiment (FGGE) by the Polar Science Center, University of Washington, Seattle, Washington. The objectives of the buoy program were to provide measurements of surface atmospheric pressure over the basin and to define the large scale field of motion of the sea ice.

The data comprise 3-hourly estimates of atmospheric pressure and temperature, and ice velocity interpolated to fixed grid-points. The number of operating buoys varies through time but averages about fifteen. Synoptic weather station data have been integrated into the pressure field calculations. Currently archived data cover the period 19 January to 31 December 1979.

The essential processing steps included: 1) editing the raw data to remove large errors; 2) interpolating the edited pressure, temperature, and location time series for each buoy; 3) merging the pressure and temperature data from the buoys with temperature and pressure data from other high latitude weather stations; and 4) interpolating to a fixed spatial grid. Details of these editing and interpolation steps may be found in Thorndike and Colony (1980), which is available from the Polar Science Center (see address below).

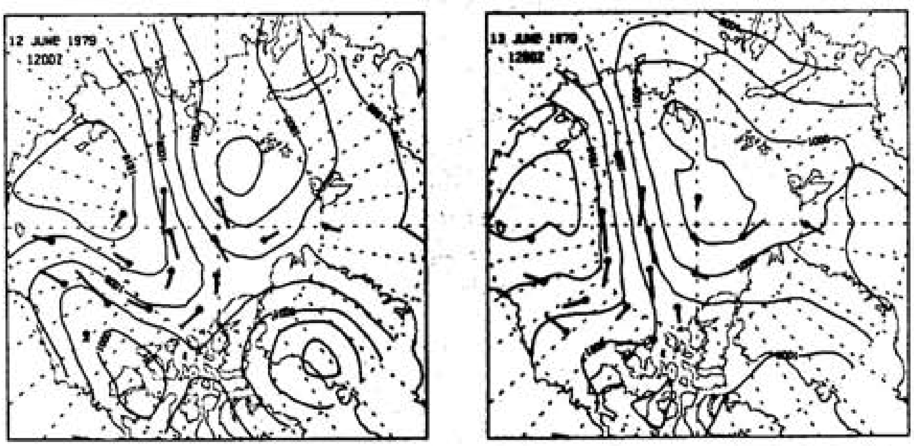


Figure 1. Graphical analysis of surface pressure at 1200 GMT, 12 and 13 June 1979, with daily buoy displacement vectors.*

*Thorndike, A.S.; Colony, R. (1980) Arctic Ocean Buoy Program, Data Report. Polar Science Center, University of Washington. 131 p. Available from PSC, University of Washington, Seattle, WA 98105.

World Data Center-A for Glaciology [Snow and Ice]
National Geophysical and Solar-Terrestrial Data Center, NOAA
Boulder, Colorado 80303

DATA DESCRIPTION

The sets archived at the WDC-A consist of the following data collected between January and December 1979:

Data Set A: Daily Pressure and Temperature Fields

Data elements include: year, month, day, hour (gmt), latitude, longitude, interpolated temperature and pressure to the grid points, and interpolated error terms for temperature and pressure.

Data Set B: Three-Hourly Pressure and Temperature Fields

This set presents the same data as A, except that the reporting interval is every three hours.

Data Set C: Daily Buoy Positions

Data elements include: year, month, day, latitude, and longtitude. Buoy positions are grouped three per logical record.

Data Set D: Interpolated Ice Velocity Fields

This data set contains ice velocity estimates on a fixed grid of points, 2' longitude by 10' latitude. Data elements include: year, month, day, hour, latitude and longitude of grid point, interpolated ice velocities in the Cartesian grid, and variance estimates of the velocity field.

DISTRIBUTION MEDIA AND FORMATS

These data are available on computer tape in the following formats:

- 9 Track, 800 or 1600 bpi, EBCDIC or ASCII.
- 7 Track, 556 or 800 bpi, BCD only.
- 80 characters per record, block length is variable but cannot exceed 3840 characters per block.

More complete documentation is available upon request.

Costs are dependent on the amount of digital and analog data requested and computer processing required. Specific cost estimates will be provided on request.

For further information, and to place an order for data, contact:

World Data Center-A for Glaciology
Campus Box 449
University of Colorado
Boulder, CO 80309

Telephone: (303) 492-5171
FTS: 320-5311

DATA ANNOUNCEMENT

81-GLA-01

DEFENSE METEOROLOGICAL SATELLITE PROGRAM DATA

The World Data Center-A (WDC-A) for Glaciology [Snow and Ice] has established an adjunct collection of satellite imagery mosaics acquired from the United States Air Force Defense Meteorological Satellite Program (DMSP). DMSP is a system of near-polar orbiting satellites providing real-time information in two spectral bands (visual: 0.4-1.1μm; and infrared: 3-13μm, changed to 10.5-12.5μm after June 1979). These data are prepared from a global, digital intensity file used operationally by Air Force Global Weather Central (AFGWC) in forecasting and are subsequently archived in Boulder. The frequent global coverage (up to four times daily) and the 3-nautical mile (nm) resolution of the products have proven useful for observing changes in snow and ice boundaries on regional to global scales, as well as for cloud studies.

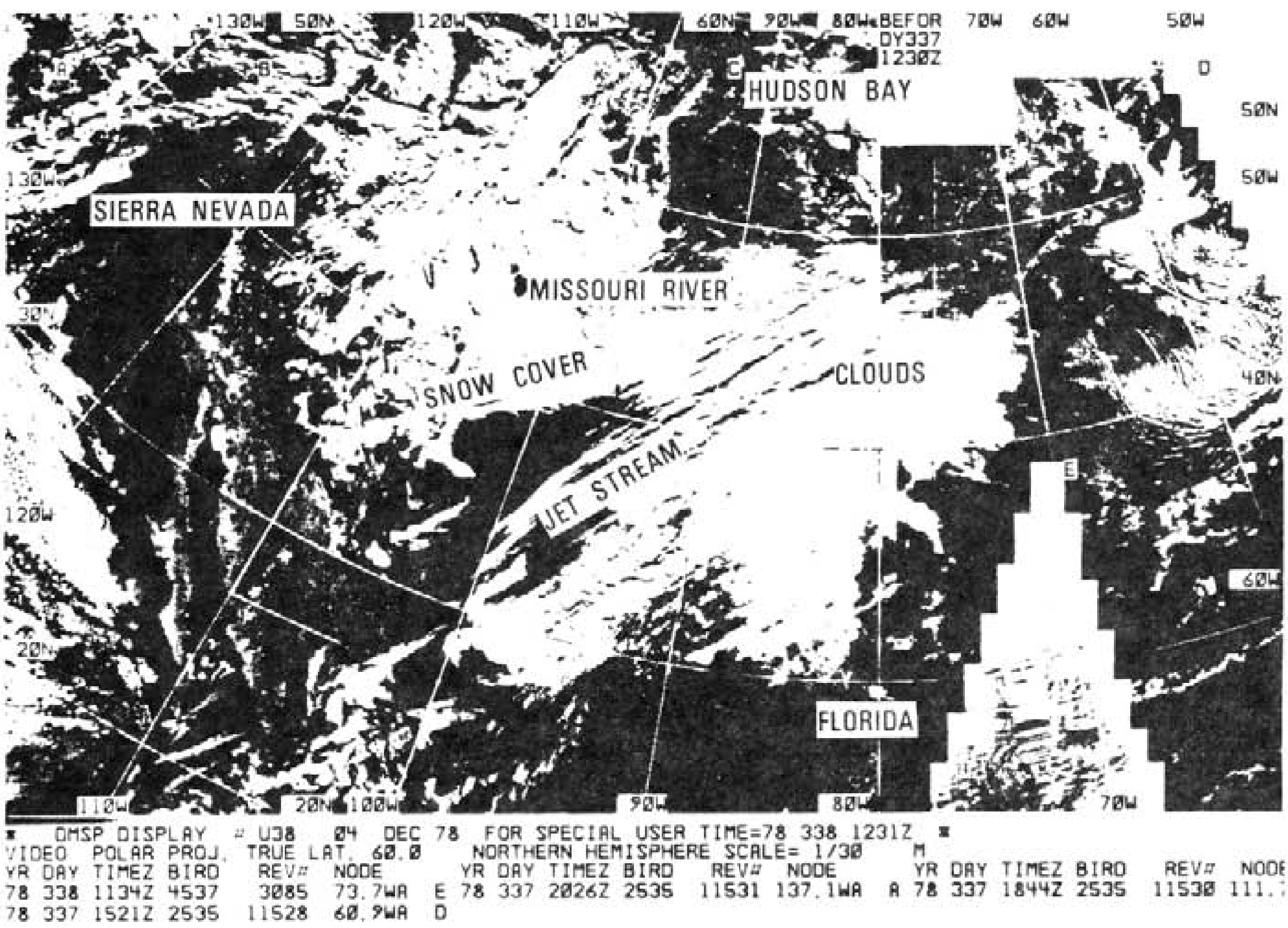
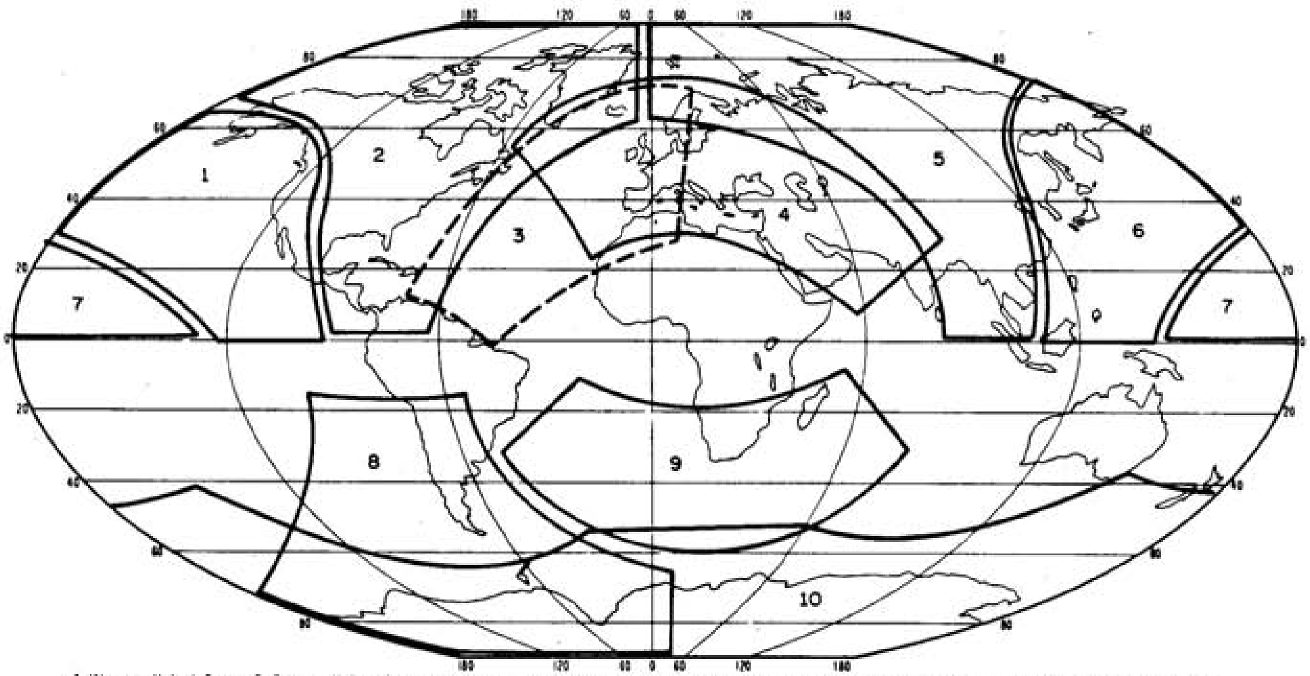


Figure 1. DMSP visual band image of the United States.

World Data Center-A for Glaciology [Snow and Ice]
National Geophysical and Solar-Terrestrial Data Center, NOAA
Boulder, Colorado 80303

The mylar mosaics are geographical combinations of orbital swaths reproduced on polar-stereographic projections at scales of 1:15,000,000 and 1:30,000,000. Some of the areas covered by the 1:15,000,000 scale mosaics are shown in figure 2. A more comprehensive view of the earth can be obtained from the 1:30,000,000 scale mosaics, four of which cover the globe. All of the mosaics are 15 inches wide by about 36 inches long. Latitude and longitude grids have been added, and the data are processed to eliminate cross-track distortion.



1. Western United States 2. Eastern United States 3. Atlantic 4. Europe 5. Asia 6. Far East 7. Central Pacific 8. Cape Horn 9. Cape of Good Hope 10. Antarctica

Figure 2. Some areas covered by 1:15,000,000 scale mosaics.

The operational scheme consists of two satellites in near-polar (inclination of 98.7°), sun-synchronous orbits at 450-nm (825 km) altitude. Orbital period is 102 minutes and the satellites step around the equator at 25° longitude increments on each successive orbit. By use of the two satellites, observations are made at near local noon and midnight, and at dawn and dusk. Each satellite utilizes an operational linescan system (OLS) which collects data continuously along a crosstrack scan 1600-nm (3000 km) wide.

The mosaics archived in the collection consist of data acquired from November 1975 onwards. The data are only available on a loan basis. Costs are dependent on quantity and time/area specifications of the request. Specific cost estimates will be provided on request. A typical request for one month of data over one region ranges between $25-$50. Additional data from March 1973 to November 1975 in single 1/4 orbit strips (global coverage) and Mercator projection mosaics of the tropics from November 1975 onward are only available by special agreement since additional sorting is necessary for these products.

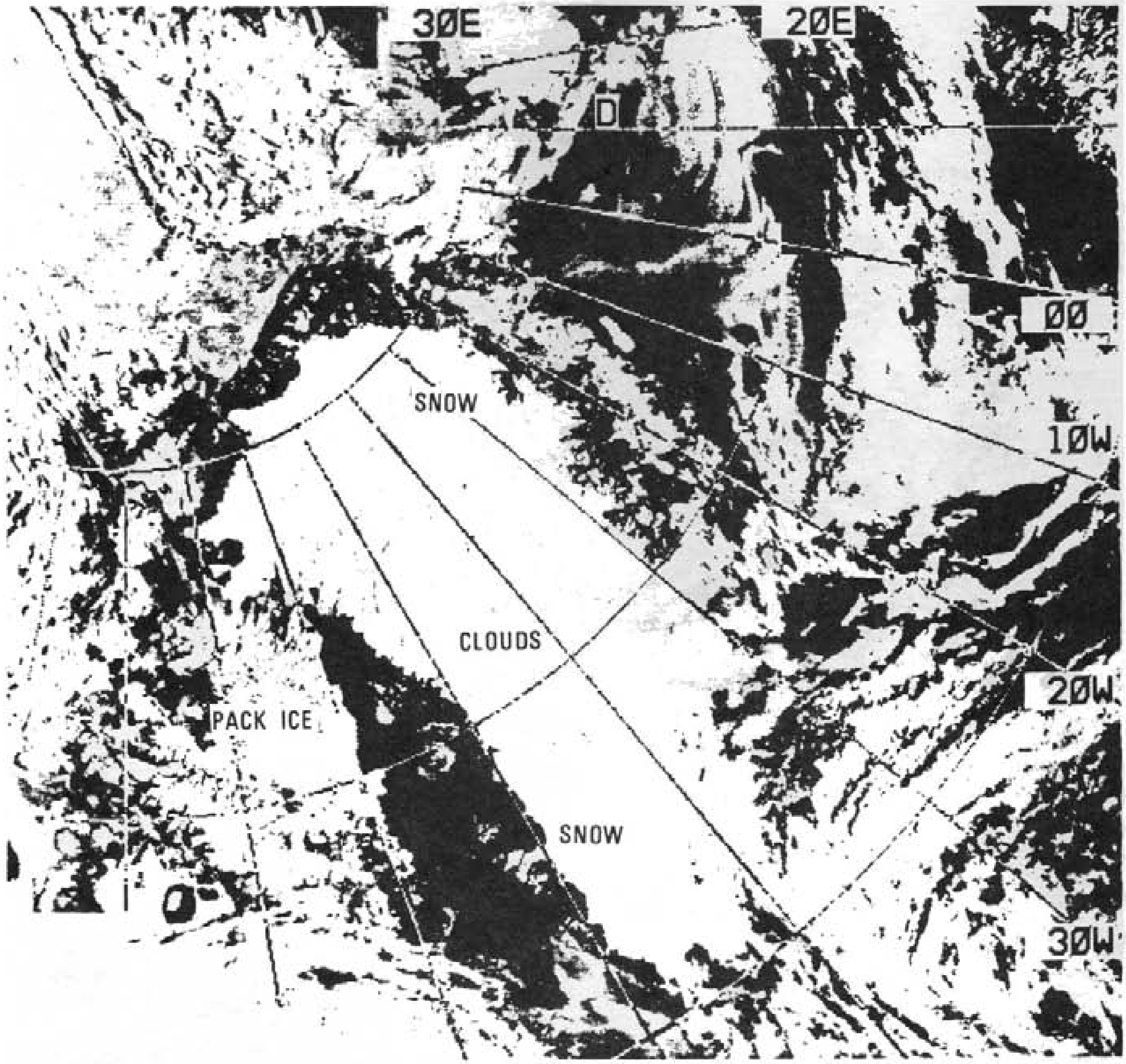


Figure 3. DMSP visual band image of the Greenland Ice Cap on 8 July 1978.

These data sets are complementary to the higher resolution ungridded DMSP orbital strips housed at the University of Wisconsin Space Science and Engineering Center and the nighttime DMSP auroral images at National Geophysical and Solar-Terrestrial Data Center (NGSDC).

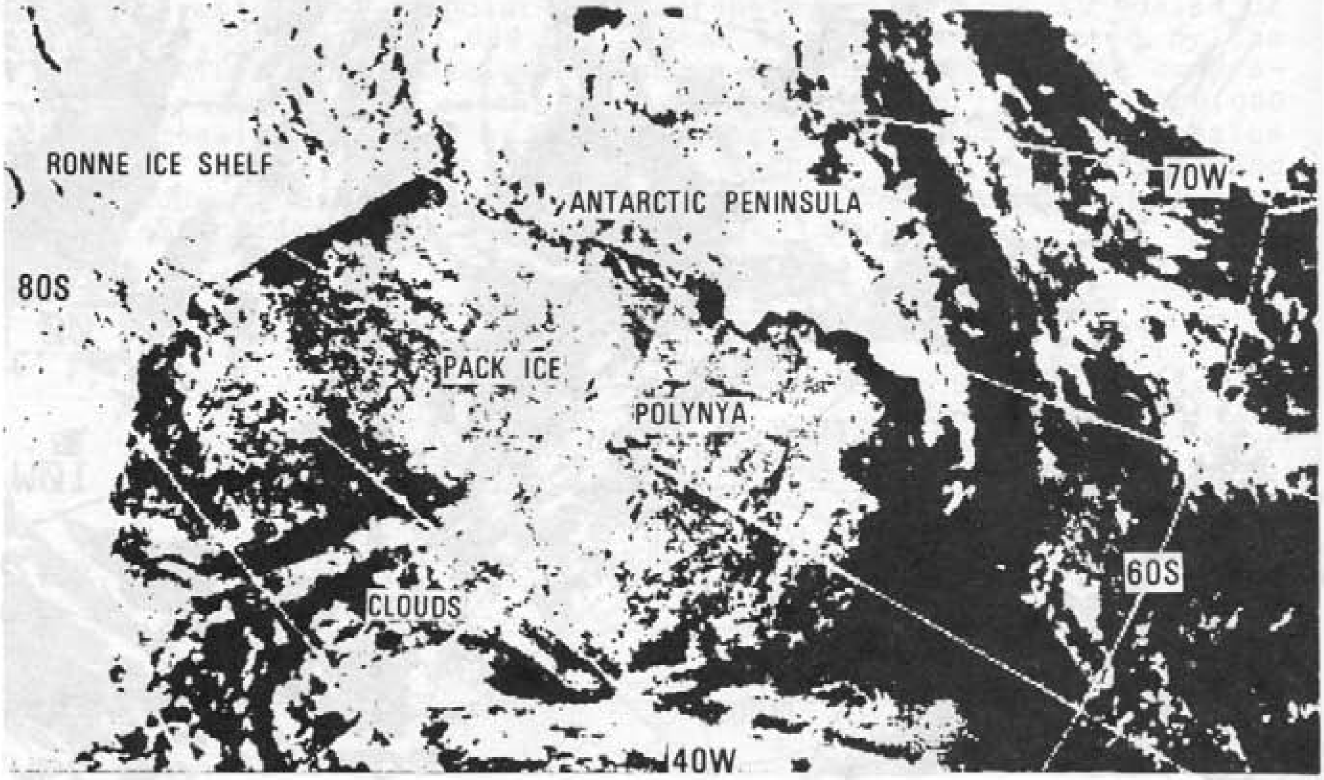


Figure 4. Sea ice along the Antarctic Peninsula on 7 February 1979.

For further information concerning DMSP, please contact:

World Data Center-A for Glaciology [Snow and Ice]
Campus Box 449
University of Colorado
Boulder, CO 80309
USA
Telephone (303) 492-5171, FTS 320-5311.

★ U.S.G.P.O. 6/81-777-030

GLACIOLOGICAL DATA SERIES

Glaciological Data, which supercedes Glaciological Notes, is published by the World Data Center-A for Glaciology (Snow and Ice) several times per year. It contains bibliographies, inventories, and survey reports relating to snow and ice data, specially prepared by the Center, as well as invited articles and brief, unsolicited statements on data sets, data collection and storage, methodology, and terminology in glaciology. Contributions are edited, but not refereed or copyrighted. WDC publications are distributed without charge to interested individuals and institutions.

Scientific Editor: Roger G. Barry
Technical Editor: Ann M. Brennan

The following issues have been published to date:

- GD- 1, Avalanches, 1977
- GD- 2, Parts 1 and 2, Arctic Sea Ice, 1978
- GD- 3, World Data Center Activities, 1978
- GD- 4, Parts 1 and 2, Glaciological Field Stations, 1979
- GD- 5, Workshop on Snow Cover and Sea Ice Data, 1979
- GD- 6, Snow Cover, 1979
- GD- 7, Inventory of Snow Cover and Sea Ice Data, 1979
- GD- 8, Ice Cores, 1980
- GD- 9, Great Lakes Ice, 1980

Contributions or correspondence should be addressed to:

World Data Center-A for Glaciology (Snow and Ice)
CIRES, Box 449
University of Colorado
Boulder, Colorado 80309
U.S.A.
Telephone (303) 492-5171; FTS 320-5311