NUMBERS 78 & 79

2nd & 3rd ISSUES 1985

ICE

INTERNATIONAL GLACIOLOGICAL SOCIETY

Future events

1986 Symposium on Remote Sensing in Glaciology, Cambridge, England
September 8, 9, 11, 12

****

1986 50th Anniversary Day, Cambridge England - September 10
50th Anniversary tour of Switzerland - September 13–20

****

1987 Symposium on Ice-core Analysis, Bern, Switzerland
March 30–April 4

****

1988 Symposium on Ice Dynamics, Hobart, Australia
February 14–19
Pre-Symposium tour of Hawaii
Post-Symposium tour of New Zealand glaciers

****

1988 Symposium on Snow and Glacier Research relating to Human Living Conditions, Norway
September (place and dates under discussion)

****

1989 Symposium on Ice and Climate, Seattle, U.S.A.
September (dates under discussion)

****

Circulars about these events will be sent to members of International Glaciological Society in due course. Enquiries should be addressed to the Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, England.

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ICE

NEWS BULLETIN OF THE

INTERNATIONAL GLACIOLOGICAL SOCIETY

NUMBERS 78 & 79 2nd & 3rd ISSUES 1985

CONTENTS

CHANGES TO **ICE**: In Iceland, Council endorsed the suggestion that the Society be more clearly identified on the cover of **ICE** and also decided that information on the officers of the Society and National Correspondents should be included. In this issue, the Glaciological Diary identifies the Society's meeting with 2 asterisks (**); those that the Society has agreed to co-sponsor with 1 asterisk (*). Readers will be noticing other changes in future issues. Preparation of copy will be moving from the Editor's basement to the Society's offices in Cambridge to take advantage of the word-processing equipment and new laser printer. With the completion of my second term as Editor, Council will be appointing a new Editor at the Cambridge meeting, to continue bringing you glaciological news from around the world. In due course the Publications Committee may be making further recommendations for changes in content, format and style, in response to your suggestions.

COVER PICTURE: Across-glacier view of ogives at base of Vaughan Lewis Glacier, Alaska (coming in from right), with part of Gilkey Glacier at top and an unnamed glacier at bottom of photo. Amplitude of the largest wave-bulge is ~20 m and the wave length is 100 m. Aerial photograph, 28 July 1978, by M.M. Miller, Juneau Icefield Research Project.

DENMARK – GREENLAND

QAMANÂRSSÛP SERMIA, WEST GREENLAND, 1984-85

(R.J. Braithwaite, GGU)*

The field station (64°28'N, 49°30'W) is at the head of Godthåbsfjord. Fieldwork was carried out for the fifth and sixth consecutive summers at Qamanârssûp sermia, an outlet glacier from the Inland Ice. It included mass balance and ice movement measurements in a sparse stake network covering 150 km^2, as well as daily climatological observations at base camp and daily ablation readings near the ice edge.

Ablation variations during the six years of record can be illustrated by the following indices (in m H_2O), obtained by applying the linear balance model to the stake data:

Year	A1	A2	A3	A4
1979/80	0.3			-0.3
1980/81	0.4	0.5	0.5	0.4
1981/82	0.4	0.3	0.4	0.3
1982/83	-0.4	-0.5	-0.5	-0.6
1983/84	-0.4	-0.4	-0.4	-0.1
1984/85	1.1	0.9		1.5

There is general agreement that 1984/85 had the highest ablation while 1982/83 had the lowest. This corresponds with temperature variations over the same six-year period.

ENERGY BALANCE AT QAMANÂRSSÛP SERMIA

(N.T. Knudsen, GeoII/ÅU)

In 1984, an energy balance station (about 600 m a.s.l.) was operated throughout the ablation period. Net radiation and convection were determined. Radiation provided 2/3 of the total energy and non-radiative terms the remaining 1/3. These totals cover large variations during the period. Observations correlated well with those at Base Camp so it will be possible to evaluate net radiation, convection and ablation from there.

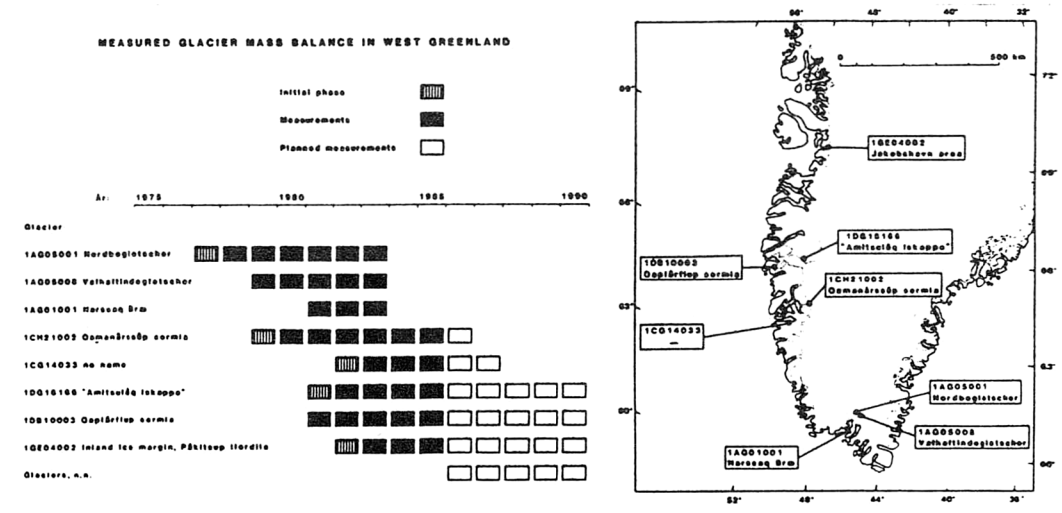
TASERSIAQ AND QAPIÂRFIUP SERMIA BASINS, WEST GREENLAND, GLACIOLOGICAL WORK IN 1985

(O.B. Olesen, GGU)

Since 1981, field work has been carried out in both Tasersiaq (66°06'N, 50°07'W) and Qapiârfiup (65°36'N, 52°15'W) basins.

At Tasersiaq, field work is concentrated on mass balance studies on the local ice cap "Amitsulôq" (165 km^2 and altitudes to 1400 m a.s.l.). A single stake line is also maintained on Tasersiaq Glacier, an outlet from the Sukkertoppen Ice Cap 70 km west of "Amitsulôq". Climatological elements are measured at four weather stations (two on land, two on the ice). At Qapiârfiup sermia, mass balance studies are carried out only on a 21 km^2 section near the coast.

After two consecutive years with comfortably positive balances, the 1984/85 balance was the most negative yet measured. The winter in West Greenland was mild and dry and the accumulation therefore very low. The summer was exceptionally warm and sunny; hence the ablation was about three times higher than in 1983 when the weather throughout the summer was cold, wet and cloudy.



Location of present and planned investigations on glacier mass balance in West Greenland by the Geological Survey of Greenland

*For abbreviations used in Recent Work see this Issue p.40 and ICE, Nos. 72 & 73, 1983, p.36

MASS BALANCE MEASUREMENTS N.E. OF JAKOBSHAVN

(H.H. Thomsen, GGU)

Mass balance measurements on the Inland Ice northeast of Jakobshavn have been continued. A stake line was set up in August 1982, starting on the outlet glacier 1GE07001 (69° 28'N, 50°12'W). The stake net ranges from about 300-1200 m a.s.l. It is visited by helicopter twice, in May and August. Transient balance and annual balance have been measured for 1982/83, 1983/84 and 1984/85.

Ablation was much greater in 1984/85 than in the previous two years. The annual equilibrium line for 1984/85 was estimated to be approximately 1100 m a.s.l.

MITDLUAGKAT GLACIER - FIELD WORK 1985

(B. Hasholt, GCI/UCPH)

The glacier is on Angmagssalik Island (65° 42'N, 38°50'W) and covers an area of 30 km^2. The first observations date to 1933 when the snout was photographed. In 1970, UCPH built the Sermilik field station 2 km west of the snout. Since then, continuous measurements have been carried out - mainly glacio-hydrological and climatological.

The 1985 resurvey of a triangulation network was used for photogrammetric mapping of the glacier, based on photos from 1972. The reliability of the map was tested and compared with measurements of the terminus carried out since 1979. Climatological parameters, runoff and suspended load were also measured.

RECENT CHANGES OF NORDBOGLETSCHER AND NORDGLETSCHER - JOHAN DAHL LAND

(N.T. Knudsen, GeoI/AU)

Marginal and surface changes of the glaciers were determined using surface topography maps drawn from aerial photographs taken in 1953, 1977 and 1981. Changes were compared with ablation and surface movement of ice measured at stakes established in 1978 at Nordbogletscher.

Advances measured at both glaciers during the period 1953-81 are the result of a higher transport rate of ice from the accumulation area than can ablate during the summers in the ablation area, under prevailing climatic conditions.

THE REGISTRATION OF GLACIERS

(A. Weidick, GGU)

The history of W. Greenland glacier changes has been updated in connection with an atlas of West Greenland glaciers (59°-71°N) and the general field work of the Geological Survey of Greenland. During the work, the location of surging glaciers on Disko Island (69°N) and the possibilities for glacier surges in South Greenland have been reported.

PILOT STUDY ON RENLAND ICE CAP

(H.B. Clausen and N. Gundestrup, GIG/UCPH)

Airborne radio-echo sounding and analysis of a hand-augered firn core suggest that the ice cap (elevation 2350 m a.s.l.) on Renland Peninsula in Scoresby Sund Fjord is well suited for drilling to bedrock by a "shallow" drill. A joint effort by the Nordic countries is envisaged for 1986 and 1987.

PAST AND PRESENT GLACIATION, DISKO ISLAND, CENTRAL WEST GREENLAND (70°N)

(O. Humlum, ARS/UCPH)

Frontal variations are being monitored at 12 glaciers on Disko Island. During the summer of 1985, a reconnaissance was carried out in the central part of the island to update glacier information. Climatic conditions were unfavourable for glaciers during the balance year 1984/85. The winter was dry, while the summer was long and characterized by frequent clear-sky conditions. Most glaciers suffered a considerable net mass loss. This is also indicated in runoff observations in a selected drainage basin.

Year-round studies on temperature, relative humidity, precipitation and the snow cover were initiated in 1983 and have been continued since. These observations are partly automatic, partly manual, and are carried out along various test lines in the mountains near Godhavn, southern Disko Island. The build-up and decay of aufeis is followed throughout the year, as are temperatures in bedrock at selected points.

During 1985, rock glaciers on the island were mapped and studied. Snout movement was monitored at 15 rock glaciers. Their climatic conditions are being measured and compared with localities without rock glacier development. Statistical studies on their spatial distribution have been initiated. About 2000 rock glaciers are found on Disko Island. Their present activity differs and active, inactive, as well as fossil features, are found.

ISOTOPE STUDIES ON THE ICE-SHEET MARGIN

(N. Reeh and H.H. Thomsen, GGU)

Snow, ice and water samples for stable isotope analysis ($\delta^{18}O$) were collected on the Greenland ice-sheet margin. At Pâkitsup, Akuliarusersua, Jacobshavn/Ilulissat, West Greenland - a proposed hydropower-plant location - more than 800 samples were collected for elucidating the hydrology and dynamics of the ice margin. Ice samples were also collected from the margin in Warming Land, N. Greenland, by N. Henriksen (GGU) and from the margin of Flade Isblink, a local ice cap in N.E. Greenland by S.S. Pedersen (UCPH). They were analysed for $\delta^{18}O$ at GIG/UCPH. Results confirm the isotope studies have various uses:

1) Their variations in melt-water runoff can help in delineating drainage basins on the ice sheet.
2) Linking locations with the same observed isotope ratios in the accumulation and ablation zones gives information on ice dynamics.
3) Surface isotope profiles from the outermost kilometre of the ice-sheet margin

provide records dating back into the Wisconsinan. Minimum information from such records are the location of the Holocene/Wisconsinan transition and the magnitude of the corresponding $\delta^{18}O$ shift; important for understanding the climatic and dynamic history of the ice sheet. However, other details known from the ice-age $\delta^{18}O$ records from deep ice cores also seem to be preserved in the ice-margin isotopic records.

DRAINAGE CONDITIONS ON THE INLAND ICE

(H.H. Thomsen and N. Reeh, GGU)

Meltwater surface drainage conditions were studied by foot and from helicopter on the Inland Ice northeast of Jakobshavn.

Surface water is draining through innumerable small rivers collecting to big river systems. The rivers run over long distances on the surface, but the water often escapes into the ice through crevasses or moulins. Surface drainage is much dependent on local surface undulations and structural features such as shear bands, healed crevasses and ridges. Rivers often run in up to 6-m deep canyons cutting through the surface undulations. The bed may incline inland opposite the ice surface inclination, directing meltwater away from the ice margin over varying distances.

Many lakes exist on the ice. Some empty through the existing surface drainage system, but for others no sign of drainage could be seen on the ice surface. Smaller crevasses cutting through the lake bottom could be observed.

Temperature profiles in lakes from different elevations on the Inland Ice were measured by float-equipped helicopters. No variation of temperature with depth was found and all were above 0°C. The temperatures increase gradually with decreasing elevation, from 0.1-0.2°C at about 1000 m a.s.l. to 0.8°C at about 350 m a.s.l.

RADIO-ECHO SOUNDING OF THE INLAND ICE MARGIN

(H.H.Thomsen & L.Thorning, GGU; P.S. Madsen, EMI)

Information about the subglacial topography of the Inland Ice margin is necessary as partial input for glacier dynamic modelling and for delineation of hydrological drainage basins on the ice. A radio-echo sounding programme was set up by GGU in cooperation with EMI. Acquisition of about 2,200 line-kilometres from the marginal zone of the Inland Ice east of Jakobshavn and Christianshåb was planned at the beginning of May 1984, using a 300 MHz ice-radar mounted in a Twin-Otter aircraft. The mission was disrupted after 800 km because no bottom echoes were recorded, probably due to technical problems with the radar and a too-simple antenna arrangement. The attempt was continued in 1985. The 300 MHz ice-radar underwent a detailed technical check and a new improved antenna arrangement was constructed for use on a Bell 206 Jet Ranger helicopter. The changes and the slow, low-altitude flying possible with the helicopter gave good results. The Inland Ice margin northeast of Jakobshavn, between 69°32'N up to about 600-700 m a.s.l., was mapped in mid-July 1985. Data processing and plotting of a subglacial topographic map is presently under way.

ICE FLOW ALONG AN ICE DIVIDE

(N. Reeh, GIG/UCPH)

The steady state ice-dynamic model, developed for studying the ice flow leading to the deep core hole at Dye 3, South Greenland, has been improved by incorporating lateral convergence/divergence and allowing for changing temperature-depth profiles along the flow line. A bottom layer of variable thickness, with flow properties different from those of the ice above, has been introduced to allow for a possible basal layer of soft Wisconsinan ice.

The improved model has been applied to study ice flow along a divide on Devon Ice Cap and in a section of Barnes Ice Cap, Canada. Very different depth distributions of velocities, strain rates and stresses may occur along an ice divide,closely related to changing convergence/divergence conditions. The closest fits to the observed surface profiles are obtained with flow law parameters n=3 and A-values as suggested by Paterson.

SHALLOW DRILLING IN CENTRAL GREENLAND

(H.B. Clausen and S.J. Johnsen, GIG/UCPH)

As part of an American-Danish-Swiss search for a favourable deep drill site in Central Greenland, eight ice cores were recovered by a mobile drill: in 1984, three cores from 25 to 106 m depth along 70.7°N latitude from the ice divide and 85 km west; and in 1985, five cores from 26 to 129 m depth along 34°W longitude from 71.8 to 70.6°N latitude. An acid layer due to fall-out from the Icelandic Laki eruption (1783) serves as a fix point of the time scale along all cores deeper than 70 metres.

GLACIO-CHEMICAL STUDIES IN THE DYE 3 REGION

(H.B. Clausen and C.U. Hammer, GIG/UCPH; C.C. Langway, Jr., SUNY/Buffalo)

A 175-m shallow core drilled 6 km upstream from Dye 3 was measured in situ for solid electrical conductivity (ECM). The conductivity profile was transformed into "acidity" in order to investigate the potential of ECM as a quantitative estimate of acidity in firn. The Laki eruption was found at a depth of 129.15 m, indicating a 200-year average accumulation of 52.7 cm ice/a. The acidities were later compared to seasonal anion composition of several 10-year segments over the core. A two-times increase in NO_3^- and SO_4^{2-} concentration was observed during the 20th century part of the core.

In a detailed pit study 8 km upstream from Dye 3, 220 samples were taken of the summer

1982 - summer 1983 snow layer and some 20-25 major individual "snowfalls" could be observed in the pit. These samples will be analyzed for dust, pH, ^{18}O, SO_4^{--}, NO_3^- and Cl^- in order to infer the characteristics of individual precipitations. The data will be used to study the air-ice transfer function of the various trace substances.

LOGGING THE BORE HOLE AT DYE 3
(N. Gundestrup, GIG/UCPH; B.L. Hansen, PICO)
The 1979-81 joint American-Danish-Swiss deep core drilling to bedrock, Greenland Ice Sheet Program, left a liquid-filled hole: diameter 13 cm; length 2038 m; initial inclination 1° near surface and 6° at bedrock. The hole was relogged in 1983 and 1985. Temperature, inclination and azimuth profiles were measured as well as hole diameter and pressure profiles. 80% of the surface velocity is due to shear in the deepest 20% of the ice. In 1985 the deepest 3.7 m was inaccessible, due to sliding along a shear plane.

SURFACE INVESTIGATIONS UPSTREAM FROM DYE 3
(H.B. Clausen and N. Gundestrup, GIG/UCPH)
Data measured along the Dye 3 deep ice core need correction for upstream deviations in accumulation, temperature, snow composition, etc. Two surface operations along the estimated flow line up to 45 km from Dye 3 included pressure altimetry, satellite positioning in a network, radio-echo sounding, pit studies, and augering or drilling of 17 shallow cores from 5 to 175-m depth.

MICROMETEORITES AND GLACIOLOGICAL STUDIES
(C.U.Hammer & N.Reeh, GIG/UCPH; M.Maurette, Lab.René Bernas, B.P.1, 91496 Orsay, France)
A French-Danish expedition investigated the use of the black surface deposits, seen in the ablation zone up to some 50 km from the ice margin, as highly concentrated placers of extra-terrestrial material.

The potential of using the ablation zone as a "horizontal ice core" (i.e. "easy" access to old ice layers by surface sampling), was also investigated. The ablation zone presents us with unique possibilities for studies of old ice layers. How old the ice is depends on various parameters, but it is estimated, that at least several tens of thousands of years can be studied. The precision and potential of such a "surface" procedure remains to be investigated.

Anker Weidick

DENMARK – NORWAY

METEOROLOGICAL AND HYDROLOGICAL INVESTIGATIONS AT OKSTINDAN AND SVARTISEN
(N.T. Knudsen and J.T. Møller, GeoI/ÅU; W.H. Theakstone, Manchester University)
Measurements of meteorological variables including radiation, temperature, wind speed, humidity and precipitation at and around Austre Okstindbre were continued, as well as meltwater flow and ablation. Samples were collected for determination of variations in O^{18}/O^{16}, chemical constituents and suspended sediment load. Ice surface velocity was determined at 12 stakes placed in the ablation area. Terrestrial photogrammetric surveys were performed at Austre Okstindbre. A detailed study of recent changes of the glacier Austerdalsisen, Svartisen has been completed.

FINLAND

ICING OF STRUCTURES
Ice accretion on stationary structures has been studied by theoretical modelling and by laboratory experiments in an attempt to understand the physics of the icing process and particularly to relate accreted ice loads to the relevant meteorological parameters.

A time-dependent ice accretion model was developed which makes use of the theory of water droplet collision efficiency. It includes simulation of ice density variation and the heat balance of the icing surface. A separate boundary-layer model of the convective heat transfer from a rough cylinder is presented and incorporated into the ice accretion model. Under wet growth icing conditions the rate of icing is very sensitive to the roughness of the icing surface. The model simulates both glaze and rime icing and the transition between these processes. It is possible to show the sensitivity of the rate of ice accretion to various meteorological variables and to predict ice loads.

Model predictions for glaze ice agree well with earlier experimental results. To test the theory for rime, extensive laboratory experiments were made in the icing wind tunnel of the National Research Council of Canada in Ottawa, Ontario. Comparisons between the theoretical and experimental data of the ice loads on rotating cylinders showed excellent agreement. Tests on icing of power line cables demonstrated that the model also predicts well the formation of ice loads on objects having slightly irregular shapes and a rough surface.

The model has been used to estimate the probabilities of extreme icing events on offshore structures off the east coast of Canada and will be used for the operational design of power lines in the U.S.A. and Canada. Empirical studies of sea spray icing

have also been made using the small outdoor icing tunnel of the Institute of Marine Research in Helsinki. These experiments suggest that the salinity of sea spray does not significantly affect the rate of icing except at temperatures close to the freezing point.

L. Makkonen

POLAND

COMMITTEE ON POLAR RESEARCH

The election of members and a supervising body of the Committee on Polar Research of the Polish Academy of Sciences (PAS) was held in 1984. K. Birkenmajer was elected its new chairman. The former chairman, A. Jahn, was appointed honorary chairman.

KING GEORGE ISLAND SURVEY AND THE BIOMASS-SIBEX PROGRAMME

Members of the 8th Expedition of the Institute of Ecology, PAS, finished a year's fieldwork at the Antarctic Arctowski Station. The 9th Expedition was sent to continue exploration. It focussed on biological and oceanographic problems. In December 1984 and January 1985, the 2nd Geodynamic Expedition under A. Guterch worked in the Bransfield Strait and on the western Antarctic Peninsula as far as the Marguerita Bay. Deep seismic surveys and seismic-acoustic profiling, together with the core sampling of bottom deposits, were carried out. During the summer months of 1983/84, PAS organized an Antarctic Expedition on the r/v "Professor Siedlecki" to participate in the BIOMASS-SIBEX programme. Financial support was provided by the Institute of Ecology. The study area comprised the Bransfield Strait and Drake Passage.

HORNSUND-SPITSBERGEN SURVEY

Members of the 6th Expedition under J. Cisak wintered over at the polar station Isbjörnhamna, Hornsund, managed by the Institute of Geophysics, PAS. They carried out geophysical research and topographical surveys for a detailed map of the Hornsund region. Afterwards, members of the 7th Expedition under J.M. Wesławski undertook oceanological and biological-marine investigations in Hornsund Banken and Storfjorden.

UNIVERSITY EXPEDITIONS

The Geography Institute (Laboratory for the Documentation of Polar Research), Jagiellonian University, worked in Hornsundneset, Breinesflya, N. Wiederfjellet and Gavrilovfjellet (June-September 1984) on geomorphology, hydrology and integrated environmental problems, as well as on the history of seasonal settlement between Torellbreen and Sorkappøya.

The Quaternary Research Institute, Adam Mickiewicz University, under W. Stankowski, visited the Petuniabukta region (June-July 1984). The research programme included geomorphology (glacial relief, slopes) and geomorphological mapping, lithology and stratigraphy of glacial deposits.

The Geographical Institute, Wrocław University, studied solifluction movement, rock glaciers (three years), microgelifraction of metamorphic rocks and the history of Spitsbergen glaciation in the Hornsund region, under H.Chmal. Geologists and geographers of the Warsaw and Silesian universities participated in expeditions organized by Adam Mickiewicz University and the expedition led by members of the Institute of Geophysics, PAS.

PERMAFROST PROGRAMME

Polish specialists, in cooperation with the International Permafrost Association, started a new permafrost research project under A. Jahn, in Spitsbergen at the PAS research station in the Hornsund region. Detailed studies of the physical properties of permafrost and ground ice are the main topics.

THE POLAR CLUB

Papers on geology, geomorphology, glaciology, climatology and oceanography in different regions of Spitsbergen and South Shetland Islands were presented in May 1984 at the 11th Polar Symposium, organized by the Polar Club and the Quaternary Research Institute of Adam Mickiewicz University of Poznań (W. Stankowski).

SYMPOSIUM AND SEMINARS

At the Spitsbergen '84 Symposium organized by the Institute of Ecology, PAS, polar explorers from Poland, the Soviet Union and Czechoslovakia presented 40 papers.

The 3rd Polar Geomorphological Seminar on "Moraines and Tills: genesis and transformations" was held at Nicolaus Copernicus University of Toruń in December 1984, organized by the Polar Section of the Polish Geographical Society and the Pomeranian Division of the Polish Geophysical Society. A Seminar on Glacio-Karst was held at the 9th Speleological School (Karpacz '84) by the Department of Karst Geomorphology of the Silesian University and the Geographical Institute of the University of Wrocław.

INFORMATION ON PERIODICALS

Since 1980 and 1960 respectively, articles on the geological results of the Polish Antarctic Expeditions (three volumes) and of the Polish Spitsbergen Expeditions (13 volumes) have been published by K. Birkenmajer in Studia Geologica Polonica.

Stefan Kozarski

SWEDEN

GLACIOLOGICAL RESEARCH AT TARFALA, 1985

In July we concluded surveys of a 32-stake network covering most of Storglaciären. These surveys were begun in 1982 and have been repeated since then at approximately weekly intervals during the four summer months and every 45 to 90 days during the rest of the year. Daily (weather permitting) surveys were begun on two five-stake networks. In these surveys, distances between stakes on the nets were measured from a fixed point, as well as angles and distances to the stakes. The locations are thus over determined, permitting a least-squares solution for stake coordinates.

As noted previously, velocities on Storglaciären increase during periods of warm or rainy weather. However we have not found a good correlation between velocity and water pressures in boreholes that are believed to have reached the glacier bed near the centerline, despite significant variations in these water pressures. This suggests that the glacier's behaviour may be controlled by water pressure variations nearer the margin. Inclinometry measurements in two boreholes on the centerline indicate that the glacier may be decoupled from the bed in this area during part of the summer. This lends credence to the above suggestion.

Dye trace studies were continued this summer. Two tests, one in late June and the second about 10 days later - both of which were in a moulin near the middle of the ablation area - produced quite different results. The peak concentration was much higher and appeared much sooner in the second test, presumably reflecting development of a more integrated drainage system over this ten-day time period. In another test from the upper part of the ablation area twice as far from the terminus, the dye required much more than twice as long to appear at the terminus. This suggests that water flow through an overdeepened area between the two input points is significantly different from that in the lower part of the glacier.

Tiltmeters are being used to sense small changes in the slope of the glacier surface. One record from late July showed a progressive uplift of the surface near the centerline, up-glacier from a riegel. Superimposed on this uplift, however, were diurnal oscillations; the surface appeared to sink in the late morning and early afternoon, possibly reflecting a draw-down as high water pressures at this time of day resulted in acceleration of ice flow over the riegel.

During the past year, calculations of the 1984 summer water balance on Storglaciären were completed. The results, which are still preliminary, suggest that about $0.8 \times 10^6 m^3$ were stored in the glacier in late May and early June. Between mid-June and the beginning of August, inputs from melt and rain balanced outputs in the streams draining the glacier. Then, from the beginning of August until mid-September, about $0.7 \times 10^6 m^3$ were released from storage. The amount remaining in storage, $0.1 \times 10^6 m^3$, is of the same order as our estimate of the volume of subglacial cavities at this time of year (see ICE, No.76). The paradox is that the water storage appears to take place in June, whereas the cavities are believed to open in late July and August. We suspect that the initial storage takes place in near-surface reservoirs, such as porous firn and crevasses. Then, as the drainage system develops later in the season, the water moves into subglacial storage locations. We infer that it is gradually released from the subglacial cavities during the winter.

The mass balance measurements were continued this year, extending our record of both winter and summer balance to 40 years. Approximate specific net balance figures, not reported previously, are: 1980/81, -0.2 m (H_2O); 1981/82, +0.2; 1982/83, +0.1; 1983/84, 0.0.

Roger LeB. Hooke and Per Holmlund

SWITZERLAND

GLACIERS

PERMANENT SERVICE ON THE FLUCTUATIONS OF GLACIERS (PSFG)

(W. Haeberli, P. Alean and P. Müller, VAW)

After a six-year interruption caused by the tragic death of F. Müller, activities were resumed in 1983. PSFG-volume IV (Fluctuations of Glaciers 1975-1980) was prepared in two years and PSFG-volume V (1980-85) will be published in 1987/88. The format of data presentation was not changed significantly, in order to preserve the coherence of this ongoing series. However, steps were undertaken to facilitate and speed up the collection and processing of data. At the same time, efforts were made to develop a future world glacier monitoring programme which would combine the PSFG and the TTS.

TEMPORARY TECHNICAL SECRETARIAT FOR THE WORLD GLACIER INVENTORY (TTS)

(K. Scherler and J. Pika, VAW)

In January 1984, the TTS was transferred from GGEZ to VAW. New glacier inventories from Bolivia, Italy, French Pyrenees, Germany, Ecuador, some Peruvian Cordilleras, Province of Neuquén (Argentina), Chitral

(Pakistan), Tinguiririca and Maipo basins (Chile) and Spitsbergen were incorporated into the TTS data bank.

Preliminary inventories based on standard LANDSAT products (MSS or RBV) were compiled by the TTS for Nepal and Bhutan, and will be compiled for some other regions (e.g. South Patagonia, Pakistan, Afghanistan). Despite difficulties such as shadows, cloud cover, snow cover etc., relatively accurate areal data were collected, giving a good idea of glacier distributions in areas not covered by detailed topographical maps.

The final publication of the World Glacier Inventory should be issued in 1986. Maps, diagrammes and tables will be produced by computer, using the TTS data bank.

ANNUAL SURVEY OF SWISS GLACIERS
(M.Aellen, VAW & GK/SNG, H.Siegenthaler VAW)
The 104th and 105th annual surveys (1983 and 1984) of glacier snouts in the Swiss Alps showed that in 1983 there were 46 advancing, 6 stationary and 57 receding glaciers. In 1984, there were 52 advancing, 5 stationary and 28 receding glaciers. In both years, the percentage of advancing glaciers was highest in the Reuss and Limmat river basins, lowest in the Rhein and Inn river basins and near average in the other parts of the Swiss Alps. Overall, the general tendency to advance has weakened in the last five years. This is confirmed by the mean annual velocities measured by stake networks on various glaciers. After a three to four year period of rapid acceleration giving maximum velocities in 1980 and 1981, movement successively slowed down and velocities have almost reached their former low values.

Summarized specific net mass balances for the glaciers of four high alpine basins (in kg/m^2) are as follows:

	Gries	Aletsch	Limmern & Plattalva	Silvretta
1982/83:	-550	+149	-738	-547
1983/84:	- 3	+784	-229	+281

After several years (5 out of 6) with excessively high values in most regions, the annual accumulation rates were near to normal in both years of this report and in all regions. Thus, the variation in mass balance shown by the above figures is mainly due to the variation in ablation rates, from rather high to rather low values, according to the duration of the melt season. Consequently, several hydro storage basins in the Swiss Alps were not filled completely by the end of the melt season in 1984.

SEASONAL VARIATIONS OF SUBGLACIAL WATER PRESSURE AND GLACIER VELOCITY
(A. Iken, VAW)
Two sets, one of 3 and one of 2 bore holes, were drilled to the bed of Findelengletscher in September 1983 and early March 1984 respectively. Water pressure was recorded as long as the holes remained connected to the subglacial drainage system. The movement of poles in the same area was measured during the same period (and is measured throughout the year at larger time intervals). This study supplements the investigations at the Findelengletscher described in ICE No.72/73.

PERIODIC SLIDES OF A SMALL, STEEP GLACIER
(A. Iken and W. Schmid, VAW)
The glacier, situated on the NW face of the Altels (cantons Berne-Wallis), slopes rather uniformly at 32°; at the snout the slope is less. The 1-km long glacier is probably partly temperate. Its largest part slides a considerable distance every few years, resulting in a step of about 20 m height between the "stationary" upper part and the sliding mass. To investigate such slides and their conditions, the changes of geometry and velocity of the glacier are monitored. A network of fixed points for the evaluation of aerial photographs has been established. Four poles near the centre line are surveyed at intervals of a few months. Changes of crevasse patterns are recorded by means of two automatic cameras. Measurements of ice thickness, ice temperature and subglacial water pressure are planned.

RADIO-ECHO SOUNDING ON ALPINE GLACIERS
(W. Haeberli, J. Alean, P. Müller and W. Schmid, VAW)
Extensive soundings, using the USGS monopulse radio-echo-sounder, were carried out on Gurgler Ferner, Austrian Alps, (with Alpine Forschungsstelle Innsbruck and Kommision für Glaziologie, Bayerische Akademie der Wissenschaften), Griesgletscher Swiss Alps and Ghiacciaio del Belvedere, Italian Alps. The total Alpine ice volume will be re-estimated using available ice-thickness measurements and glacier inventory data.

PARAMETERIZATION OF GLACIER-CLIMATE RELATIONSHIPS
(P. Müller and W. Haeberli, VAW)
Fluctuation data on glaciers in the Swiss Alps are stored in the ETH computer. This enables statistical software to be used to test existing methods, as well as to develop new models for classifying glaciers and for predicting on an empirical basis such parameters as the time lag between balance and length changes of the mean and extreme values of the extent and speed of glacier advance/retreat. It is hoped that results will be useful for practical applications (glacier hazards) as well as for a better understanding of past glacier fluctuations.

ICE AVALANCHES
(J. Alean, VAW)
Empirical data on ice avalanches were used to calibrate a two-parameter model (normally used for snow avalanches) for predicting runout distances. Calibration uncertainties are mainly due to the fact that ice avalanche

deposits are usually built up by several individual falls and that the volume of the largest fall cannot be determined accurately.

Ice avalanche reaches were also analysed using an entirely statistical approach incorporating a terrain parameter of the avalanche paths.

Characteristics of the starting zones influence the maximum volume of ice released. Some, but not all types of starting zones, produce ice avalanches primarily in summer and autumn. The starting zone on the Fletschhorngletscher (Valais) is being observed using automatic cameras. The glacier has produced a series of avalanches roughly every two to three years since at least 1968. It is hoped that daily photography will put an upper limit on the volume of individual events. These may, in turn, be used to improve the calibration of models for runout predictions.

NUMERICAL ANALYSIS OF A HIGH-ALTITUDE HANGING GLACIER IN THE ALPS
(J. Schweizer and A. Iken, VAW)
A hanging glacier (4150 m a.s.l., mean slope 48°) on the north face of Lyskamm (Monte Rosa) served as a model for calculating the distribution of stress and velocity by the finite-element method using a linear viscous flow law. Analysing the stress field, a probable simple geometry of the unknown glacier bed could be determined. A study on possible break-off mechanisms of ice avalanches leads to the assumption that only small parts with volumes of about 1000 m^3 break off at any one time. Analysis of the velocity field yielded a depth-age relationship which could serve as a basis for stratigraphic interpretations.

ARCHING IN GLACIERS
(B. Ott, H. Röthlisberger, A. Iken and K. Hutter, VAW)
Deformation of vault-like structures in glaciers were modelled using the finite-element method. The studies included arched crevasses, free-standing arches and crescent-shaped fracture lines above the starting point of large ice avalanches. Special attention was given to the zones of tensile stress in relation to the stability of arched structures.

CONTINUUM MODELLING OF POLYTHERMAL ICE
(T. Alts and K. Hutter, VAW)
Recognizing that temperate ice is a mixture of ice and water with the water in bubbly inclusions or along grain boundaries, a thermodynamic model was developed in which the phase change surfaces are mathematically treated as singular surfaces equipped with mass, energy etc. The thermodynamic implications of this surface continuum are deduced and the results are compared with the alternative model in which the phase change is modelled as a physical boundary layer, with a continuous but steep transition from the properties of pure ice to those of pure water. This comparison yields interesting new results for the dynamic behaviour of phase change surface. It can be shown that: (1) the mass distribution within the phase change surface depends on curvature of this surface; (2) the surface tension depends on curvature and differs for water inclusions in ice and for ice inclusions in water; (3) inclusions of the lighter phase in the heavier phase at very small inclusion size are thermodynamically unstable; (4) melting and freezing are not the same, as each is characterized by its own Clausius-Clapeyron equation. A proper deduction of the properties of temperate or polythermal ice has to consider a statistical average of ice having liquid inclusions, together with the application of a theoretical model of this kind.

NUMERICAL SOLUTIONS OF DYNAMIC PROBLEMS CONCERNING COLD AND TEMPERATE ICE SHEETS
(K. Hutter, VAW in collaboration with S. Yakowitz, ARIZ and F.Szidarovszky, Budapest)
The field equations which describe the slow creeping flow of large ice masses are based on the balance laws of mass, momentum and energy; as well as on the constitutive relations expressing that cold ice is an incompressible, non-linear, viscous, heat-conducting fluid. The time evolution of the flow of large ice masses is governed by the climatological input (accumulation/ablation, surface temperature) and the geothermal heat at the base. Further, mechanical boundary conditions are (1) a nonlinear sliding law at the base and (2) a stress-free condition at the free surface. This general boundary value problem is very complicated, particularly because the determination of the free surface profile is part of the solution of the problem. Simplifications of the mathematical problem are achieved by focussing on the limiting case in which horizontal length scales are much larger than corresponding vertical scales. The emerging boundary value problems permit numerical solutions with relatively moderate computational expenditure, provided that flow configurations are plane or exhibit axial symmetries. For various different configurations (steep glaciers, flat plane ice sheets, circular ice sheets), the geometry, temperature and velocity distributions are numerically determined. The ultimate goal is the determination of steady or time-dependent three-dimensional flow states.

SNOW AND ICE HYDROLOGY

SNOW HYDROLOGY-LYSIMETER
(J. Martinec, SLF)
Data on snowmelt taken with a snow lysimeter (5 m^2) in the spring of 1984 and 1985 are being correlated with air temperature and sun radiation.

SIMULATION OF SNOWMELT-RUNOFF IN LOWLAND AND LOWER ALPINE REGIONS OF SWITZERLAND
(L. Braun, GGEZ)
The influence of snowmelt model structure on the overall performance of runoff modelling in various-sized basins in eastern Switzerland was investigated. It could be shown that more complex snowmelt models may increase the performance of runoff modelling in basins smaller than about 1000 km^2 during years characterized by an above-normal snow pack. When simulating runoff over several years, snowmelt model structure influences performance insignificantly.

SIMULATION OF SNOW ACCUMULATION AND ABLATION
(H.Lang, H.Jensen, L.Braun & M.Rohrer, GGEZ)
An attempt is being made to simulate snow accumulation and ablation in the Swiss Alps based on operationally available meteorological data for the purpose of runoff forecasts. Records of water equivalent measurements over a time period of up to 40 years and from about 50 stations (14-day measurement intervals), serve as a basis for calibration and verification. It is hoped to complete the project by 1987/88.

GLACIER HYDROLOGY
(H. Lang, H. Müller, Kang Ersi & H. Jensen, GGEZ; H. Röthlisberger, VAW)
In connection with glacier runoff forecasting and modelling, a detailed study on the radiation budget in the Alps for elevations above 1500 m a.s.l. has been completed. The relationships between the components of the radiation budget, elevation, season, day time, cloudiness and albedo were investigated using all available observation data (H. Lang and H. Müller).

A comparative study of snout positions, mass balances, heat balances and runoff for research glacier areas under the different climatic conditions of the Swiss Alps and the Chinese Tien Shan was attempted. During the period 1962-1978, more than half of the glaciers observed in both mountain regions retreated. Due to higher precipitation in the Swiss Alps and probably also to the lower variability in meteorological conditions in the continental climate of the Tien Shan, the specific mass balance variations in the Tien Shan are less than the corresponding figures in the Alps. In the comparison of heat balance components, the large value for the latent heat of evaporation in the Tien Shan is remarkable. As a result of the different climatic conditions, the specific runoff for glacier basins in the Alps is much larger (60.8 mm for Aletsch basin, 66.7% glacierized area) than the Tien Shan (33.7 mm for Tailan, 53% glacierized area). This holds,even under comparable temperature conditions (K.Ersi,H.Lang,H.Röthlisberger).

The operational forecasting model (regression type) for the Zermatt Glacier basin is being recalibrated and revised on the basis of recent data and incorporation of additional conceptual components (H. Jensen, Kang Ersi and H. Lang).

DYE TRACING
(Th.Moeri & Chr.Leibundgut,GGB; A.Iken,VAW)
Dye solutions were injected through drilling hoses into boreholes in Findelengletscher in early March 1984 (winter conditions - appr. -10°C air temperature). The boreholes were rinsed with 1 m^3 of water from melted snow. Samples were taken at the terminus for one month; even in the last samples, dye was detected. The discharge was also recorded during this sampling period.

SNOW AND AVALANCHES

SNOW DRIFT
(R. Meister, SLF)
New measurements taken during winter 1983/84 on and ahead of a ridge behind the institute have been analysed, together with the results from previous winters.

SHEAR FRAME MEASUREMENTS
(P. Föhn and R. Meister, SLF)
The series of measurements from the last few winters have been continued, analysed and compared to results from the sliding block test (Swiss method), in order to calibrate this field method for practical purposes.

MAPPING OF SNOW HEIGHTS IN SWITZERLAND
(U. Witmer, GGB; P. Föhn & R. Meister, SLF)
Snow depths from more than 200 stations of the long-term (40 yrs) observational net of the SLF and Schweizerische Meteorologische Anstalt are being used to map snow height conditions in Switzerland. An empirical model for the distributional pattern of snow heights is being applied to take variations in time, altitude, slope orientation and surface gradient into account. Four maps at a scale of 1:300 000 are being prepared for the months of December to March. They will be published in the Klimaatlas der Schweiz, Part 2: maps of applied climatology.

REGIONAL SNOW DISTRIBUTION
(J. Martinec, SLF)
The distribution of maximum snow heights in the Swiss Alps has been compiled and edited as a basis for the planning of avalanche protection measures.

ACOUSTIC PROPERTIES OF SNOW
(O. Buser, SLF)
An automatic apparatus, based on the principle of Kundt's tube, has been used to measure the complex acoustic impedance of different snow samples in relation to the structure and mechanical strength of the material.

AUTOMATIC STRUCTURE CHARACTERIZATION OF SNOW
(W. Good, SLF)
Thin sections and serial cuts are analysed with an automatic, computerized device. Structural parameters are related to the mechanical strength of the snow material.

FORMAL AVALANCHE FORECAST
(P. Föhn, W. Good and O. Buser, SLF)
The statistical model "NXDAYS" has been tested during winter 1983-84. Its perfomance with a discrimination limit has been critically tested. Test and model development continued in winter 1984/85.

SNOW DISTRIBUTION, AVALANCHE ACTIVITY
(J. Rychetnik, SLF)
Photographic enlargements are used for systematic monitoring of snow and avalanches on a reforestation test field (Stillberg).

SNOW, AVALANCHES, SUPPORTING STRUCTURES AND REFORESTATION
(J. Rychetnik, W. Frey, H. in der Gand and M. Meyer, SLF)
A 100,000 tree test plantation is being used to develop suitable biological, technical and economical reforestation techniques in avalanche starting zones, and to test temporary wooden supporting structures and their influence on snow cover, avalanche activity and development of forest plants.

SNOW GLIDING STABILIZING STRUCTURES AND REFORESTATION
(W. Frey, H. in der Gand and M. Meyer, SLF)
Several types of stabilizing devices against snow gliding were tested on a steep, reforested field equipped with temporary supporting structures.

ECOLOGICAL INVESTIGATIONS IN A PICEO-ADENOSTYLETUM
(H. Imbeck, SLF)
In a four-year programme, collaborating with the Institute for Forest and Wood Research of ETHZ (Dr. Ott), the relation between snow distribution, avalanches and plant growth has been examined in clearings produced in a Norway spruce forest.

AVALANCHE DANGER AND WARNING
(P. Föhn, SLF)
Together with an international working group, the classification of avalanche danger has been re-examined and the definitions of the different danger levels reformulated.

RADAR MEASUREMENTS OF SNOW PACK
(H. Gubler, SLF)
Measurements with a FMCW radar have been pursued on horizontal test fields in potential avalanche release zones. They give information on the total water equivalent, stratigraphy and the melt process in spring - either at selected points or along a line with the equipment on a sledge.

AVALANCHE MECHANICS
(H. Gubler, SLF)
Velocity measurements have been performed with a Doppler Radar on large avalanches near the Lukmanierpass, as a function of space along the avalanche path and as a function of time at fixed positions. Results show several types of movement, from gliding to complete fluidization.

SIMULATION OF POWDER SNOW AVALANCHES
(T. Scheiwiller, K. Hutter and F. Hermann, VAW; H. Gubler, SLF)
Powder snow avalanches are simulated in the laboratory as a turbulent, gravity-driven suspension of polystyrene particles and water. Particle velocity and concentration profiles in the steady laboratory avalanche body were measured by means of an Ultrasonic Doppler Technique through frequency shift and reflected intensity, respectively. Laboratory data are used to test two numerical models. The first one is a standard FD-model for the above-mentioned two-phase flow. In the second one, the method of weighted residuals is applied to integrate the governing field equations. The snow settling process will be considered next.

FLOW AVALANCHES AS A GRANULAR CONTINUUM OF PARTICLES BOUNCING AGAINST EACH OTHER
(K. Hutter, VAW in collaboration with S. Yakowitz, ARIZ and F.Szidarovszky, Budapest)
Since 1982, when it was proposed that rapid shear flow of an assemblage of grains might be an adequate model to describe the motion of a snow mass in a flow avalanche, researchers in the field of granular materials have deduced continuum models which need be tested against concrete flow configurations. By analysing plane steady chute flow of the Jenkings-Savage model, both numerical difficulties and theoretical inadequacies of the model were detected. The computer code is written in a general-purpose fashion and permits variation in the boundary conditions,the base and the free surface, so that basal sliding and surface-wind resistance can be accounted for. In an attempt to understand the transition from flow avalanches to powder snow avalanches, a binary mixture model of granules and interstitial air was deduced. It was shown that in entrainment, the upper surface must be a ruling factor in the formation of powder snow avalanches.

ICE CORE STUDIES

COLLE GNIFETTI
(H. Oeschger and collaborators, LLC; various members of VAW; collaboration with the Institut für Umweltphysik, Heidelberg)
The laboratory work focused on the calibration of the continuous electrical conductivity measurements, which were performed in the field on the ice core drilled in 1982. Based on measurements of melted samples, the signal of the electrical conductivity can be taken as an acidity record as well as a dust record.

The field work included the collection of surface snow samples for chemical analyses and the installation of a meteorological

mast (Heidelberg) to obtain direct information on temperature, radiation, windspeed and wind direction. Stake measurements of balance and velocity were analysed to define the flow field at the core drilling site. Two-dimensional, steady state flow models are being used to roughly date the ice cores and to correct for local variations in snow accumulation, melt layer frequency and other stratigraphic characteristics.

ICE CORE DRILLING IN ANTARCTICA
(H. Oeschger and collaborators, LLC)
Members of LLC participated in two US-funded ice core drilling projects at the South Pole and at Siple Station. Core drilling was performed by PICO and registration and processing of the ice cores by LLC.

In December 1983, core drilling reached a depth of 354 m at South Pole and a depth of 195 m at Siple Station. The core quality is excellent down to a depth of 145 m. Electrical conductivity measurements show seasonal variations and thus allow an accurate dating of the core. Porosity measurements have been performed on about 250 firn samples to investigate the air enclosure in bubbles during the transition from firn to ice. The mean gas age is 95 years younger than the surrounding ice; the span of the age distribution is about 22 years. This short span is the main reason that the Siple ice core is well suited for the investigation of changes in the atmospheric composition since industrialization.

HISTORY OF ATMOSPHERIC COMPOSITION
(H. Oeschger and collaborators, LLC)
Analyses of air in bubbles of ice samples from Greenland and Antarctica, extracted using a new dry extraction procedure, gave the following main results:

From Dye 3 deep samples, the possibility that rapid changes in the climatic conditions which occurred several times during the last glaciation were accompanied by changes in atmospheric CO_2 concentration. This phenomenon cannot yet be verified by measurements of samples from Byrd Station.

The increase in atmospheric CO_2 during the past 200 years could be reconstructed using CO_2 concentration measurements on air extracted from ice samples from Siple Station.

The first $^{13}C/^{12}C$ measurements on CO_2, separated from air extracted from ice samples from the South Pole and from Byrd Station, have been performed.

CO_2 from air bubbles has been used for ^{14}C dating with an Accelerator Mass Spectrometer.

Methane concentration measurements were performed on air extracted from the Siple ice core. Dry extraction and melt extraction methods have been used and are compared.

^{10}BE CONCENTRATION MEASUREMENTS
(H. Oeschger and collaborators, LLC)
From 40,000 - 30,000 years B.P., the ^{10}Be concentration in the Dye 3 ice core shows strong variations which correlate well with the $\delta^{18}O$ and the CO_2 data and which probably reflect climatic changes.

The first continuous ^{10}Be record on a deep polar ice core (Camp Century), representing about the last 100,000 years, has been completed. A comparison of results with the 8,000-year long $\Delta^{14}C$ record obtained from tree-ring measurements reveals a generally good agreement.

Detailed analysis of ^{10}Be data from the Milcent ice core shows that the solar cycle can be detected over the whole period (1200-1800 A.D.), even during the Maunder Minimum (1645-1715 A.D.) when almost no sunspots could be observed.

FROZEN GROUND

LABORATORY TESTS ON FROZEN GROUND
(J. Huder, A. Hofer and P. Herzog, IGB)
Shear and creep tests (both uni- and triaxial) on undisturbed and remoulded samples were carried out to determine the behaviour of frozen ground in terms of its strength and deformation. The different compactness of the unfrozen ground, the time of freezing and the volume behaviour of the samples are considered during the tests. The characteristics obtained are used in mathematical and/or rheological models to design the construction of artificially frozen ground.

MICROCLIMATIC INFLUENCE ON SOLIFLUCTION ACTIVITY
(M. Gamper, GGUZ)
In the Swiss National Park, studies on the interaction between microclimate, vegetation cover and periglacial morphodynamics (solifluction, frost weathering, soil formation) are carried out within the transition zone of Alpine meadows and the frost debris belt. Ground and air temperatures have been recorded since autumn 1978 at different places on solifluction lobes of various slopes, orientations and types of vegetation cover. Since 1975, movements of slope debris have been measured at 100-180 points within the same area and to a depth of 0.9 m. The goal of the study is to establish a long time series of temperature and solifluction measurements and to investigate the influence of parameters such as snow cover, soil humidity or wind conditions on solifluction activity.

ROCK GLACIER STUDIES (SWISS ALPS)
(W. Haeberli and W. Schmid, VAW)
Long-term observations were started on the well-studied active rock glaciers Muragl (Engadin) and Gruben (Saas Valley). Ground control for repetitive photogrammetric surveys was prepared and the permafrost distribution studied in both cases. Flow patterns and volume change at five yearly intervals will be analyzed as a way of monitoring the aggradation/degradation of Alpine permafrost.

GLACIGENIC SEDIMENTS
(Ch. Schlüchter, IGB)
Investigations on the lateral and frontal sediment production and reworking associated with the readvance of Findelengletscher have been continued: e.g., the genesis of basal till lenses and their incorporation in lateral till complexes could be verified.
A detailed till-facies study was started in the Alpine foreland to reconstruct the genetic processes active during the last advance of Rhonegletscher to the Plateau-area. Evidence pro and contra "cold-based phases" during this advance can be listed.

LITHOLOGY OF GLACIER BEDS
(W. Haeberli, VAW)
A parameter study was carried out on factors which influence the geographical distribution of rocky and sedimentary glacier beds in the Alps. The relation between the production of debris in the surrounding rock walls and the capacity of the meltwater streams to evacuate non-consolidated sediments, seems to be of primary importance. A simple sedimentation/erosion index was developed to predict whether a glacier bed is likely to consist of eroded bedrock or of thick morainic sediments.

MAXIMUM GLACIERIZATION (1850) DURING THE PAST CENTURY IN THE ALPS OF GRISONS
(M. Maisch, GGUZ)
Aerial photos, old maps and field observations are the basis for reconstructing all glaciers of the Grison Alps which existed at the time of maximum glacierization in the last century (around 1850). Several glaciological parameters such as surface area, length, hypsography etc. are being compiled and compared to the Swiss Glacier Inventory (1973). Emphasis rests on reconstruction of former equilibrium lines and their regional analysis with respect to climatic factors. It is hoped that this data collection will lead to an improvement in the interpretations of spatially variable late-glacial (17,000-10,000 B.P.) snow-line information.

PAST GLACIER VARIATIONS IN THE GASTERNTAL
(P. Mani, GGB)
An attempt is being made to reconstruct the history of glacier variations in the Gasterntal, Bernese Alps by geomorphological mapping. Emphasis is on events which occured during the "Little Ice Age".

HISTORY OF ALPINE GLACIERS FROM 16th TO 19th CENTURY SOURCES
(H.J. Zumbühl, GGB)
A new project was started to investigate the history of selected Alpine glaciers (Rhone-, Unteraar-, and Rosenlauigletscher in the Swiss Alps: Mer de Glace and Glacier des Bossons in the French Alps). Written and pictorial sources are used and the results compared with historical information on climate. Most progress has been made in the case of Rosenlauigletscher, where the quantity and quality of pictorial sources (paintings) enables detailed reconstruction of glacier length variations since 1760; the glacier seems to have behaved similarly to the tongues of the two Grindelwald glaciers. At the same time, a parallel study on glaciers and ice as a subject matter for Alpine landscape paintings is being carried out.

SNOW COVER IN THE SWISS LOWLANDS AND THE ALPINE AREAS SINCE THE 16th CENTURY
(Ch. Pfister, GGB)
Temporal variability in the duration of snow cover and the frequency of snow fall has been documented from historical observations from 1525 to the present. For the lowlands, continuous observations date to the end of the 17th century; for the lower Alpine levels, the serial data go back to 1760. Fluctuations on the higher levels are in good agreement with glacier activity, as can be documented from the long series of thaw observations (1821-1851, 1885 to the present) on top of Saentis (2465 m). In addition, the covariation of Alpine thaw with the blossoming and ripening dates of vines has been analysed.

HOLOCENE GLACIER VARIATIONS IN THE ALPS
(H. Holzhauser, GGUZ)
Holocene glacier variations are being reconstructed using ^{14}C dating of fossil soils and wood in moraines, as well as paintings, written historical sources and dendrochronological analysis of fossil trees. Efforts focus on medieval glacier history in the Wallis region.

QUATERNARY GLACIER FLUCTUATIONS AND CLIMATE VARIATIONS
(G. Furrer and collaborators, GGUZ)
The history of glacier fluctuations and climate variations since the Eem-period is being investigated in the Swiss Alps (including the Mont Blanc-group) and in the area of the former Rheingletscher. Investigations include geomorphological studies, tree-ring analysis on living as well as fossil trees, and interpretation of pollen spectra.

ALPINE GLACIATION AT THE OLIGOCENE/MIOCENE BOUNDARY
(R. Hantke, GLEZ)
At the Oligocene/Miocene boundary, enormous ice streams flowed from the Bergell massif which was uplifted to Andean heights, through the Bergell and Valtellina valleys to Lake Como. This is shown by gigantic erratics in the southern Alpine Molasse of Como, by fission-track age determinations on the boulders and on the massif, and also by a climatic depression proven by pollen analysis and plant remains.

Ice streams must have flowed to the NE and to the N, into the Engadine valley and over the Septimer, Julier and Albula passes from the ice-covered high areas of the Bergell Massif and the adjacent Bernina Mts. The total extension of the ice, later pre-Quaternary glaciations in the developing mountains of the Grisons area, and further early ice transfluences are still to be investigated.

Wilfried Haeberli

SWITZERLAND - CANADA

ENGLACIAL TEMPERATURES
(H. Blatter, GGEZ)
From 1974-1984, 32 holes were drilled on White Glacier, Axel Heiberg Island and five on Laika Glacier, Coburg Island, N.W.T. using an open system hot water drill. The englacial temperature profiles of both glaciers showed an extended layer of temperate or near-temperate ice at the bedrock in the ablation zone. An extended temperature minimum (-16°C), at 100 to 150 m depth below the ice surface in the accumulation zone of White Glacier, probably reflects the general warming trend during this century.

DEPTH SOUNDING ON THE WHITE GLACIER
(M. Funk and H. Blatter, GGEZ)
A total of 350 soundings using the USGS monopulse radio-echo sounder were carried out on White Glacier, Axel Heiberg Island. The tongue area shows the expected glacier valley shape; the accumulation area has a more rugged bedrock topography and suggests a new evaluation of englacial temperatures. The greatest depth is around 380 m.

WHITE GLACIER, AXEL HEIBERG ISLAND
(J. Weiss, GGEZ and GGUZ)
Mass balance measurements for 1962-1981 were re-evaluated and compared. The dependence on elevation has been estimated, even though year-to-year variability and the variations within an elevation belt are substantial.

NORTH WATER PROJECT, NORTHERN BAFFIN BAY
(K. Steffen, GGEZ)
The heat flux measurements from the two winters 1978/79 and 1980/81 at the Resolute Bay sea ice station are under evaluation. This data set enables the energy balance at the sea-ice/atmosphere boundary during the growth of the ice to be studied. The flux measurements are further used for an ice growth model.

The seasonal change of the fast-ice edge of the North Water is under investigation, using Nimbus 7 microwave satellite data. A sea-ice type classification will be done. The low level infrared thermometry measurements made over the North Water during the two winters are used as ground truth.

Wilfried Haeberli

UNITED KINGDOM

BRITISH ANTARCTIC SURVEY, 1984-85

ICE SHELF STUDIES
Recent work has focussed on the critical transition where ice streams draining the West Antarctic ice sheet start to slide on their beds and then flow on to the sea. Field work has continued in an area of partial grounding of the Ronne Ice Shelf between Korff and Henry ice rises. A.M. Smith has used a combination of velocity and strain data obtained from optical surveys and from geodetic satellite receivers to study the variation of the basal shear stress in an area of basal sliding. This work complements a new study of the dynamics of Rutford Ice Stream, in which R.M. Frolich and R.V.Otto concentrated on the transitional zone where the sliding velocity begins to dominate over internal deformation processes.

Glaciological and oceanographic studies on George VI Ice Shelf are leading to a better understanding of the mechanism of heat transfer and bottom melting rates under ice shelves. George VI Ice Shelf overlies a deep channel and is open to the sea at two narrow ice fronts. J.G.Paren and M.Pedley obtained the first continuous sea-bed pressure and current measurements at the southern ice front, and analysis of the data by J.R. Potter and M. Pedley has allowed the tidal characteristics to be determined. The data indicate that much less energy propagates into George VI Sound than should be expected, according to a theory of tidal dissipation by ice shelves. To investigate this further, two oceanographic current meters and a tide gauge were recovered in February 1985 after one year's operation in the same area.

A hot-water drill, newly designed by S. Cooper with a depth capability of 400 m, has been used to penetrate George VI Ice Shelf near its northern ice front. A thermistor chain has been installed through the drill hole for a study of the heat flow from the underlying sea water into the ice shelf. Earlier studies were confined to sites giving a natural access to sea water. A major advantage of hot water drilling is that sites can now be selected in undisturbed ice which is more typical of the ice shelf environment.

ICE CHEMISTRY
Measurements of trends in the composition of impurities in Antarctic ice provide a permanent record of global-scale air pollution, E.W. Wolff has analysed recent snow from two

sites in the Antarctic Peninsula for aluminium, cadmium, copper, lead and zinc. Whilst the concentration of lead agrees with data from other investigators who sampled recent snow from central Antarctica, the values for cadmium, copper and zinc are about 10 times lower than any reported earlier, even for ancient Antarctic ice. Dr D.A. Peel and E.W. Wolff now suggest that in comparison with natural background levels, the following limits are applicable for today's increases resulting from industrialization: lead (1-40 times), copper (1-5 times) and zinc (1-6 times).

The link between trace elements in snowfall and the composition of the atmosphere associated with it is being explored by simultaneous collection of aerosol and freshly-fallen snow. For the heavy metals, results obtained by A.L. Dick have given very much smaller ambient concentrations and crustal enrichment factors than any values previously reported from Antarctica. The observed relationship between aerosol and snowfall composition appears to accord with a simple model of aerosol scavenging. If this can be shown to apply generally in Antarctica it may help to simplify the interpretation of time-series data from ice cores.

CREEP OF ICE
Dr C.S.M. Doake and E.W. Wolff have re-examined the basic flow law for ice which relates stress to strain rate. Using all available data from both ice shelves and deep boreholes, they have shown that a simple linear relationship is probably more justifiable than the non-linear relationship hitherto generally assumed. These findings should help to simplify physical models describing the flow of ice sheets.

REMOTE SENSING
An airborne radio-echo sounding programme carried out by Dr C.S.M. Doake and R.D. Crabtree was able to add a further 15,000 line kilometres of ice-depth profiling to extend knowledge of Ronne Ice Shelf and the sub-glacial land surface in Palmer Land.

C.W.M. Swithinbank

U.S.A. - WESTERN REGION

Last report of U.S.A. - Eastern region:
see **ICE**, No.76, 1984, p.7-11
Last report of U.S.A. - Alaska region:
see **ICE**, Nos 72 & 73, 1983, p.23-31

GLACIERS AND ICE SHEETS

GLACIER INVENTORY OF THE UNITED STATES
(C.S. Brown, GPO/USGS, Tacoma, WA)
The inventory of U.S. glaciers in Alaska for the World Glacier Inventory has been completed for eight of the nine basins, totalling almost 5500 glaciers. The Taku River basin in SE Alaska remains to be inventoried. In the lower 48, all glaciers have been inventoried except a few on isolated volcanoes in Washington, Oregon, California and in the Wind River Range of Wyoming. The vast majority of glaciers outside Alaska are located in Washington (1045 out of approximately 1600 glaciers). For all the glaciers in Alaska longer than 8 km, area, length, terminus elevation and classification are given; in Washington and California, these data are recorded for all the glaciers. The basic compilation for all U.S. glaciers should be completed shortly for publication in 1986.

GLACIERS AS REFUGIA FOR MICRO-ORGANISMS
(R.A. Wharton and C.P. Mackay, NASA/Ames; G.M. Simmons, Biology/VPI)
Research centers on glaciers as refugia for micro-organisms during ice ages. Cryoconite holes, water-filled depressions on the surface of glaciers, often contain microbial communities. The mechanisms by which they survive in the holes and their contribution to hole formation and enlargement are being studied, as well as the role cryoconite holes play in the survival of micro-organisms during ice ages and the colonizing of exposed areas after a glacier retreats.

COMPUTATION METHODS
(S. Yakowitz, ARIZ; K. Hutter, VAW; F. Szidarovszky, ARIZ)
Numerical solutions of the full, thermo-mechanically coupled pde model for stationary ice sheets and glaciers have been obtained. So far, only solutions for very idealized geometries (uniaxial and radial cases) have been computed. Current efforts are directed at discarding the "shallow-ice" approximation and attempting ice sheets with dynamic profiles. (See also Swiss report, this Issue, p.10)

THERMAL BALANCE IN SUBGLACIAL WATER
(N.F. Humphrey, Geophysics/WASH)
The temperature of stream water emerging from beneath glaciers is lower than predicted by an application of a basal conduit flow model and a bulk water temperature heat transfer equation. This discrepancy has been noted for outburst floods by both Nye, and Spring and Hutter, where both employed a heat-transfer coefficient-type equation. The enhanced heat transfer from a subglacial conduit may result from incorrect assumptions of flow geometry, or the assumed approximation to the heat balance equation which leads to the simple heat transfer equation.

The correct heat transfer equation is derived for a self-heated fluid flowing in

its own solid, in both laminar flow and smooth-walled turbulent flow conditions. This is shown to be both conceptually and computationally different than a typical engineering heat transfer equation and, in addition, it yields a three-times greater heat transfer for a given bulk water to ice temperature difference. The analysis is extended to include the thermal energy balance and temperature field for both water and adjacent ice in the region of a laminar conduit. It is shown that an englacial conduit with laminar flow is stable against small perturbations and hence will be smooth.

GLACIERS – ALASKA – COLUMBIA

AIRBORNE RADAR SOUNDING

(C.S. Brown, L.A. Rasmussen and M.F. Meier, GPO/USGS)

Columbia Glacier is a large (1100 km^2), grounded, iceberg-calving glacier 38 km west of Valdez, Alaska. The bed topography of the lowest 7 km of Columbia Glacier was mapped from radar sounding obtained from the first (1978) airborne sounding of a temperate glacier by R. Watts and D.Wright (USGS/Denver). A three-dimensional geometric method of determining the envelope of the reflection lobes was developed for interpreting the data, instead of the differential method used by previous investigators. This analysis provided bedrock altitude determinations at every node of a 200-m square grid. The probable error in the inferred bed altitudes was estimated to be 30 m and the greatest depth was 370 m below sea level.

HYDROLOGY OF A TIDEWATER GLACIER

(R.A. Walters, C.L. Driedger and E.G. Josberger, GPO/CIP/USGS)

The subglacial flow of freshwater from Columbia Glacier into the salt water of Prince William Sound was calculated from measured profiles of water current, salinity and temperature. The resultant stratified flow over the terminal moraine and the interactions between the subglacial freshwater and far-field salt water are currently under study. In addition, a small network of river stage gauges and meteorological stations around Columbia Glacier are providing information about nonglacierized runoff and the general meteorological environment.

ORIGIN OF LOW FREQUENCY ICEQUAKES

(A. Qamar, Geophysics/WASH)

The investigation of low-frequency (1-2 Hz) seismic signals, using earthquake recorders around the lower 10 km of the Columbia Glacier, shows that virtually all such signals result from the calving of icebergs at the glacier terminus.

Apparently, the long time constant of the ice fracture process and the occasional occurrence of multiple calving events give rise to the low frequency content of the seismic waves and the extended codes of some of the seismic signals. The duration of the seismic signals can be used to estimate the amount of ice calved. As judged by the seismic records, the calving activity of the grounded Columbia Glacier is not strongly affected by tides.

VELOCITY AND RETREAT

(R.M. Krimmel, B.H. Vaughn, W. Dunlap and M.F. Meier, GPO/USGS)

The velocity near the terminus of Columbia Glacier increased in the fall of 1984 to a peak of 17 m/d in response to high calving rates. By early summer, velocity was about 14 m/d. During August 1985, when an automated laser ranging system was in use to measure distance to three longitudinally aligned reflectors, velocity was about 10 m/d. Seasonal advance continued into the early summer of 1985, perhaps in response to an abnormally cool and wet spring. But, even with a relatively late start on the summer retreat, the glacier was 500 m shorter in September 1985 than in September 1984. The terminus of the glacier continued to thin; it was about 20 m thinner in 1984 than in 1983 and an additional 20 m thinner in 1985.

GLACIERS – ALASKA – VARIEGATED

(B. Kamb, CALTECH; C. Raymond, WASH; W. Harrison, ALASKA; H. Engelhardt, Univ. Münster, FRG; M. Brugman and M. Fahnestock, CALTECH)

A six-year program of field measurements and observations on Variegated Glacier has been carried out, culminating in 1982-83 with the occurrence of a spectacular surge anticipated from the glacier's prior surging history. The work aims to reveal the cause and mechanism of the surge and involves observations of basal conditions by borehole TV; borehole measurements of internal deformation,basal sliding and basal water pressure; dye-tracer experiments; and short-term velocity, strain and surface uplift measurements. These showed that the surge motion is due to rapid basal sliding, caused by high basal water pressure approaching and sometimes exceeding the ice overburden pressure at the bed. The advance of the surge front involves the development of a succession of thrust faults and folds in the ice, analogous to the imbricated structures in tectonic fold-and-thrust belts. Tracer experiments show that the cause of the high basal water pressure during surge is a substantial restriction in the carrying capacity of the basal water system: the mean transit speed of water along the length of the glacier was very much slower during surge (only 80 m/h) than after (2500 m/h, a value typical of normal nonsurging glaciers). We infer that, in surge, the large tunnels of the normal basal water system are destroyed and replaced by a "linked-cavity system", involving numerous lee-side basal cavities linked

hydraulically by narrow passageways at the ice-rock interface. A quantitative model of this system has been developed and its properties evaluated. The analysis reveals a stability-instability parameter that controls whether the basal water conduits develop as a linked-cavity system or a tunnel system. It therefore may determine whether a given glacier will be in the surging or nonsurging state. A differential equation modelling the propagation of pressure waves in the basal water system has been studied numerically, in relation to the observed downglacier propagation of coupled peaks of rapid glacier motion and high basal water pressure in surge pulses and also in mini-surges prior to the surge. The observed wave forms and propagation speeds of mini-surge waves (about 400 m/h) are accounted for with a nonlinear relation between basal water pressure and the hydraulic conductivity of the basal water system.

SUSPENDED SEDIMENT DISCHARGE DURING THE PRE-SURGE AND SURGE PHASES OF MOTION
(N.F. Humphrey, Geophysics/WASH)
Suspended sediment concentrations in the outlet stream of the Variegated Glacier were monitored for part of each summer from 1980 to 1984. Although water discharge and sediment concentration were positively correlated, the major peaks and shifts in background of suspended sediment concentration were associated with changes in the speed of the glacier. This implies that the suspended sediment concentration was controlled primarily by mobilization of rock debris by basal sliding, with a secondary effect from flushing by high discharges. Suspended sediment concentration was estimated by measuring the water turbidity, calibrated by concurrent water sampling. Sediment concentrations ranged from less than 0.1 kg/m^3 during winter, to peaks of over 55 kg/m^3 during the 1982-83 surge. The total suspended sediment discharge from the glacier for the second half of June 1980 was about 1.6×10^7 kg. If the bedrock is assumed to erode at the same rate that debris is evacuated, the monthly erosion in the presurge motion was about 1.0 cm rock/month. In the second half of June 1983, during the peak of the surge, approximately 6.8×10^8 kg of sediment were carried in suspension away from the glacier. This corresponds to a rock erosion rate of about 45 cm/month.

POST-SURGE OBSERVATIONS
(C.F. Raymond, Geophysics/WASH)
Post-surge monitoring of Variegated Glacier is continuing (with W. Harrison, ALASKA). The measurements provide limited information about the velocity and surface elevation distributions. Of particular interest is post-surge settlement of the glacier surface due to closure of void space created during the surge. Analysis of the pre-surge evolution of the velocity and geometry has been completed to determine the apparent rheology of the ice, but the sliding behavior does not follow any of the existing proposed sliding laws. Current attention is focussed on the seasonal cycle of the surge itself, which occurred in two pulses each starting in winter and terminating in early summer. The winter initiation is proposed to occur by a combination of collapse of the subglacial conduits before all summer meltwater has escaped and subsequent redistribution of the trapped water to the bed. This proposition is supported by semiquantitative analysis of the complete history of measurements.

SURGE PROPAGATION INTO STAGNANT ICE - TECTONIC AND GEOMORPHIC IMPLICATIONS
(M. Sharp, Univ. Cambridge; R.S. Anderson, QRC/WASH)
The 1982-83 surge began in the upper glacier in 1982 and the zone affected by the surge spread downglacier. The surge speed reached 65 m/d in mid-1983 as the lower edge of the surging zone entered the nearly stagnant terminal lobe, creating a steep topographic ramp and sharp horizontal velocity jump. Extremely high values of upward vertical velocity, longitudinal compressive strain rate and stress were encountered in the transition zone between surging and stagnant ice. Compressional tectonic processes led to rapid development of unusual ice surface structures, including thrust-faults, nappes, buckle folds and longitudinally-oriented cracks. Measurements of the deformation of surface ice allow us to establish relationships between the formation of these structures and the magnitude and orientation of principal surface incremental and finite strains. These observations of deformation, in a region of intense longitudinal compression at the front of a sliding mass, show a pattern very similar to that envisaged during the formation of thin-skinned fold and thrust belts. The deformation also produces significant redistribution of englacial and subglacially-derived debris and has considerable influence on the processes and patterns of sedimentation associated with surging glaciers.

EFFECT OF A SURGE ON STRUCTURAL FEATURES AND CRYSTALLOGRAPHIC FABRIC
(T. Pfeffer, Geophysics/WASH)
Structural mapping and c-axis fabric analysis were done in the terminal lobe region of the 1982/83 surge. Penetrative structures in the ice are complex and suggest extensive high-angle faulting. One result is that foliation, while well developed (or well preserved?) around the margin of the surge, is absent within the bounds of the margin.

Multiple maximum c-axis fabrics were measured from surface samples in the terminal lobe region, allaying fears that fabrics developed during the surge would be diffused after the passage of two years.

MODELLING THE TERMINUS DURING ITS SURGE
(T. Pfeffer, Geophysics/WASH)
Finite-element modelling of flow in the terminus is continuing in order to calculate total strains experienced by the ice in the terminus region and to determine why the surge front had the shape and propagation characteristics that it did.

SHORT-PERIOD VELOCITY ANOMALIES
(M.J. Balise, Geophysics/WASH)
Theoretical modelling is being done to study the flow pattern in glacier ice for short-period velocity anomalies. The differences between basal and surface velocity are of special interest and depend on the spatial scale of the velocity anomaly. This modelling will be applied to the minisurges of the Variegated Glacier.

STUDIES OF INTERNAL WATER BODIES IN TEMPERATE ICE
(R. Jacobel, OLAF)
Efforts were concentrated on electronics development and construction of a portable digital recording system for the impulse ice-radar unit. Only with digital recording and processing techniques can the dynamic range and resolution, necessary to locate interstitial water bodies and study their changes over time, be achieved. Work continued on further analysis of radar data from englacial echoes, recorded during the 1982-83 surge of Variegated Glacier. In addition to the resonant water-filled cavities reported from the 1982 data, echoes from several water-filled voids were detected in 1983 which were located spatially by profiling. The echoes show variations over time interpreted as arising from changes in cavity dimensions. A model of impulse scattering, from regions of strong dielectric contrast to aid in interpretations of these data, is being developed.

OPENING AND CLOSURE OF ENGLACIAL CONDUITS
(M.M. Magnusson, Geophysics/WASH)
The evolution of englacial void space, due to conduits from the surface down to the basal drainage system, was studied using an approximation whereby the (unknown) conduit network geometry is not a factor. Gravitational potential loss and heat advected downward by the meltwater from measured or parameterized ablation, melts out conduits. The net void space production rate is a function of basal water pressure and (weekly) the existing void volume. For the Variegated Glacier, Alaska, an upper limit of 4×10^{4} for total fractional void space due to englacial conduits was established, assuming that melting is the only process of void space production.

GLACIERS – ALASKA

SUSITNA RIVER WATERSHED
(W.V. Tangborn, Hymet Co. Seattle, WA)
A hydrometeorological study of glaciers in the Susitna watershed was made to evaluate their effect on a proposed hydroelectric development at the Devils Canyon and Watana sites. Using existing gauging stations, the watershed was divided into glacierized and unglacierized sub-basins to determine the contribution of glaciers during periods of low precipitation. The 24% glacier-covered basin contributes up to one order of magnitude more streamflow per unit area during June and July, following a winter of deficient precipitation, than the unglacierized basin. It is believed that much of the large differences in flow are due to the low albedo on glaciers that prevails after a winter of low snowfall.

JUNEAU ICEFIELD RESEARCH PROGRAM
(M.M. Miller, B.W. Prather, R. Carlson, R. Marston, B. Colman, W. Welsch, R. Asher and A. Pinchak, College of Mines and Earth Resources, Univ. Idaho, Moscow, ID 83843)
For many years annual mass balance measurements have been made on the Lemon, Mendenhall, Twin, Taku, Gilkey, Llewellyn and Cathedral Massif glacier systems of the Juneau Icefield. On Taku Glacier, 1985 culminated 40 years of records at some 30 test pits and crevasse wall sites, reoccupied annually for comparisons. In these decades, the regime pattern on low-elevation névés has been persistently negative. In contrast at intermediate and high elevations, the Taku, Twin and Mendenhall glacier systems have increased in volume and across the icefield the 1984/85 firn pack far exceeded any positive mass balance measured since 1948. The possible relationship to changes in the general circulation and related accumulation through increasing global CO_2 is being analyzed. With a 40:1 accumulator-dissipator ratio and multiple névé source areas, the 355 km^2 Taku Glacier has thickened significantly in its upper elevation sectors and experienced a 10-km advance since 1894. A four-color, 1:5000 terrestrial photogrammetric map of the terminal zone shows successive frontal positions in five-year increments since 1960. At its present rate, Taku Glacier should cut off the mouth of the Taku River and begin to fill an ice-dammed lake in the 1990s. Relict strandlines on the walls of the Taku River Valley, for 63 km to the east, suggest this pattern occurred periodically during the Neoglacial at some 200-year intervals. This phenomena is being closely monitored by survey means at fixed bench marks.

On Lemon Glacier, annual changes in size and the self-dumping character of marginal-dammed Lake Linda are being investigated and

1000 m of a glacier cave reservoir system explored and mapped. Jökulhlaups from this lake are noted each summer by a stage recorder on Lemon Creek and related to meteorological and ablation trends in the upper glacier basin. Castastrophic drainage of the lake correlates with stream gauge peaks, with about a four-hour lag. Studies continue annually on this, on two ice-dammed lakes in Gilkey Glacier Trench and on two others in the Talsekwe Glacier Trench on the western and eastern flanks of the icefield respectively. An allied project involves mapping 3500 m of glacier caves on Llewellyn Glacier in the Camp 36 sector in Canada. This is tied to bedrock configuration measurements, using geophysical methods.

Seismic and gravity profiles were measured on Taku and Llewellyn glaciers in 1984 and 1985, supplementing transects made in the '50s and '60s. On the lower Taku Glacier, depths of 300-600 m have been determined with data from the crestal sector, revealing unexpectedly deep (500-600 m) depths on the uppermost névés shared by these two glaciers at surface elevations >2000 m. This may relate to abnormally heavy net accumulation trends this century on the upper névés.

Ice deformation surveys were continued on 14 selected transects and longitudinal lines on the Lemon, Llewellyn, Gilkey, Vaughan Lewis, Cathedral Massif and Taku glaciers. The results show parabolic flow on all but the Taku Glacier; the latter exhibiting pronounced rectilinear (plug) flow on its lower tributary and distributary branches, reflecting the contrasting negative and positive regimes in these respective glacier systems. On Vaughan Lewis Glacier, detailed mapping of tectonic (flow) foliation and thrust structures aims to explain the wave ogives and wave bulges down glacier from the Vaughan Lewis Icefall. Overturned isoclinal folds in the foliation have been mapped and subsurface interpretations made of supplemental effects of compressive up-bulging and development of thrust slices in the ice apron below the icefall. A series of folds, replicating cover-rock deformation and sets of rhombohedral surface strain structures, have been studied in the snowcover and underlying firn-pack compressively stressed between the Vaughan Lewis and Gilkey glaciers. These investigations are clarifying the subsurface structural glaciology of the main Vaughan Lewis and Gilkey Glacier systems.

Morphometric changes in supraglacial streams, surveyed on the Vaughan Lewis and Cathedral Massif glaciers, includes the evolution of flutings and sinuosities related to diurnal variations in meteorological parameters. The rapidity of change has exceeded expectations and, on Vaughan Lewis Glacier, is considered to relate to excessive water flow from a complex network of radial crevasses within the expanded basal apron of the icefall. An investigation of avalanche frequency in the icefall is underway, using hydrophones and relating ice deformation surveys and meteorological effects.

GLACIERS - CANADA

ISKUT RIVER WATERSHED, BRITISH COLUMBIA
(W.V. Tangborn, Hymet Co., Seattle, WA)
A Probable Maximum Flood study was conducted for BC Hydro in the Iskut River basin for a proposed hydroelectic development. The contribution of the 894 km^2 of glacier cover in this basin to extreme flow events was significant, due to the addition of ice melt and to the rapid release of englacially stored liquid water. The latter is particularly important in the Forrest Kerr watershed, which is 67% glacierized. An evaluation of prediction error produced by a simulation model showed that some regularity exists in the storage-release mechanism, but that prediction of both the timing and magnitude of releases from internal storage are difficult.

GLACIERS - LOWER 48

GLACIER VOLUME ESTIMATION ON CASCADE VOLCANOES
(C.L. Driedger and P.M. Kennard, GPO/USGS)
During the 1980 eruption of Mount St.Helens, the occurrence of floods and mudflows showed a requirement for models to assess mudflow hazards on other Cascade volcanoes. Information about the volume and distribution of snow and ice is needed for this analysis. A backpack impulse radar was used for point measurements of ice thickness on major glaciers of Mount Rainier (Washington); Mount Hood and the Three Sisters (Oregon); and Mount Shasta (California). Ice thickness and bedrock topographic maps were generated for developing and testing volume estimation methods. Generally, for glaciers shorter than 2.6 km, volume was best estimated by glacier area raised to a power. For longer glaciers, it was best estimated with a power relationship including slope and shear stress. The necessary variables can be estimated from topographic maps and aerial photographs. The estimation methods are being applied to unmeasured glaciers on the remaining volcanoes, including Mount Baker, Mount Adams and Glacier Peak.

GLACIERS - LOWER 48 - MONTANA

MEASUREMENTS OF ICE MOTION OVER BEDROCK AT SUBFREEZING TEMPERATURES
(B. Hallet, C.E. Gregory, C.W. Stubbs and R.S. Anderson - QRC/WASH)
Observations in subglacial cavities, formed as Grinnell Glacier slides over a ledged limestone surface, indicate that: minimum air temperatures in the cavities reach several degrees below zero; basal sliding, which averages about 12 m/a, slows and perhaps stops in the winter; and rock is fractured and entrained subglacially.

Instrumentation was installed under 15-20 m of ice to measure sliding rates and temperatures throughout the year. An excavation extending about 1 m upglacier from a subglacial cavity exposed about 1 m^2 of the gently sloping striated bedrock. An array of thermistors precise to 0.02°C were anchored to the glacier bed. The basal velocity was measured nearby with a wheel pressed against the ice roof of the cavity. Results indicate that ice continues to move over a bedrock ledge at temperatures that locally are nearly 1°C below the inferred melting point. At this site, temperate conditions may only exist during the summer, while the measured temperatures reflected the variations in stresses due to ice flow over the uneven bed. The inferred stick-slip motion of basal ice is consistent with expectations of shear tractions at the glacier bed, sufficient for shear failures to develop in the ice or at the ice/rock interface. Such high shear stresses applied cyclically may contribute importantly to subglacial fracture of rock.

GLACIERS – LOWER 48 – WASHINGTON

ICE DIVIDE MIGRATION AT BLUE GLACIER

(E.D. Waddington & M.J. Balise, Geophysics/WASH; R.T. Marriott, Atmos/WASH)

Blue Glacier mass balance has been measured since the IGY. Recent strain-rate surveys of the flow divide between Blue and Black glaciers, together with a study of existing topographic maps, imply that the divide migrates up to 350 m in response to variations in mass balance gradient - maybe introducing large errors into the net balance calculations which have assumed a fixed, and, as it turns out, an extreme divide position. A radio echo survey identified bedrock features which probably control the flow at depth and may influence divide stability.

Filter function studies to relate the time series of divide position and residual snow depth to the net balance of Blue Glacier are underway.

MASS BALANCE HISTORY OF THE BLUE GLACIER

(C.F. Raymond and S.G. Warren, WASH; R.L. Armstrong, CIRES/COLO)

Nearly 30 years of mass balance and terminus location data will be compiled and reduced. Based on analysis of the data, a method to model and compute the mass balance will be developed. A set of simplified field measurements will be defined for the future collection of data necessary to support the model.

SOUTH CASCADE MASS BALANCE

(R.M. Krimmel and B.H. Vaughn, GPO/USGS)

Mass balance measurements were continued in 1984/85. A slightly below-normal spring snowpack, combined with an especially dry summer, resulted in a very negative mass balance. Preliminary results show a mass balance of -1.2 m and retreat of 20 m.

FIRN WATER TABLE - SOUTH CASCADE GLACIER

(A.G. Fountain and B.H. Vaughn, GPO/USGS)

In June 1985, 13 wells were drilled through the water-saturated layer in the accumulation zone of South Cascade Glacier. Water levels were measured automatically at four wells and intermittently at the remaining wells. Permeability tests were made once a month at each of the nonrecording wells using the slug test technique. The data have yet to be examined, however we anticipate higher than previously observed water levels caused by the unusually warm, dry summer.

HYDROLOGY OF SOUTH CASCADE GLACIER

(A.G. Fountain, GPO/USGS)

Stage and conductivity recorders were installed at each of the four principal streams that drain the glacier, to better delineate the hydrological activity of its different parts. The data were collected every 15 minutes during the summer; solar radiation, precipitation and air temperature were also measured.

This past summer was unusually warm and dry causing much glacial melt, which kept the streams very high. In June the largest glacial stream (in terms of discharge) was not the usual central one, but the west side marginal stream. By late July, the major discharge was again issuing from the central stream. An examination of the terminus revealed that a temporary ice dam could have caused the water to reroute from its normal path. However, the only evidence of an outbreak flood is from the west side stream. Hopefully, continued study of these streams will elucidate the relationship between them and the hydrology of the glacier.

SHOESTRING GLACIER

(M.M. Brugman and B. Kamb, CALTECH)

Shoestring Glacier on Mount St. Helens has been studied from 1979 to 1983, with special attention to its reaction to the catastrophic "beheading" by the great explosion of May 18, 1980. Block-type flow in the lower part of the glacier is not caused by basal sliding, but by internal shear across an englacial layer loaded with rock debris. This remarkable phenomenon also occurs in other glaciers on Mount St. Helens and something similar was involved in the surge of Variegated Glacier: the thrusts that formed were localized in debris-rich layers in the ice.

GLACIERS – LOWER 48 – CALIFORNIA

MOUNT SHASTA GLACIER NOTES, 1985

(P.T. Rhodes, Mt. Shasta, CA)

Hotlum Glacier thinned 1-2 m at a transect about 500 m above the terminus, reversing a thickening trend that began in 1982. Within 100 m of the terminus, a slight (1-2 m) increase in ice thickness occurred. Outburst floods from Whitney Glacier in early July caused severe damage to roads 14 km downstream. Associated mudflows carried boulders

the size of small trucks down Whitney Creek. The floods may have come from water pooled in a depression and crevasses created by major distortion of the glacier from an apparent kinematic wave. Ponding was seen July 22 at 3350 m elevation, 1.6 km above the terminus. An unknown glacier was observed on a south-facing slope at 3500 m elevation in Avalanche Gulch. It has a prominent bergschrund and the terminal moraine is ice cored, with coarse crystalline ice exhibiting bedding planes dipping toward the direction of presumed ice flow. The number and trend of ice exposures in the moraine suggest that ice movement is present. Glacier budgets on Mount Shasta were more strongly negative for 1984/85 than any budget year since 1976/77. Despite this, firn coverage was impressive due to a record two-year accumulation in 1981-83.

ICE SHEETS

OXYGEN ISOTOPE PALEOCLIMATOLOGY/GLACIOLOGY

(P.M. Grootes and M. Stuiver, QRC/WASH)
From a 200-m long South Pole core and the J-9 Ross Ice Shelf (Antarctica) core, $\delta^{18}O/^{16}O$ profiles were completed. The measuring phase of the Quelccaya Ice Cap (Peru) cores is finished and work on the interpretation (with L.G.Thompson, IPS/OHIO & W. Dansgaard, GIL/UCPH) is in progress, as are measurements of a 200-m core from the Dominion Range, Antarctica (for P.Mayewski, GRG/UNH).

FINITE-ELEMENT MODELLING OF ICE FLOW

(S. Hodge, CIP/USGS)
A two-dimensional, time-dependent model of an arbitrarily shaped ice mass is being extended to three spatial dimensions and temperature-dependence is being made more realistic. The improvements are being done so the model can be applied to analysis of radar data from Greenland and Antarctica.

IMPULSE RADAR SOUNDING

(S. Hodge, CIP/USGS; D. Wright, USGS/Denver, CO; R. Watts, USGS/Reston, VA; R. Jacobel, OLAF; I. Whillans, IPS/OHIO)
Basal conditions and internal layering in ice sheets are being investigated at lower frequencies, using the 1-50 MHz impulse radar previously developed by the USGS for temperate glaciers. Major improvements will be made to the system, particularly the recording part. High-speed transient digitizing and stacking techniques and continuous profiling will be utilized. Initial field work will be on the ice streams of West Antarctica and in the area of a possible new corehole in central Greenland for the Greenland Ice Sheet Program II (GISP II).

ICE SHEETS - ANTARCTICA

DERIVED PHYSICAL CHARACTERISTICS OF THE ANTARCTIC ICE SHEET - AN UPDATE

(U. Radok, CIRES/COLO)
The 1970 description of the Antarctic ice sheet as a steady-state zero-net-even balance system is being updated using more recent information, especially the SPRI Antarctic Map Folio. The analysis uses a 20-km grid and is part of a study of the surging potential of Antarctic ice streams (with University of Melbourne, Australia).

WEST ANTARCTIC ICE SHEET - NUMERICAL STUDIES

(C.S. Lingle, CIRES/COLO)
A numerical modelling study has been initiated to determine whether warming of the atmosphere and ocean (due to increasing CO_2 and other "greenhouse" gases) might cause accelerated discharge from West Antarctic ice streams. The objective is a realistic, coupled, ice stream/ice shelf model. Work is being done: on the grounded ice stream component of the model (C.S.Lingle & T.J.Brown); on the theoretical framework for a one-dimensional ice shelf model (W.S.B. Paterson); on development of a solution of the heat flow equation (J.L. Fastook); and on a solution of the equation of mass continuity for the ice shelf model (D.H. Schilling and C.S. Lingle.

PICO DRILLING ACTIVITIES, 1984-85

(K.C. Kuivinen and B.R. Koci, PICO)
In the Dominion Range, a single 201-m hole was drilled for ice chemistry (P. Mayewski and B. Lyons, GRG/UNH) in nine days at an average rate of 3 m/h. Core quality was good to 150 m; below that it was poor due to strain history, cold-ice and bubble pressure at depth. The core was drilled with the PICO 4-inch electro-mechanical coring drill and 200-m winch (PICO 4/200). The diameters of the core and hole are 10 cm and 15 cm. Double-angled cutters and improved bit stabilization produced better quality core than flat bits. A simplified DC-power winch and drill control package performed flawlessly in its initial field application. The borehole was logged for temperature at 10-m intervals; repeated every 30 m during thermistor retrieval. Tests of a new lightweight solar panel provided by Solarex Corporation were also conducted. The drilling team included B. Koci and M.S. Watson (PICO) and H. Rufli (LLC). Watson collected the borehole temperature data.

At Upstream B on the Siple Coast, PICO collected a 104-m core for study of the texture of firn and the processes that cause the transformation of firn to ice (R. Alley, WISC-M). Drilling was completed in four days. Core quality was excellent and recovery was nearly 100%. Drilling was also with the PICO 4/200. The power control systems were AC for the winch and DC for the drill.

Upon completion of the coring activity at Upstream B, a hot water drilling system was used to drill 102 17-m deep shot holes for seismic studies (Bentley & Rooney, WISC-M) in four days, using equipment towed between sites by a Tucker Sno-Cat. They were spaced at 360-m intervals in four lines between margins of Ice Stream B. Four of the holes were drilled into crevasses at 12-17 m below the surface. The PICO drilling team included J. Kitwak, B. Boller and K. Kuivinen.

At South Pole Station, the team from Upstream B collected a 10.5-m firn core and retrieved from cold storage residual portions of a 200-m Siple Station core for E. Mosley-Thompson (IPS/OHIO). M.S. Watson logged temperature profiles in two holes to depths of 200 m and 280 m and assisted H. Rufli in the LLC's borehole gas sampling program (see Swiss report, p.13).

PICO equipment was loaned to three research projects: solar panels to I. Whillans (IPS/OHIO) and C. Bentley (WISC-M); and lightweight coring augers to P. Kyle (New Mexico State Univ.) and I. Whillans. All cores collected this season were retrograded to the scientists' home institutions, but due to freezer problems during shipment portions of each core melted.

ICE SHEETS – GREENLAND

PICO FIELD ACTIVITIES IN GREENLAND, 1984-84

(K.C. Kuivinen and B.R. Koci, PICO)

PICO collected 96 and 109-m ice cores and logged temperature profiles in both holes at Site A (70°38.1'N, 35°49.2'W) for the GISP II site selection program. A WISC-M team member logged and packaged the core which is stored at the Ice Core Laboratory, SUNY/Buffalo. The deep borehole at Dye 3 was logged for temperature, inclination and azimuth (with UCPH). PICO provided field operations management and logistics support to projects from ALASKA and University of Maine-Orono at the Jakobshavn Glacier, the GISP II program in central Greenland and glaciological and atmospheric science projects at Dye 3.

BASAL ICE TEMPERATURE AT CRETE THROUGHOUT A GLACIAL CYCLE

(W.S.B. Paterson, Paterson Geophysics Inc., B.C., Canada; E.D. Waddington, WASH)

If the basal ice at Crete, Greenland has ever reached the melting point, the oldest ice ($0.5\text{-}1.0 \times 10^6$ years) may have melted. Numerical integration of the heat equation, allowing for horizontal variation of the velocity, horizontal heat transfer and thermal inertia of the bedrock, was carried out. Basal temperature is highest during glaciations due to low vertical velocity with low mass balance. It is always about three degrees warmer under the divide than at several ice depths to either side, due to lateral variation of the vertical velocity. If the geothermal heat flux is less than about 48 mWm^{-2}, it is unlikely there has been basal melting at Crete.

GISP II SITE SELECTION - SURFACE AND BED TOPOGRAPHY

(S. Hodge, CIP/USGS; P. Gudmansen, TUD)

The major criteria for choosing a suitable location for the proposed new corehole in Greenland are based on surface and bed topography. The measurements will be done from an LC-139 aircraft with the TUD 60 MHz radar. Data will be recorded on heat-sensitive paper and analog magnetic tape, as well as the standard photographic film. In addition to the topography, detailed studies of the internal layering and basal reflection characteristics will also be made.

GLACIAL GEOLOGY

QUATERNARY GLACIATION OF PATAGONIA

(S. Porter, WASH)

Preliminary results from southernmost Chile indicate the last glaciation culminated more than 16,000 years ago and the principal ice lobes had retreated by about 12,500 years ago. Emerged marine terraces along the Strait of Magellan and Beagle Channel formed during the middle Holocene, when relative sea level was some 3-4 m higher than today. Well-preserved ice-wedge casts, just beyond the limit of the outermost drift sheet near the Chile-Argentine border, point to cold continental conditions.

QUATERNARY GLACIATION IN THE ANDES

(S. Porter, WASH)

A glacial record, traceable across the crest of the Andes on the south side of Cerro Aconcagua, is being dated. Three drifts on each side of the crest appear correlative and younger than a widespread tephra 250,000 years old. Travertine, interstratified with the deposits, offers hope for obtaining a chronology for at least the younger part of this record.

UPPER COOK INLET REGION, ALASKA

(H.R. Schmoll, L.A. Yehle and J.K. Odum, USGS/Denver, CO)

Surficial (especially glacial) geologic studies, including mapping at scales of 1:31,680 and 1:63,360, are in progress.

GLACIOLOGY - GEOPHYSICS: SOUTHEAST ALASKA

(B. Hammond, Geophysics, Univ. of Idaho)

Research is continuing on the use of the USGS impulse ice radar for detection and delineation of sulphide deposits beneath several glaciers in The Haines, Alaska area. A micro computer-based radar receiver, to replace the sampling oscilloscope commonly used in the USGS radar system, is being developed. Field testing of the new receiver will be completed in late 1985, with anticipated use during the 1986 field season.

COTTONWOOD LAKES, SIERRA NEVADA, CALIFORNIA
(L.Mezger and D.Burbank, Geol/USC)
Geomorphological mapping of the Cottonwood Lakes drainage basin was undertaken to delineate the extent of former glaciations in this relatively high altitude (3000 m), low-gradient basin in the southern Sierra Nevada. Relative-dating techniques, including P-wave velocity studies, were used to separate morainal successions into different age groupings. Initial radiocarbon dates indicate the terminal portions of the late Wisconsin glaciers had receded and forests had established themselves by 10800 years B.P. in areas more than 3200 m high.

ROCKY MOUNTAINS, COLORADO
(J.B. Benedict, Center for Mountain Archeology, Ward, CO)
Mapping of Holocene moraines and rock glaciers in the Indian Peaks region of the Front Range continued, emphasizing radiocarbon dating and use of calibrated rates of rock weathering and lichen growth for age determination. A long-term field experiment to explain differences in the shapes of the growth-rate curves of Rhizocarpon geographicum, Lecanora novomexicana and Xanthoparmelia conspersa was initiated. Movement markers installed by H.A. Waldrop on the Arapaho Rock Glacier in 1960 were resurveyed, suggesting average long-term velocities of 6.2 to 19.3 cm/a.

SEA-LEVEL INDICATOR, FALKLAND ISLANDS
(J.F. Splettstoesser, MGS/MINN)
Rock striations were seen in 1984 to be of use in locating "fossil" penguin breeding sites and dating former sea levels. The striations are caused by the claws of rockhopper penguins, who must live at or near sea level because of their nearby oceanic food supply. As sea level changed through geologic time, the penguins moved their breeding sites. The bedrock striations are preserved and can be used, together with ages of associated organic remains, to date sea level changes.

PALEOGLACIOLOGY, LEMHI MOUNTAINS, IDAHO
(D.R. Butler, Geography/OSU)
Mapping of geomorphic crosscutting and overriding relationships among late Pleistocene and Holocene moraines shows a complex chronology of glaciation. Several Pinedale-equivalent and Holocene deposits have been identified. A possible early Holocene glacial moraine has been radiocarbon-dated at approximately 7,500 yr BP. Neoglacial avalanche deposits and their deposition chronology are currently being examined.

PRIEST RIVER PLEISTOCENE GLACIATION, IDAHO
(R. Breckenridge, Idaho Geological Survey)
The chronology of advances, deglaciation and correlation with the alpine glaciers of the Selkirk Range are being established, as well as relationships to the floods from Glacial Lake Missoula.

GLACIAL LAKE SOURIS, NORTH DAKOTA
(A.E. Kehew and M.L. Lord, Geology/NDAK)
Mapping and drilling commenced in the Glacial Lake Souris basin (north-central North Dakota) to determine the distribution and stratigraphy of Pleistocene glacial-lake deposits. The most significant stratigraphic unit is a large sand and gravel fan, deposited by catastrophic floods originating from the rapid drainage of Lake Regina in Saskatchewan.

LATE PLEISTOCENE GLACIATION IN UTAH
(D.R. Currey, Geography/UTAH)
The last Pleistocene glacial maximum in the Wasatch Mountains postdated 26,080 yrs B.P.; deglaciation was at least 70% completed by 12,300 B.P. At its maximum extent, the largest glacier (49 km^2) in the Wasatch Mountains (40°34'N) had a probable ELA of 2604 m. The southernmost occurrence of late Pleistocene glaciation in Utah was on the Markagunt Plateau (37°42'N), where the largest body of glacier ice (11 km^2) had an ELA of about 3140 m; deglaciation was at least 50% completed by 14,400 B.P. Lake Bonneville may have served as a mesoscale source of water vapor for glacial accumulation in Utah; during the last glacial maximum, the regional glaciation limit on the downwind (E) coast of Lake Bonneville was at least 500 m lower than on the upwind (W) side of the paleolake.

ICE-SHEET RECONSTRUCTION AND GLACIAL SEDIMENTATION, PUGET LOWLAND, WASHINGTON
(D.B. Booth, QRC/WASH)
Reconstructed glacial parameters, including mass balance, sliding velocity and meltwater discharge,have been determined for the southwest Cordilleran ice sheet during the last glaciation. These have been applied to problems of glacial erosion of non-streamlined landforms, depositional processes of ice-marginal and subglacial sediments, and the distribution and engineering properties of glacially transported materials.

A LOESS OF MID-WISCONSIN (OLYMPIA) AGE IN THE PUGET LOWLAND, WASHINGTON STATE
(G.W. Thorsen, Washington State Div. of Geol/Earth Resources, Olympia, WA)
A massive weathering silt is exposed in some beach bluffs of the SE Strait of Juan de Fuca. The best exposure is a blanket of uniform thickness (7-8 m) in the upper bluffs. In places,it appears to drape a pre-existing surface and, at former lows, either interfingers with alluvial or mixes with lacustrine sediments. The "upland" deposits are commonly floored by a paleosol and/or a lag. The silt generally overlies drift or thick (30 m+) sections of outwash sand. In places, the drift is of glaciomarine origin. The silt is generally overlain by outwash or by till of the last major glaciation, but in places by glaciolacustrine silts or fine gravel of Olympic Penninsula origin.

Dates of 31,500 and 33,500 have been obtained near the base of the unit and one of 28,200 from material above the main section of silt. This age, the stratigraphic setting and the lithology suggest that the unit may be correlative with sections of the upper "fluvial/estuarine" member of the Cowichan Head Formation in SW British Columbia.

GLACIOGENIC SEDIMENTS OF THE PUGET LOBE
(S. Chernicoff, Geology/WASH)
Glaciogenic sediments at the contact between Vashon till, deposited by the Puget lobe of the Fraser Glaciation (Late Wisconsin maximum) and subcropping drift or bedrock, are being studied to deduce the nature of the basal zone of a temperate Pleistocene ice sheet occupying a maritime environment. Grain-size distribution, clast and grain fabric, clay mineralogy, magnetic susceptibility and various geotechnical properties of sediments, above and below the basal contact, are being analyzed to determine if subglacial water played a significant role in modifying basal drift. These analyses will reveal the local degree of incorporation of subcropping materials, generating a lobe-wide picture of subglacial behavior.

Preliminary analysis reveals that a zone, several meters in thickness, exists at the base of many exposures of the Vashon till above the contact with the local subcropping material. It is characterized by increased incorporation of materials from the local substrate and by evidence of considerable subglacial waterflow. Evidence for waterflow includes the occurrence of discontinuous lenses of cross-bedded and rippled sand and data from granulometric analysis that indicate the preferential removal of texturally fine components from the basal till.

GLACIAL HISTORY OF THE COLUMBIA RIVER LOBE, NORTHEASTERN WASHINGTON
(E.P. Kiver, Geol/ & D.F. Stradling, Geog/Anthro., E. Washington Univ., Cheney, WA)
The chronology of ice movements and glacial environments along the Columbia River, from Grand Coulee to Canada, is being studied. Three major episodes of glaciation occurred and four late Wisconsin-age ice positions are recognized. Sediments and landforms record a complex interaction of glacial, glacial-lacustrine and outburst flood activity along the Columbia River valley.

QUATERNARY GLACIATION, WIND RIVER MOUNTAINS, WYOMING
(G.M. Richmond, USGS/Denver, CO)
Mapping and stratigraphic study of glacial and related deposits west of the Continental Divide has been completed. Samples are now being obtained for various methods of dating the several glaciations and interglaciations or interstadials.

GROS VENTRE RIVER, WYOMING
(D. Burbank, Geology/USC)
Paleomagnetic analyses were performed on a succession of lacustrine samples in the lower Gros Ventre River drainage, thought to belong to an early Pleistocene glacial advance. All specimens in this 100-m-thick sequence were normally magnetized. This suggests that they are Brunhes-aged (less than 730 Kyr), rather than early Pleistocene.

SNOW

SNOW AND SOIL MOISTURE CHANGES UNDER VARIOUS PINE STAND DENSITIES IN WESTERN MONTANA
(D.F.Potts, Univ.Montana,Missoula, MT 59812)
A systematic grid snowcourse was established across a low elevation (1200 m) 50-year-old lodgepole pine stand in western Montana. The 3.85 ha stand was divided into five equal subunits (clearcut, control - 1750 stems/ha, thinnings at 3 m x 3 m, 4.5 m x 4.5 m and 6 m x 6 m spacing). Forty-five aluminum soil moisture access tubes were systematically placed throughout the stand.

During the winters of 1983-84 and 1984-85, snow depths were measured at each grid point every two weeks. A smaller random sample of snow water equivalent was obtained in each subunit. Soil moisture measurements began in October and were repeated monthly until snowcover was gone. Soil pits and soil moisture depletion curves from the summer of 1983 clearly indicated the primary root occupancy zone limited to a depth of 45-60 cm. Thus, soil moisture recharge measurements were made at depths of 30 cm and 100 cm.

Soil moisture at the beginning of the recharge period, spatial variability in snow accumulation and differential melt rates are strongly related to treatment basal area. Development and expansion of saturated zones and the influence of gentle topographic relief (about 15 m from highest to lowest points in the stand) are clearly demonstrated with the aid of computer graphics.

SPATIAL AND TEMPORAL VARIABILITY IN FOREST SOIL FROST DEVELOPMENT IN WESTERN MONTANA
(D.F.Potts, Univ.Montana,Missoula, MT 59812)
Grids of 20-30 frost tubes with 5-m spacing were established at four sites in Lubrecht Experimental Forest on gentle slopes with north aspects. Each site pair has a standard instrument shelter, equipped with a recording thermograph. Gravimetrically determined soil moisture content was sample estimated for each site at the onset of frost and with the completion of thaw in the spring. The occurrence and depth of frost was measured weekly at each tube in the grids during the winter months. Snow depth at each tube and an estimate of water equivalent were recorded at each sampling interval.

SNOW ACCUMULATION PATTERNS IN IOWA
(P. Waite, Iowa Department of Agriculture, Des Moines, Iowa)
The Iowa Department of Agriculture (IDA) State Climatology Office focussed on secular snowfall patterns, particularly during recent decades, and upon the changing characteristics of recent era snowfall patterns (to be published in Iowa Secular Precipitation Patterns as one of the "Climatology of Iowa Series"). During the past 15 years, snowfall increased about 10 % above the long-term normals, with the greatest increases during October-November and April, thereby lengthening the effective snow season.

SNOW METAMORPHISM
(P.J. Burns, CSU)
Both transient and steady-state finite-element calculations of effective diffusion coefficients in dry snow are being performed for two-dimensional and three-dimensional idealized snowpack geometries. In addition, time-lapse video tapes of sublimation and accretion are being generated by computer in order to investigate temperature gradient metamorphism and, for the future, the impact of this process on the short-term, transient acid pulse released into the ground water when the snow begins to melt.

DENSITY AND TEMPERATURE STUDIES OF DRY SNOW
(C.H. Ling, CIP/USGS)
An analytical study of the densification of dry snow is being extended from a steady state solution that requires a maximum of one free coefficient to a time-dependent solution. In addition, the temperature distribution as a function of depth and time is also being attempted. The objective is to assist in decoding satellite images of snow in the Colorado Basin, and then apply the analytical method to the polar ice sheets.

BLOWING SNOW AND SNOWDRIFT CONTROL
(R.D. Tabler, RMF&RES/USDA/Laramie, WY)
Theoretical studies continue on the erosion, transport and deposition of blowing snow in relation to wind profile characteristics in flows characterized by free turbulent mixing. Field tests of snow fences, scheduled for the 1985-86 winter, include those of the newly revised 4.2 and 2.7-m tall "Wyoming" wood-slat snow fences and fences constructed from various synthetic materials ranging from 1.4-4.0 m high. Streamflow has increased by 140% for two years since constructing 800 m of 3.8-m tall snow fence on a 300 ha calibrated watershed at 2350 m elevation.

BLOWING SNOW: EROSION PROFILES DUE TO PARTICLES ENTRAINED BY WIND: APPLICATION OF AN EOLIAN SEDIMENT TRANSPORT MODEL
(R.S. Anderson - QRC/WASH)
Erosion by impacts of particles entrained in the wind reflects delivery of kinetic energy to the obstacle. A recent model of eolian sediment transport permits calculation of expected erosion patterns in both man-made and natural objects. Modelling vertical erosion profiles also provides an exacting test of the transport model.

Realistic distributions of liftoff velocities for saltating grains give rise to kinetic energy flux profiles, characterized by a strong maximum up to 0.1-0.4 m above the bed during strong winds. Kinetic energy flux due to suspended grains also peaks above the bed; the height and strength of the maxima depend very strongly on grain size. As grain size diminishes, increased particle deflection by the air flow around an obstacle reduces delivery of kinetic energy to the surface. For both saltating and suspended grains, kinetic energy flux scales with the fifth power of the wind shear velocity. Erosion profiles in man-made obstacles are well modelled, with only slight modification of the saltation model to account for the relatively high elasticity of actual deflationary surfaces.

BLOWING SNOW: SEDIMENT TRANSPORT BY WIND: TOWARD A GENERAL MODEL
(R.S. Anderson and B. Hallet, QRC/WASH)
A general model of eolian sediment transport by both saltation and suspension has been developed. Saltation is analyzed through calculations of single trajectories given initial conditions of liftoff speed, angle and spin. Profiles of particle concentration and mass flux, generated assuming all trajectories are identical, display distinct maxima at the top of the trajectory. By incorporating the realistic distribution of trajectories arising from the stochastic nature of grain impacts with a granular bed, the model yields monotonic decreases in particle concentration and mass flux with height, in accord with published empirical data.

The analysis of suspension, as the balance between downward advective flux due to the settling of grains and their upward diffusive flux due to turbulence, results in concentration profiles that fall off as power laws with height, also in accord with empirical data. A relation for reference level concentrations is presented for both blowing snow and dust profiles.

The solutions for saltation and suspension are combined to yield mass flux profiles for the entire range of grain sizes in the bed. The saltation layer emerges naturally as the region where the total flux of saltating grains exceeds that of suspended grains. The model points clearly to the need for further research on the stochastic grain-bed interactions, which control both the probability distribution of liftoff velocities in saltaton and the production of fine particles in suspension.

SNOW – AVALANCHES

SNOW AVALANCHE CHRONOLOGY, GLACIER NATIONAL PARK, MONTANA
(D.R. Butler, Geography/OSU)
A chronology of winters with high-magnitude snow avalanches was compiled from historical data and tree ring data. Large avalanches occur synchronously throughout Glacier Park on both sides of the Continental Divide; wet-snow avalanches primarily on the west side and dry-snow ones on the east.

AVALANCHE DYNAMICS MODELLING
(T.W. Tesche, Alpine Geophysics Inc., El Cerrito, CA)
A numerical, three-dimensional model of turbulent snow avalanche dynamics is being developed for calculating avalanche velocity distributions, impact pressures, entrainment rates and deposition zone characteristics. The hybrid modelling approach integrates Eulerian and Lagrangian concepts and uses gradient transfer theory for the closure problem. Model validation and sensitivity analyses are underway, using high resolution stereophotogrammetric measurements of artificially released avalanches.

AVALANCHE HAZARD, SAN JUAN MOUNTAINS, CO
(R.L. Armstrong, CIRES/COLO)
A method to incorporate snow structure parameters into numerical avalanche prediction techniques is being developed. The existing data base will be used to define relationships between several snow structure classifications and associated avalanche activity. A simple, operational model will then be developed to monitor snow cover structure throughout the winter season.

AVALANCHE HAZARD IN THE U.S.
(K.Elder & B.R.Armstrong, Colorado Avalanche Information Center (CAIC), Golden, CO)
A statistical method to quantify avalanche hazard ratings has been investigated, based on 30+ years of avalanche event data from selected sites in Colorado. It will be tested during the 1985-86 winter.

U.S. AVALANCHE ACCIDENT ANALYSIS
(B.R. Armstrong, CAIC)
Compilation and analysis of U.S. avalanche accidents is an on-going project of the CAIC. Results are published periodically and presented at workshops and avalanche training courses, to increase avalanche awareness.

HOAR FROST
(S. Breyfogle, Washington State Dept. of Trans., Olympia, WA)
Topography and climate often produce an inversion climate, suitable for hoar frost growth, within the Central Washington Cascades. Quantitative description of environmental parameters of the snow/air interface from the test field and subsequent field data acquisition will form the basis for an Avalanche Hazard Forecasting index, where hoar frost is a factor.

ACOUSTIC EMISSION MONITORING OF SNOW PACK
(R.J. Watters, Geography & Engineering/NEV)
Acoustic emission monitoring of avalanche-prone slopes continued during the 1984-85 winter; mainly at Alpine Meadows Ski Resort, CA (with L. Heywood). Experiments used different wave guide shapes, orientations, areas and materials for detecting emissions. Frequencies of 30-35 KHz were monitored. Noise levels varied markedly with the orientation and shape of the wave guide.

SNOW CHEMISTRY

SNOW CHEMISTRY, SEQUOIA NATIONAL PARK
(J.Dozier, D.Marks, J.Melack & R.Kattelmann, CALIF/Santa Barbara, CA 93106; K. Tonneson, CARB; J.Dracup, CALIF/Los Angeles, CA 90024)
The snow hydrology of a small alpine watershed in southern Sierra Nevada, California, was studied from 1984 to assess the current status and sensitivity of the alpine environment to damage from acid deposition. The project, funded by the California Air Resources Board (CARB), involves: the development and testing of physical models of snowmelt and runoff processes; digital terrain analysis techniques to simplify the terrain inputs in models of the distribution of hydrometeorological parameters over the watershed and evaluation of the optimum number and location of measurement sites; techniques for measuring physical and chemical properties of snow, snowmelt and runoff; and low-power instrumentation for automated data-collection systems. The techniques will be combined to calculate chemical cycling through the watershed during snowmelt and rainfall runoff events.

SIERRA NEVADA SNOWPACK CHEMISTRY AND DISPOSITION OF POLLUTANTS IN CALIFORNIA SNOW ZONE
(N.Berg, D. Azuma, J. Bergman, L. MacDonald, B. McGurk, R. Kattelmann & S.Woo, PFS & RES)
Contrary to findings in other areas, analyses of precipitation, basal snowpack outflow and stream chemistry in the central Sierra Nevada do not identify elevated stream water acidity levels during spring snowmelt periods. The lack of a spring acidity "shock" may be the consequence of the relative purity of precipitation (mean snowfall pH = 5.2 - 5.3). Comparatively few pollutants were available for release from the snowpack. Alternatively, snowpack stratification may lengthen the time span for melt water release, diluting the acidification effect. During the 1985 winter, annual pH minima were associated with rain-on-snow events. An acidity shock may be occurring, but it is triggered by early or mid-winter influxes of rainwater.

SNOW ACID STUDIES IN COLORADO
(Marlett and Hepler, CSU)
Intercomparisons have been made of acid snow in various ski areas and the Flat Tops Wilderness area, to determine levels of acidity. Elevated levels of $SO_4^=$ and NO_3^- were found in the snowpack at Vail and Telluride, as compared to the remote Flat Tops Wilderness area. The presence of Ca^{++}, probably resulting from $CaCl_2$ application to streets and parking lots, effectively prevented the pH of the snow from becoming acidic.

FUMIGATION OF SNOW WITH SO_2
(G.A. Dawson and R.C. Bales, ARIZ)
Field and laboratory experiments to measure dry, gaseous deposition velocities of sulfur dioxide to snow are underway. Primary variables are SO_2 concentration, snow temperature, liquid-water content and illumination. Results should provide insight into chemical and physical factors limiting uptake rates of SO_2 gas on to snow surfaces.

CHEMICAL PROPERTIES OF RIME-ICE AND SNOW
(D. Lamb and D. Mitchell, DRI/NEV)
Fresh snow and rime have been collected near a mountain top in the Sierra Nevada for the purpose of measuring their respective chemical compositions. Analyses are made for a range of ions including NO_3^-, $SO_4^=$, Cl^-, Na^+, K^+, NH_4^+ and H^+. Although average concentrations can vary considerably from storm to storm, the ionic concentrations in the rime samples are consistently higher than those in the snow. Such differences are ascribed to the microphysics of the snow formation, which select against the transfer of trace chemicals to the snow from the chemically rich cloud water. Attempts are being made to estimate the relative contributions of surface riming and snowfall to the total flux of chemicals to the watershed.

SNOW – REMOTE SENSING

RADIATIVE PROPERTIES OF SNOW
(J. Dozier and R.E. Davis, CALIF/Santa Barbara; A.T.C. Chang and K. Brown, NASA/GSFC)
Spectral measurements of the bidirectional reflectance-distribution function of snow at wavelengths 0.4-2.5 μm are made at a variety of solar zenith, viewing and azimuths with a spectro-radiometer. In the winter of 1984-85, our data cover surface reflectance for new snow, old snow and melting snow, microwave emission at 35 GHz and snow properties. Grain size and shape were examined in the field and in prepared sections. Liquid water measurements by dilution were made for melting snow. Preliminary analysis shows that the volume-to-surface area ratio, measured from the sections, gives a good estimate for an "equivalent sphere" to use in calculating Mie scattering properties and that snow reflectance deviates from Lambertian when the solar and viewing angles exceed 45°.

REMOTE SENSING SNOW, SOUTHERN SIERRA NEVADA
(J. Dozier, CALIF/Santa Barbara, CA 93106)
Satellite data from the Landsat Thematic Mapper and NOAA Advanced Very High Resolution Radiometer are used to measure snow spectral albedo and surface temperature in the drainage basins of the Kern, Kings, Tule, Kaweah and San Joaquin Rivers. The data are corrected for atmospheric attenuation of the signal and varying illumination caused by the terrain, so the USGS Digital Elevation Models must be registered to the satellite data. Basin-wide distributions of the components of the snow surface radiation balance are examined for development of a distributed snowmelt runoff model.

AIRBORNE SNOW WATER EQUIVALENT MEASUREMENTS
(T.R. Carroll, NWS/NOAA, Minneapolis, MN)
The National Weather Service maintains an operational Airborne Gamma Radiation Snow Survey Program covering 16 states and four Canadian provinces. Terrestrial gamma radiation measurements are made during the winter over 1,049 flight lines to infer mean areal snow water equivalent. During snow-free periods, airborne radiation data are collected to measure soil moisture in the upper 20 cm. Recent research has focussed on the error structure associated with airborne snow water equivalent and soil moisture measurements over agricultural and forest environments. Additionally, research has been conducted to assess the cost benefit of airborne snow water equivalent data used in operational snowmelt flood forecasting.

REMOTE SENSING OF SNOW
(W.J. Campbell and E. Josberger, CIP/USGS)
A technique to determine snow water equivalent from space observations is being developed, using passive microwave data from the SMMR on the NIMBUS 7 satellite. The program consists of: an analysis of the six-year satellite data set combined with the corresponding surface snow measurements; and a field program to provide key internal snow pack properties, density and grain size, not usually measured by snow reporting sites.

SNOW – RUNOFF

IMPROVED METHODS FOR RUNOFF ESTIMATION IN CALIFORNIA SNOW ZONE AREAS, PARTICULARLY DURING AND AFTER RAIN-ON-SNOW EVENTS
(D.Azuma, N.Berg, J.Bergman, R. Kattelmann, L. Ma[illegible]onald, B. McGurk & S. Woo, PSF & RES)
A system for nondestructive, insitu monitoring of snowpack liquid water was redesigned and operated successfully during 1985. Data will be collected for a second year before final probe evaluations are made. Several snowmelt prediction equations for rain-on-snow situations were evaluated, as were five clear weather melt equations. Both analyses provided information for the comprehensive snow accumulation, melt and runoff prediction model being developed by the work unit.

SNOWMELT RUNOFF SIMULATION
(G.H. Leavesley & L.G. Saindon, USGS/Denver)
Evaluation of the SNOTEL network data for modelling snowmelt runoff is being conducted using the USGS Precipitation-Runoff Modeling System. East Fork Carson River, CA; Lower Willow Creek, MT; Weber River, UT; and the South Fork Rio Grande, CO are being used in the initial phase of the study.

LIQUID WATER MEASUREMENTS IN SNOWPACK
(H.S. Boyne, CSU)
Measurements of liquid water in snowpack have been made, based on electrical path length differences in the snowpack depth in the region of high dielectric dispersion of water. Measurement is by a microwave system operating at two frequency bands of 2-5 GHz and 5-8 GHz. The system was tested, evaluated and intercompared with a dilution measurement technique in both laboratory and field environments. The intercomparisons showed equivalence of the two measurement methods, provided the snowpack was homogeneous and free of stratigraphy. Work is continuing to show equivalence in more complex stratified media.

RAIN-ON-SNOW, WESTERN CASCADES, OREGON
(R.D. Harr, FS/USDA/Corvallis, OR)
Monitoring of microclimatological instruments and snowmelt lysimeters continued on three plots in a clearcut-logged area, an adjacent old-growth forest and an adjacent 20-year-old forest plantation to determine differences in snow accumulation and subsequent melt during rainfall. Analysis of past data indicate the clearcut plot had up to three times more snow water equivalent and twice as much energy available to melt snow during rainfall than the forested plot. The total amount of water available for soil infiltration during the largest rain storm was 20% greater in the clearcut plot than in the forested plot.

FLOATING ICE/SEA, LAKE AND RIVER

MARGINAL ICE ZONE (MIZ)
(R. Picard, NEPRF, Monterey, CA)
The Naval Environmental Prediction Research Facility (NEPRF) is conducting MIZ research using satellite imagery to determine and evaluate meteorological factors which significantly affect or are affected by the position of the ice edge

OCEANOGRAPHIC MEASUREMENTS IN THE MIZ
(R.H. Bourke, R.G. Paquette, Naval Postgraduate School, Monterey, CA; and J.L. Newton, Sci. Appli. Inc., La Jolla, CA)
Oceanographic measurements in and near the ice of the northern Greenland Sea were in progress in September. Similar observations in autumn 1981 and summer 1984 have been reported. The cruise made unusually deep penetrations into the sea ice and even into a fjord. Interest centers on the structure of the East Greenland Polar Front and its temperature finestructure, and on water, ice circulation, speeds and water properties both in the front and adjacent waters, particularly over the continental shelf.

MARGINAL ICE ZONE EXPERIMENT (MIZEX)
(W.J. Campbell and E. Josberger, CIP/USGS)
Satellite and aircraft microwave observations are used to investigate sea ice morphology in the MIZ - ice type, ice concentration and ice edge position from the 1983 and 1984 MIZEX experiments. Remote sensing and standard oceanographic data are used to analyze the dynamics and thermodynamics of oceanographic eddies in the Fram Strait region and their effects on the MIZ.

MIZEX 84, HEAT AND MASS BALANCE OBSERVATIONS
(G. Maykut, D. Perovich and T. Grenfell, Atmospheric Sciences/WASH)
Heat and mass balance studies of sea ice in the MIZ of the Greenland Sea were carried out in June and July 1984 as part of MIZEX. Primary goals were: to determine how spatial and temporal changes in the properties of the ice cover (thickness, concentration, floe size, albedo, snow depth and pond coverage) influence the decay cycle across the MIZ; to identify the dominant processes controlling the transport of heat from the water to the ice; and to gauge the importance of ocean-ice interactions relative to those between the atmosphere and the ice. Data collected included: mass changes at the top, bottom and edges of the floes; physical properties (grain size, bubble density, crystal structure and salinity) of the upper layers of the ice; snow depth, density and freewater content; internal ice temperature profiles; incoming longwave and shortwave radiation over the ice; downwelling spectral irradiance under different cloud conditions; total and spectral albedos of the major surface types; spatially averaged aerial albedos in three wavelength bands; light levels beneath the ice in six wavelength bands; and heat content of leads down to 20 m.

MICROWAVE EMISSION FROM SEA ICE SURFACES
(T.C. Grenfell, Atmospheric Sciences/WASH)
Surface-based passive microwave data and physical properties of the predominant sea ice types are being obtained. Algorithms for interpreting ESMR, SMMR and other satellite data in terms of geophysical parameters needed for sea ice research, such as ice concentration and ice type distribution, are being developed. During the past year, spectral emissivities from new and young ice types were determined during the joint CRREL ice tank experiment. Dual polarization measurements were made at frequencies of 6.7, 10, 18, 37 and 90 GHz. MIZEX data sets from 1983 and 1984 are being reduced and interpreted.

HEAT TRANSPORT IN LEADS
(D. Perovich and G. Maykut, Atmos.Sci./WASH)
Theoretical models have been developed to study heat transport and lateral melting in leads. Field data from the Canadian Archipelago were successfully used to test the performance of a two-dimensional lead model, which was applied to conditions in the MIZ and Central Arctic to examine the interaction of solar radiation with the ice and ocean in these regions. For practical applications, parameterizations were developed which allow a simple, well-mixed lead model to approximate predictions made by the more cumbersome two-dimensional model. Using these results, a model was formulated to examine the effects of floe size and lead width distributions on regional ice decay. Preliminary calculations were made on the impact of floe breakup on the rate of ice decay. The studies indicate that the relationship between lead width and lateral melt rate is considerably more complex than the linear increase previously postulated. Regional decay rates were found to be sensitive to both the amount of open water and its distribution. For a given ice concentration, predicted decay rates varied inversely with average floe diameter.

SEA ICE MELT FROM PASSIVE MICROWAVE DATA
(M.R. Anderson, CIRES/COLO)
The onset of melt in the seasonal Arctic sea ice zone has been shown, using passive microwave data from the Nimbus-7 Scanning Multichannel Microwave Radiometer (SMMR). The data are associated with the spring, when the snow pack has started to melt and incipient puddles are forming at the snow/ice interface. The events have been analyzed for 1979 and 1980, and continued analysis is planned for more recent SMMR data and the associated synoptic conditions.

MODELLING SEA ICE LEADS
(T.S.Ledley, Space Physics & Astronomy/RICE)
A thermodynamic sea ice model has been numerically structured to take time steps in the order of a week, which have a large impact on the thickness of new ice on open ocean and in lead, because high initial ice growth rates are extrapolated over the length of the long time step. A lead parameterization has been developed to reduce the model's sensitivity to time step size, in which the thickness of new sea ice is controlled through power law relations between the new ice thickness at the end of 7.6 days, the initial energy deficit in the ocean and between the new ice thickness and time. These relations reflect the reduction in ice growth rate as ice thickens. It is assumed that new leads open at a constant rate.

Tests show that the method of determining new ice growth is relatively insensitive to time step size, and the mean ice thickness is relatively insensitive to the lead opening rate in latitude zones where summer ice-free conditions exist.

ARCTIC POLYNYA EXPERIMENT - BERING SEA
(R.D. Muench, Sci. App. Int. Corp, Bellevue, WA; C.H. Pease & J.D.Schumacher USPMEL/NOAA, Seattle, WA; M. Reynolds, Coastal Climate)
Physical processes in the ocean, sea ice and atmosphere near St.Lawrence Island, northern Bering Sea, are being investigated and the interaction of a wind-generated polynya with regional oceanic and atmospheric dynamics and thermodynamics observed. Nine ocean moorings, deployed from October 1984 to July 1985, measured current velocity, salinity, water temperature and bottom pressure. Fourteen ARGOS buoys, deployed on sea ice in February 1985, measured ice floe position and air temperature. Four GOES stations, two in ice and two on St. Lawrence Island deployed in February 1985, measured wind velocity, air temperature and, for the two ice stations, relative current velocity, air temperature and air pressure. A few general conclusions can be drawn from the on-going data analyses. The direction of wind, ice drift and currents are quite different from one year to another. The net drift of ice in 1985 was southward toward the ice edge in sharp contrast to 1982, when the ice drifted toward the north through the Bering Strait.

BERING-CHUKCHI SEA ICE AND OCEAN MODELING
(J.E. Overland, A.T. Roach, H.O. Mofjeld and C.H. Pease, USPMEL/NOAA, Seattle, WA)
Physically meaningful models of sea ice drift and currents in the Bering Strait region and along coasts with broad continental shelves are being constructed. Prediction of ice drift near St. Lawrence Island is a complicated function of wind speed,water depth, ice thickness, tidal mixing and currents. Barotropic currents, caused by wind-driven set-up of sea surface slope against the coast, are particularly important. The ice and current momentum equations are jointly solved at each location in a 9-km mesh from about 62° to 70°N latitude. The mean background current through Bering Strait seems best modelled by a sea surface slope down toward the north of 0.5 m over the model domain, consistent with measurements in the area. Numerical experiments are being made to determine ice and current response to the passage of major weather systems. Development of an improved force balance formulation for sea ice floes on a sloping sea surface and development of an ice rheology, appropriate for small-scales and coastal environments, are also in the first stages.

EFFECT OF NUCLEAR WAR "SMOKEFALL" ON SEA ICE
(T.S.Ledley, Space Physics & Astronomy/RICE; S.L. Thompson, NCAR)
A large nuclear war could produce massive quantities of smoke, some of which would fall on Arctic sea ice, lowering its albedo

and potentially increasing the solar energy absorbed by the ice and the snow that covers it. The effect of smokefall on the seasonal variation of sea ice, with a one-dimensional thermodynamic sea ice model, was examined. The sensitivity of the model results to the time of year, duration and latitude of smokefall was tested. Sea ice thickness variations and the period of summer ice-free conditions are sensitive to the season of smokefall. The largest sea ice perturbations are generated by spring smokefall, when the period of ice-free conditions during the summer can increase by 2-3.5 months between 67.5°N and 82.5°N. In any season, the annual cycle of sea ice is not very sensitive to smokefall duration. The equilibrium annual cycle of sea ice variation is restored within a few years of smokefall, when the smoke is flushed out of the ice/snow system.

Since the model used is not a comprehensive global climate model, it is difficult to predict the mid-latitude climate effects of the massive, but temporary, Arctic sea ice changes. Results do suggest that future global climate model simulation of the effects of nuclear war smoke include interactive sea ice calculations.

SEA ICE AS A GEOLOGIC AGENT

(E.Reimnitz, P.W. Barnes, E.W. Kempema, D.M. Rearic and L.R. Phillips, USGS/Menlo Park)
Work continues on the interaction of sea ice with continental shelves and the coast in the Beaufort and Chukchi Seas, on the influence of excess ice in the coastal plain on the continental shelf profile, on the processes of sediment rafting by ice and on the phenomenon of supercooling, underwater ice formation, anchor ice and mechanisms of sediment entrainment by ice. The latter are supported by flume studies in both fresh and salt water with sediment.

PELAGIC CALCAREOUS MICROPLANKTON BENEATH THE ARCTIC SEA ICE

(Y.Herman, Geol/Washington State Univ, Pullman; O.G.N.Anderson/UZM,Copenhagen, Denmark)
Several planktonic foraminifera and one pteropod species, living in Arctic water at water temperatures of -1.77°C and salinites of ~32°/₀₀ beneath perennial sea-ice, were collected under a 2.5-m thick sea-ice platform during the International FRAM 1 Expedition. The presence of subpolar species, as well as polar taxa, indicates either a wider geographic range than hitherto suggested for the former group or their transport from lower latitudes via the West Spitsbergen Current into the Arctic Ocean, whence they are refluxed westward to the East Greenland Current. Further sampling of larger areas is needed before this problem can be resolved.

NALED ICE GROWTH

(R. Ettema and G. Schohl, IHR/IOWA)
Based on theoretical formulation and dimensional analysis, supported by laboratory experiments, a theory and detailed description of naled ice growth are being developed. The experiments are being conducted using a refrigerated laboratory flume. The growth of a two-dimensional or laterally confined (flume) naled has been found to depend primarily on seven, independent, dimensionless parameters. The early, two-dimensional phase of naled ice growth depends on only four of the seven parameters. During this phase of growth, a naled consists of a mixture of ice and water or ice-water slush, forming on a frigid base. The influence of two of the three remaining parameters is not felt until after a transition time has passed, which apparently coincides with the beginning of the process by which the ice-water slush on a naled's surface freezes solid. After a slush layer on a naled begins to freeze solid, a new slush layer forms over its frozen surface. The continuing, cyclic process by which slush layers form and eventually freeze results in the ice laminations that are a feature of naled ice. The seventh governing parameter is a Reynolds number. Because it provides a meaningful length scale for normalization, a key concept to identifying the dimensionless parameters is the concept of equilibrium length. The equilibrium length of a naled is its length of spread that represents a mass balance between the water supplied to the naled's surface and the ice that freezes onto its surface.

SIMPLE-SHEAR-BOX EXPERIMENTS ON THE STRENGTH CHARACTERISTICS OF FLOATING RUBBLE ICE

(R. Ettema and G. Urroz, IHR/IOWA)
The shear strength behavior of continuously deforming rubble ice is being studied using a simple-shear-box, such that vertically unconstrained, floating rubble ice can be deformed in a state of almost pure shear. The shear box is similar to the simple shear-device used in strength testing of soils. Time histories of normal and tangential forces are obtained for each test and used to study the deformation characteristics of the material and effects on shear strength of ice piece size, normal stress, rubble thickness, porosity and shear velocity.

ICE REGROWTH AND BRASH-ICE ACCUMULATION IN NAVIGATION CHANNELS

(R. Ettema and H.P. Huang, IHR/IOWA)
A laboratory study on ice regrowth and brash-ice accumulation in frequently transitted navigation channels is being conducted, involving experiments on the rates of ice regrowth and brash-ice accumulation for a range of parameters, such as air temperature, frequency of vessel transit, water depth and vessel shape. The experiments are guided by a numerical model for predicting rates of ice regrowth.

LAKE ICE-COVER SIMULATION MODEL
(G. Horsch and H.G. Stefan, St. Anthony Falls Hydr. Lab., Univ. Minneapolis, MN)
A lake ice-cover simulation model is being developed. The heat exchange equations, between a water body and the atmosphere at subfreezing temperatures, have been formulated for time-variable conditions. Growth of an ice cover, including a snow blanket, can be simulated. Melting will be investigated in the coming year. The solutions are numerical at time steps of one day.

STUDIES OF PERENNIALLY ICE-COVERED LAKES IN SOUTHERN VICTORIA LAND, ANTARCTICA
(R.A. Wharton, Jr. and C.P. McKay, Life Sci. Div., NASA/AMES; G.M. Simmons,Jr., Biol/VPI)
Research is focussed on understanding the physical, chemical and biological properties of several perennially ice-covered lakes in the relatively ice-free dry valleys of Southern Victoria Land, Antarctica and their interaction(s) with the surrounding glacial and periglacial environments. Using a mathematical model incorporating physical and meteorological data, the thickness of the perennial ice covers have been accurately predicted. It appears that the ablation rate is the critical factor in determining the thickness of ice. Lake Hoare, for example, has an ablation rate of ~30 cm/a, which results in an ice cover of ~5 m.

The perennial ice cover helps concentrate oxygen in the water column below the ice cover. Oxygen is carried into Lake Hoare in glacial meltstreams and is left behind when this water is removed, as ice, by ablation and sublimation. Measured values of the total oxygen in the water column indicate that the time scale of oxygen turnover is 30 years. We predict that the amount of oxygen in the water column does not change significantly throughout the year and that the lake is supersaturated with nitrogen. In the 1985-86 austral summer, an automatic sensing system will be deployed in Lake Hoare to obtain heretofore unavailable year-round oxygen, temperature and light data. Remote meteorological instruments will be placed on the lake surface.

ICE AND SNOW MODELS

ICE AND SNOW IN CLIMATE MODELS
(W.W. Kellogg, NCAR)
Ice and snow are crucial for the current generation of numerical models to simulate the climate system and make the seasonal transition from summer to winter and back again. Climate model research at NCAR is directed by W.M. Washington. Modelling of sea ice in the Arctic and Antarctic is being pursued by B. Semtner, Jr. The NCAR "Community Climate Model" has been used by a number of scientists at NCAR and elsewhere, to study the response of the climate system to changing solar radiation and the onset and retreat of ice ages (J. Kutzback, WISC-M). At present the model does not properly include the dynamics of large ice sheets.

RADIATIVE PROPERTIES OF ICE AND SNOW
(S.G.Warren & T.C.Grenfell, Atmos.Sci./WASH; P.C. Mullen, Geophysics/WASH)
The theory of spectral albedo of lake ice was developed and tested by measurements on Moses Lake. Spectral albedo and optical transmission of snow were studied in March 1985 at Blue Glacier, Mt. Olympus. This location was chosen because of its relative lack of pollution. Equipment was built and tested for a planned experiment at the South Pole to measure spectral albedo and transmission, the effect of sastrugi on the bidirectional reflectance pattern and the spatial range over which pollution from the station affects radiation measurements. The parameterization of spectrally-averaged snow albedo for climate modelling, based on radiative transfer modelling of spectral albedo, is underway (with S. Marshall, COLO). Laboratory measurements of the complex refractive index of CO_2-ice were reviewed for use in remote sensing of Martian polar caps.

PERMAFROST/ROCK GLACIERS/GROUND ICE

SUBSURFACE DIPS BY RADAR PROBING
(R.R. Unterberger, Geophysics/TX A&M)
Several radar experiments were carried out at or near Umiat, Alaska to determine the capability of 250 MHz radar waves to: penetrate permafrost; determine the presence of subsurface reflectors within the permafrost; and determine the depth of permafrost. An assumption of $\varepsilon'/\varepsilon_o = 3.0$ for the relative electric permittivity of the average permafrost formations (ice = 3.2, dry sandstone = 2.55) was made. Radar dips (direction and amount) compared favorably with shallow dips measured in wells drilled in or on the Umiat anticline. In some cases, radar penetration was **greater** than the known depths of permafrost, possibly because of tight rock or oil-filled porous sandstone. Maximum depth of radar penetration into permafrost at Umiat was 617 m. Such airborne radar systems give promise of fast reconnaissance of permafrost country for finding dip direction of subsurface formations, shallow faults or other subsurface structures and for mapping the bottom of permafrost. However, research and testing are required.

PLANETARY PERMAFROST
(D.M. Anderson, Assoc. Provost, Res, TX A&M)
The assembly and analysis of data on the physical properties and physical/chemical processes associated with the formation and degradation of terrestrial permafrost and, by extrapolation, with the landforms and landforming processes on the terrestrial planets and the icy satellites of Jupiter

and Saturn are continuing, as well as the development of scientific strategies and experiments for the orbiting space station and future planetary missions.

Recent photogeologic studies of Mars have indicated that an ice sheet(s) may have once covered part of Utopia Planitia. Impact crater data have been analyzed to establish age relationships for an area near Elysium Mons, which included all of Granicus Valles and the surrounding terrain.

A comprehensive assessment of research on ice segregation and frost heaving was made by a select group of experts and published in 1984 by the National Research Council and National Academy of Sciences. It is being revised and updated to apply to planetary geology investigations.

ROCK GLACIERS

PERIGLACIAL ICE PROCESSES, BLANCA PEAK REGION, COLORADO
(J.D. Vitek, Geography/OSU)
The fabric of a variety of rock glaciers is being analyzed to better understand movement mechanisms. Active stone polygons are monitored for annual rates of movement, using repeat photography. The hydrology of a nearby patterned fen is also under examination.

SNOWDON ROCK GLACIER, SAN JUAN MOUNTAINS, CO
(R. Blair and D. May, Fort Lewis College, Durango, CO 81301)
The movement of Snowdon Rock Glacier, at 3,650 m in a north-facing cirque, is being measured. The 10 stations (large stones marked with small drill holes) have recorded movements of 2->30 cm/a. The meaning of some movements, possibly anomalous, are still being interpreted.

ROCK GLACIERS
(J.R. Giardino, Geology/TX A&M; J.D. Vitek, Geography/OSU; S.W. Johnson, TX A&M)
The movement mechanics of rock glaciers in the Sangre de Cristo Mountains of Colorado are being investigated with dendrogeomorphology to determine periods of movement and with fabric studies, strain-nets and borehole data to develop a rheological model of rock glaciers. Borehole data are being used to study the unfrozen/frozen interface between the thawed portion of the rock glacier and the permanently frozen base.

FROZEN GROUND

INSTRUMENTATION OF SORTED PATTERNS IN PERIGLACIAL SOILS, SPITSBERGEN
(B. Hallet, S. Prestrud, C. Gregory and C. Stubbs, WASH)
Despite a number of hypotheses, little conclusive information is available about the processes that form and maintain sorted circles and other periglacial soil patterns in arctic and alpine areas. This is due in part to the lack of data defining the physical characteristics of active patterned ground. To improve this situation, three independent instrumentation arrays have been installed near Ny-Alesund, Spitsbergen in areas with particularly well-developed stone circles. Temperature, total vertical stress, pore water pressure, moisture content, surface heave and sub-surface motions in the active layer are monitored automatically throughout the year. These measurements are complimented by laboratory experiments, field observations, physical property measurements, detailed geomorphic mapping, examination of cross sections and soil sampling. It appears that sorted patterns reflect systematic motion of the soil, as well as motion of clasts relative to the soil. Freeze-thaw experiments suggest the separation of clasts from fines results from the relative motion of clasts in the direction of heat flow. The primary soil motion is viewed as a form of gravity-driven free convection of the soil that arises from an inferred decrease in bulk density with depth in thawing soils. Preliminary theoretical calculations suggest such convection is active in frost-susceptible soils, but that motions are small and intermittent, being largely restricted to a portion of the thaw season. This working model of relative clast motion and soil convection helps explain the size, regularity, sorting and micro-topography of sorted soil patterns.

PATTERNED GROUND REGULARITY
(S.M. Berta, Geography/University of Oklahoma, Norman, Oklahoma)
A field investigation of stone stripes in the Blanca Peak region of the Sangre de Cristo Mountains, Colorado is being used to test the Rayleigh convection cell model proposed by researchers at COLO. The model predicts the width to depth-of-sorting ratio for polygons and stripes. Topographic details, macro fabric and sedimentary characteristics, as well as width-depth ratios, will be used to explain stone stripe regularity in this area.

BANK EROSION PROCESSES, LAKE SAKAKAWEA, NORTH DAKOTA
(J.R. Reid and B. Sandberg, Geology/NDAK)
A measurement of bank recession causes and rates along the shores of Lake Sakakawea has been underway since 1983, after completion of a test study along Orwell Lake, Minnesota between 1980 and 1983. Although wave erosion is the immediate cause of the up to 20-m high banks, subsequent bank recession is largely the result of thaw failure and joint extension. Present bank recession averages about 2 m/a. Fall precipitation seems to be the most critical annual variable affecting thaw failure at a given site, but the

highest banks experience the greatest amount of such failure because of their larger surface area. The temperature fluctuates around the 0°C isotherm for about 100 days. The bank recession over the planned 500-year lifetime of this, the US Army Corps of Engineers' largest reservoir, will be predicted.

PHYSICS OF FROST DAMAGE TO ROCKS
(J. Walder and B. Hallet, QRC/WASH)
A theoretical model has been developed to examine the physics of crack growth during freezing of water-saturated rock. Theory predicts the influence of various environmental variables (temperature, temperature gradient, pore-water pressure) and material properties (grain size and shape, permeability) on the rate of crack growth and guides an experimental program aimed at testing these predictions. Experimental methods include measurements of strain, temperature, pore-water uptake or expulsion and detection/location of acoustic emissions generated by crack growth. Careful control of thermal and hydraulic boundary conditions is essential and clearly distinguishes this study from early experimental work on frost cracking.

ATMOSPHERIC ICE

RIME ICE
(J. Hallett and Dong, Ya Yi, DRI/NEV)
Accretion and freezing of supercooled droplets (mean size 10-20 μm) are being studied under controlled conditions of temperature (to -15°C) and air velocity (to 3 m/s). At high temperature and air speeds, the ice forms as "fingers", growing into the air stream with a size much larger than the droplets. At lower air speed and temperature, drops freeze as individuals in a random accretion pattern. The criteria for secondary ice crystal production, during accretional growth of graupel in the atmosphere, is being examined.

THUNDERSTORM AND AIRCRAFT CHARGING BY ICE COLLISIONS
(B. Gardiner, J. Hallett, D. Lamb, R. Pitter, DRI/NEV)
Mechanisms for thunderstorm electrification and aircraft charging are being analyzed, using aircraft data gathered during the CCOPE project (summer 1981); including vertical electric field, particle charge, ice particle type and concentration, cloud liquid water content, temperature and vertical velocity. Analysis indicates a strong correlation between the development of ice precipitation in clouds and the electric field. Laboratory measurements, that show charging is due to collisions between graupel particles and vapor-grown crystals, are being related to field observations through the use of an ID microphysical computer model.

ATMOSPHERIC ICE CRYSTALS

SCHEINER'S HALO
(A. Weinheimer and C. Knight, NCAR)
An analysis of this very rare halo at 28° from the sun or the moon suggests it is probably caused by exceptional concentrations of ice polycrystals - not, as was recently suggested, by the presence of cubic ice in the atmosphere. The most common relative orientation in natural polycrystals is 70° between **c**-axes. This would produce a halo at 28°, obviating the need to postulate the existence of cubic ice at atmospheric temperature and pressure, where it has never otherwise been observed.

ICE PHYSICS – BIOLOGY

ANTIFREEZE PROTEIN STUDIES
(C. Knight, NCAR; J. Duman, Univ. of Notre Dame; A.L. DeVries, Univ. Illinois)
Laboratory investigations are continuing into the action of protein antifreezes in insects and fish. The insect antifreeze protein appears to influence the freezing of water differently from that of fish: the growth habit modification is different and the crystallization is more complex and irregular. The insect antifreeze also strongly inhibits recrystallization of ice. This action may be its biological role in insects that are freeze tolerant.

ICE ENGINEERING

VESSEL ICING
(J.E. Overland and C.H. Pease, USPMEL/NOAA; A.L. Comiskey, NORTEC)
An important meteorological variable for operations in high latitudes is the rate of accumulation of ice on vessels and structures. A set of 85 icing observations were collected in Alaskan waters from intermediate-size vessels (20-75 m) during 1979-84, verified by interviews with vessel operators and compared with National Weather Services analyses. Of the set, 58 were open-ocean observations where the vessel was not heading down-wind; 25% of the reduced set had icing rates in excess of 2.0 cm/h. An algorithm has been developed for relating vessel potential icing rate to a simplified predictor which considers wind speed, fetch, air and sea temperatures. The new algorithm predicts icing rates greater than four times those of most previous icing nomograms.

Andrew Fountain

In 1984, glaciological studies were conducted in the Caucasus, Central Asia, the Khibiny Mountains, Siberia, the Far East, Kamchatka, the Arctic and in Antarctica.

CAUCASUS

The **Institute of Geography, USSR Academy of Sciences** repeated terrestrial photogrammetric surveys of the Buba Glacier. In 1971-1984 the glacier retreated 130-140 m and its flow rate was 10-11 m/a. Up to an altitude of 3200 m, the glacier margin shrank by 30-40 m and the thickness of its tongue also decreased considerably.

Present-day and former rock glaciers were studied in the Urukh River basin on the northern slope of the Caucasus and in the Nenska River basin on the southern slope. Six periods of development during the Holocene could be distinguished in the step-like rock glaciers.

The **Transcaucasian Hydrometeorological Institute** and the **Transcaucasian Hydrometeorological Service** conducted observations on the Tikhitsar and Murkar glaciers. Their retreat was measured and the longitudinal profile of the whole Murkar Glacier was surveyed. Terrestrial photogrammetric surveys were made on the Gergeti and Devdoraki glaciers. Ablation, velocity and surface level were measured on all the glaciers. Activation and degradation zones were revealed in the regime of the Murkar surging glacier. A new ice mass was found in the activation zone: its length is 750 m and its thickness exceeds by 80 m the underlying part of the surging glacier. The glacier-melt contribution to river discharge during the ablation period was revealed. During snow-poor winters, the discharge of glacier-fed rivers throughout the ablation season exceeded by 30-40% their discharge in snow-rich winters.

The **North Caucasus Hydrometeorological Service** continued investigations of the annual fluctuations of 24 glaciers on the northern slope of the Greater Caucasus. Glaciers of the Central and Western Caucasus were observed by helicopter. Fifteen terrestrial and 21 aerial snow courses were surveyed. Avalanching was recorded along the same routes. As in recent years, the majority of glaciers retreated (19 of 24) at a rate of 1.6-16.6 m/a; the Marukh Glacier was stable, while four glaciers advanced at rates ranging from 0.6-17.8 m/a. The percentage of advancing glaciers in 1984 (23%) was a bit greater than in 1983 (21%), but less than in 1982 (26%).

Reduction of IHD data from the Marukh Glacier has been completed. Four daily runoff regimes were distinguished in the warm period. Abrupt variations of water discharge (up to 40-50%), with a duration of from 10-15 to 50-60 minutes, are observed in summer. Snout fluctuations were analysed for 1800-1980 and in detail for 1964-1980. Over the last two centuries, the glacier was stationary five times and even advanced creating terminal moraines, but its length shrank by 1927 m - an average of 6.8 m/a. Since 1964, a stable retreat of the glacier has been observed averaging 10.5 m/a. The seasonal nature of the retreats has been recorded.

The **Alpine Geophysical Institute** developed methods of actively impacting the snow cover to release avalanches. A 4-5 kg avalanche gun has been developed for artificial release. A prototype aerial system for the automatic acquisition of snow-avalanche information (LAVINA) was developed. The **Alpine Institute** continues to work on methods of predicting avalanches, and glacier- and heavy rain-induced mudflows.

Moscow University's Avalanche and Mudslide Laboratory continued its study of mountain glaciers' response to climate change in the Elbrus area. Long-term predictions of variations of the Dzhankuat Glacier and of the activity of glacial mudslides occurring on this glacier, were generalized. The **Laboratory** developed a statistical model for predicting climatic change in the Central Caucasus and made qualitative predictions of periods of maximum avalanche activity to the year 2050.

Field tests on the brittle fracture of snow, relating physical-mechanical properties to snow structure and temperature, were carried out. Operational forecasting procedures for slab avalanches and large, new- and drifting-snow avalanches were improved. Microwave remote sensing techniques for the determination of snow humidity and structure were tested, and preliminary correlations between these parameters and the radio brightness temperature of snow were found. The dynamics of time changes in the radio brightness temperature of snow were determined. The efficiency of avalanche prevention structures was tested under different avalanche formation conditions along the Transcaucasian Highway.

Moscow University's Laboratory of Aerospace Methods began repeated phototheodolite surveys of glaciers in the Elbrus area, to reveal their dynamics for the last 25 years. Images were made of glaciers situated on the northern slope. Kyukurtlyu Glacier is advancing down the valley and its advance is accompanied by a surface rise, an increase of ice velocity in the lower part of the tongue and a decrease in the upper part.

CENTRAL ASIA

The **Central Asia Hydrometeorological Institute** continued glaciological and

hydrometeorological observations on Abramov Glacier. Methods of calculating temporal changes in the main properties of the mountain snow cover were improved and a series of regime maps of snow cover in Central Asia were constructed. Guidelines for compiling maps of avalanche hazard, predicting wet avalanches and for the long-term prediction of glacier runoff (3-5 months ahead) were prepared.

The **Institute of Geography, Academy of Sciences of the Kazakh SSR** continued comprehensive studies on the glaciers of Zailisky and Dzhungarsky Alatau, with detailed investigations in the Malaya Almatinka River basin. Techniques for computing, predicting and reconstructing glacier regime and distribution from available information were improved as well as methods for determining the thickness of ice and icings, snow storage, till and loose sedimentary deposits in mountain-glacier basins. The structure, composition and dynamics of till were studied and the mean annual velocity of moving debris evaluated. Mudflow-formation agents were predicted and the most dangerous sites of glacial mudflows identified.

The variation of some glaciers in Zailysky Alatau was determined and the impending surge of the right branch of Shokalsky Glacier noted. The snouts of the Tuyuksu, Molodezhniy, Shokalsky and Talgar Yuzhniy were mapped. The latter glacier has advanced regularly for the last 15 years, the rest continue to retreat. Winter and annual mass balances on glaciers of the Tuyuksu River basin were mapped for the 1982/83 balance year; that of the Tuyuksu Glacier appeared negative again.

A mean estimate of avalanche danger was made for the Altai and Saur-Tarbagatai. The nature of the avalanche hazard in different areas of Central Asia and Kazakhstan has been investigated by computing avalanche activity indices from ground observations.

The **Tien Shan Physico-Geographical Station** determined the volume of glacier runoff in some rivers of the Northern Tien Shan and its seasonal characteristics. The variability of glacier melting has been established. Investigations continued on the Karabatkak Glacier; in 1984 its mass balance was negative and the tongue was retreating. Despite the reduction in ice volumes, the summer value of river runoff exceeds the mean perennial value. This is due to a 200-300 m rise in the snow line and inclusion of large accumulation areas into the zone of active melting. Results of accumulation, ablation and mass balance measurements of the Karabatkak Glacier were generalized for 1975-1980. Over this period, mass balance was negative and its retreat was stabilizing. Geodetic, geophysical and glaciological studies were made on Zapadniy Suek Glacier, Central Tien Shan. The first map of subglacial topography of this glacier was compiled. High rates of ice wasting were revealed in this region.

The **Geological and Geophysical Institute, the Uzbek Academy of Sciences** determined the age and genesis of rocks in all the mountain-glacier basins of the Pamirs and Western Tien Shan. The age of rocks influences the hypsometric position of glaciers. The impact of geothermal heat, particularly in the East Pamirs, is negligible over short time periods. Numerical indices of the dynamics and evacuation of solid and dissolved mineral substances from the glacierized zone were obtained. The extent of the present-day shrinkage of glaciers was determined and the external features of the glacial mudflow hazard were revealed.

The **Kazakh Hydrometeorological Service** continued developing methods for predicting different types of avalanches in the mountains of Kazakhstan. The snow cover data from the alpine snow surveys of Kazakhstan have been published. The **Service** compiled an Avalanche Inventory of Kazakhstan for 1975-1980, completed assemblage of materials for the 1981-1985 inventory and continued to map and inventory avalanche sites in Talasski Alatau and Tarbagatai.

The **University of Kharkov** refined and improved dendrochronological methods. Together with the **Institute of Geography, Academy of Sciences of the Kazakh SSR**, 10 junipers were studied to reconstruct meteorological conditions on the northern slope of the Dzhungarsky Alatau. Based on this total degree days and winter precipitation were computed for 1955-1980.

The **National Research Centre "Prioroda"**, together with the **Institute of Geography, USSR Academy of Sciences**, completed a map of surging glaciers in the Central Pamirs, showing glacier variations for the last 15 years.

The **Institute of Permafrost, Siberian Branch of the USSR Academy of Sciences** studied underground ice and ice-containing permafrost in the Pamirs. Thermal erosion of the banks of Karakul Lake gave retreat rates for 1977-1984 of 22 m/a. Ice masses are buried not only under fluvioglacial and alluvial sediments, but also under slope and mudslide sediments. The structure of buried glacier ice, its age ranging from several decades to 1.5 to two thousand years, was studied.

The **Tadzhik Hydrometeorological Service** studied 18 glaciers, observing variations in their lower limit, and their surface and measuring annual rates of ice flow. Byrs and Muzdazi surging glaciers, which became more active recently, have also been studied.

The **Institute of Geography, USSR Academy of Sciences** made a deterministic prediction of the behaviour of the surging Medvezhiy glacier in the Pamirs. Given a critical mass in the accumulation area of the glacier it is possible to forecast its next surge. Expert examination of the glacier state in October 1984 confirmed the computations.

KHIBINY

The **Mine Institute of the Kola Branch of the USSR Academy of Sciences** investigated the physical-mechanical properties of fluvioglacial and Quaternary morainic deposits in connection with constructing overburdens of apatite deposits for securing dumps and protecting the environment.

The **"Apatit" Industrial Association** studied the spatial and statistical nature of the snow cover and the physical-mechanical properties of snow in avalanche catchments. Accuracy evaluations of the main parameters, characterizing snow stability on slopes, were made. The statistics on snow discharge during snow drifting were investigated.

Moscow University's Avalanche and Mudslide Laboratory continued to collect data on the history of avalanche activity in Khibiny over the last millenium. The general pattern of climatic fluctuations and avalanche activity was plotted based on the expected "technogenic" changes in the environment.

SIBERIA

The **University of Tomsk, Altai** carried out snow surveys during the period of maximum snow storage in the Aktru and Verkhnaya Katuni River basins, confirming the major influence of two parameters on the distribution of snow cover in Altai: the distance of the observation point from the crests and the absolute altitude.

Aerial photography revealed an 8-70 m retreat of the main glaciers of Belukha Massif from 1980 to 1984. Ground observations in the Severo-Chuiski Range showed that in the 1983/84 balance year, the glaciers shrank by 4-11 , and the ice velocity decreased. However, snow accumulation that year was excessive. On all the glaciers of Aktru basin, it exceeded the indices of the previous balance year by 70-200 kg m^{-2}. All glaciers of the Bish-Irdu Mountain group had a positive mass balance for 1983/84. Six glaciers were radio-echo sounded; maximum depths were 70-160 m.

The **University of Altai, Barnaul** continued studies of snow and ice masses in the Altai-Sayan mountain area. Terrestrial photogrammetric surveys were made on some glaciers. Fifty-two new glaciers with a total area of 2.3 km^2 were recorded in the Western Sayan Mountains and 22 glaciers with an area of about 1.6 km^2 in the western part of the Terektinsky Range.

The **Novosibirsk Institute of Railway Transport** continued field experiments on drifting and snow accumulation, showed the nature of interactions between snow and avalanche structures and studied snow characteristics on slopes along the route of the Baikal-Amur and Krasnoyarskaya railways. The nature of events, in particular avalanche catchments, was substantiated and recommendations for the construction of avalanche sheds were developed. Experiments were made in an avalanche path and in a wind tunnel: for modelling interactions between the snow mass and braking structures; for modelling air flow around a mountain; and for modelling snow storages using small simulations. Field snow and wind surveys were made along some railways of Sakhalin and Surgut-Urengoi Railway. Guidelines for snow protection along the railways of the USSR were prepared.

The **Institute of Permafrost, Siberian Branch of the USSR Academy of Sciences** carried out investigations in Central and Western Yakutiya. Much higher ice content than previously supposed was found in the alluvium which is widespread over the Siberian Platform. A new type of ice mass, a platform created by Holocene polygonal wedge-ice, was identified. Studies on underground ice were continued in the lower reaches of the Yenisei. The structure of ice masses in a large deposit "Ledyanaya Gora" was studied. The ice was compared to that of the buried glaciers in Tien Shan and the Pamir. A map of underground ice covering the northern areas of Yenisei was compiled. The cause of the icing formation near the Vilyui Power Station was identified.

The **Institute of Siberian and Far Eastern Geography, Siberian Branch of the USSR Academy of Sciences** developed basic methods for calculating and predicting aufeis on rivers: an observation programme for aufeis water passages and special icing polygons was proposed. Methods for the aerial evaluation of aufeis hazards were developed. Computation techniques for determining the morphometric characteristics of icings and river ice were improved, together with new methods of predicting the probability of occurrence of icings in this region at two to three months' notice.

The **Institute** summarized data from long-term studies of glacial and permafrost-geological processes and phenomena in the zone of active icing formation. The general nature and characteristics of the development of vein ice, injected ice, ground heaving, thermal erosion, frost heaving, vegetation and soils were revealed. Trafficability guidelines for aufeis-covered parts of river valleys were prepared.

A theory for the creation of loose-structured ice was developed. Thermodynamic conditions and freezing nuclei in the artificial rain spray cone were studied in the open air. The relationships of ice formation to the temperature and humidity of the near-to-ground air layer, wind speed, solar radiation, salinity of frozen liquid and parameters of spraying instruments were determined. Supercooling water drops at temperatures from 0 to -30°C has a great effect on the rate of their crystallization.

The role of the ice cover in the winter runoff formation of rivers in the Baikal region was estimated. The volume of water

accumulated in icings and river ice, averages 9.2 mm over the region.

Moscow University's Laboratory on Investigations of the North worked out criteria and methods for evaluating the thermo-erosive and thermal slump stability of permafrost in some northern regions of Western Siberia. An idea of the temporal and spatial structure of underground glaciation as an integral natural system of the lower zone of ice formation in the cryosphere was developed.

Research Institute of Constructive Engineering proposed new methods for the statistical and cartographic analysis of inventories, revealing regional relationships between the icing formation and geological-tectonic, geomorphological, hydrogeological and cryological conditions of the Verkhoyano-Kolymskaya region.

Laboratory analyses on artificial ice of different salinities have been performed. Its physical, chemical and mechanical properties were examined. Experiments using sea water and kerosene thermal piles were conducted near Amdera. The construction of long-lasting marine structures using the volumetric freezing method was proved feasible. Wedge ice and other types of underground ice were studied in the area of the Kolyma River.

The **State Hydrological Research Institute** revealed the characteristics of ice jams in controlled sections of rivers and showed the impact of power stations on ice processes. Possible changes in the properties of ice and the thermal regime of northern and Siberian rivers caused by runoff diversion were evaluated. Guidelines for terrestrial and aerial surveys of icings for designing and operating ice roads were prepared.

Moscow University's Avalanche and Mudslide Laboratory identified avalanche-formation characteristics on satellite images and the local properties of avalanche sites on photo-heodolite images. Avalanche formation conditions were evaluated for the mountains of East Siberia. Maps of the relief types and limits of seasonal snow were prepared for some mountain areas of East Siberia, using satellite images. Criteria for determining the reliability and efficiency of avalanche structures were analyzed.

KAMCHATKA

The **Institute of Volcanology, Far East Branch of the USSR Academy of Sciences** investigated avalanche hazards on Ratmanov Island (Demidov Island, Bering Strait). Conditions of glacier occurrence associated with intense fumarole activity were studied in the caldera glaciers of Mutnovskiy Volcano. The mass balance for 1983/84 was positive on both the glaciers. The calculations considered internal nourishment and ablation, due to the thermal influence of the Mutnovskiy Volcano.

Interactions between volcanos and glaciers during a summit crater eruption were studied on the Klyuchevskoy Volcano. The rate of ice accumulation at 3500 m a.s.l. was found to be 30 cm/a. On the glaciers of Lyuchevskaya Group of volcanos, the 1984 firn line was at the highest position for the last ten years (2700-2900 m) and the glacier mass balance was negative.

In the fumarole cauldron and southern crater on the summit of Dalniy Ploskiy Volcano, the **Institute** studied the upper parts of the Bilchenok Glacier accumulation area. Ice velocity decreased at the snout of the Bilchenok Glacier.

In the middle of September, flights were made over the glaciers of eastern Kamchatka. The firn line altitude on the glaciers of Kronotskiy Peninsula was 600-700 m; on the volcano glaciers of Kronotskiy natural reserve it was 1600-1700 m; and in the Avachinskaya Group of volcanos, it was 1200-1400 m. Glacier mass balance was positive on these glaciers and the accumulation area made up 60-70% of their total area. Data were collected on mass balance and changes of the Kozelskiy Glacier front for 1973-1980, caldera glaciers of the Mutnovskiy Volcano in 1979/80 and on Grechishkin Glacier in 1978/79.

The **University of Kazen'** together with the **Institute of Volcanology** has developed a model of interactions between eruption products and glaciers causing phreatic explosions. Three stages of the explosion are distinguished and attempts are made to evaluate the duration of each stage with the discharge rate of water-vapour mixture through the break in eruption products.

ARCTIC

The **Institute of Geography, USSR Academy of Sciences** did aerial radio-echo sounding of Spitsbergen glaciers, including Eastfonna, where it is planned to drill a deep core hole in 1985. New equipment for low-frequency radio-echo sounding was successfully tested on a temperate glacier. The relationship between the nature of radio-echo returns (620 MHz) from the surface, the glacier bed and from internal reflections to the state and structure of the near-surface stratigraphy was confirmed. It testifies to the possibility of remote evaluation and mapping of ice-formation zones on Spitsbergen glaciers.

Long-term balance observations were continued on the representative Vöring, Boger and Bertil' glaciers. A method of distinguishing annual layers directly while drilling was worked out. For the first time, the rate of core processing taken from the borehole matched the rate of core drilling.

The **Arctic and Antarctic Institute** analyzed the results of investigations on the Vavilov Ice Dome, Severnaya Zemlya. Snow

survey data were analysed and the core from seven boreholes (from 146 to 556 m deep) was studied. Genetic types of ice and structural zones were distinguished in the vertical section of the glacier. Conditions of melting and types of ice formation related to them were determined. The relationship between precipitation and total positive temperatures was established. Periods of cooling took place 3500-1400 yrs BP and warming 1400-1100 yrs B.P. Over the last 8000 years, the temperature rose by 3°C causing the shrinkage of accumulation areas and growth of ablation areas. The ice dome shrank most actively during the last 1500 years.

Leningrad University determined the main characteristics of interactions between the glacier and the near-glacier layer of the atmosphere, based on studies of the Vavilov Dome. The glacier cooling effect was evaluated and the thickness of the boundary layer of the atmosphere was estimated to be 1400-1600 m; the latter value determined by the lower limit of altitudinal inversion, while the structure of the boundary layer is mainly related to the process of advection.

The **Geological Institute, Estonian Academy of Sciences** studied glacio-climatic conditions of the Holocene and Pleistocene by showing correlations between the distribution of isotopes, chemical elements and the natural conditions causing their variations. Variations of the oxygen isotope composition in permafrost were analysed. Primary isotope information on the temperatures of underground ice formation is preserved in some types of permafrost. In co-operation with the **Institute of Geography, USSR Academy of Sciences**, climatic fluctuations during the Holocene were reconstructed for the European part of the Arctic.

The **Institute of Mechanics, Moscow State University**, building on a previous model, numerically modelled the Greenland Ice Sheet to reveal new aspects of its dynamics. The nature of two-layered Spitsbergen glaciers, with a basal layer of melt ice, has been explained. Using a mathematical model, the role of debris in the summer discharge from glaciers has been studied.

ANTARCTICA

The **Arctic and Antarctic Institute** determined the ice sheet velocity at four polygons by repeatedly recording radar signals from the bed. The velocity was 0.4-0.8 m/a, with an error of +0.2 m/a. Radio-echo sounding detected accumulations of water at the bed under ice 3800 m thick. The temperature in the borehole below 15 m was -57.7°C. A traverse was made from Mirniy to Pionerskaya Station. The height and position of 18 points were determined, using a ground-satellite system of the "Geoceiver" type. Snow samples were selected for chemical and isotope analysis.

In the 2083-m deep Vostok borehole, temperature, inclination and diameter were repeatedly measured. At 25 m depth the temperature was -56°C; at 2083 m it was -35.2°C.

Glaciological and engineering studies to modify snow cover for the construction of airfields for heavy planes were continued at Molodezhnaya Station and initiated at Vostok Station. The morphology of a submarine part of an ice coast was studied near Molodezhnaya Station, the melting rate of part of it was measured and experiments were made on the artifical freezing of ice moorings.

Ice structures in the Vostok borehole were measured down to a depth of 1400 m. The studies indicate that the dimensions of crystals, air inclusions, and the values of their specific surface and relative volume bear genetic features that can be used for paleoclimatic interpretations.

Results of ice regime investigations of the Southern Ocean for 1956-1982 have been summarized. The seasonal variability of sea ice properties and the nature of their formation and structure were examined. Maps of ice distribution over the Southern Ocean were compiled and the preparation of maps for a new Atlas of Antarctica was initiated.

The **Institute of Geography, USSR Academy of Sciences** studied present-day and former glaciation of the Prince Charles Mts. region, including the geomorphological and periglacial characteristics of the ice-free areas. Former moraines indicated major Antarctic glaciations in the Upper Pleistocene.

An important phase of glaciological investigations has been accomplished in East Antarctica. An abrupt decrease in accumulation rate when moving from Pionerskaya Station to Dome C, and the greatest time and spatial variability of accumulation in the transition area from the ice slope to the high Antarctic Plateau were found. Nearly a 30% excess of ice input over ice discharge was established in a large ice catchment basin of East Antarctica for 1977-1982. The main periglacial features of Schiermakher Oasis were revealed, suggesting the presence of a permafrost layer up to 150 m thick and temperatures below -8°C.

Maps of ice melting in sea water, including melting, freezing and permafrost under the Antarctic Ice Sheet have been prepared. The former map shows the probable northward routes of iceberg transport, the latter summarises the results of a 20-year long thermal regime investigation of the Antarctic Ice Sheet, depicting the areas of subglacial melting, freezing and melting under the ice shelves and the thickness of permafrost.

The **University of Kazan'** together with the **Arctic and Antarctic Institute** and **Leningrad University** developed a paleoclimatic model based on temperature data from the Vostok borehole. The model confirms the existence

of ice melting at the bed at a rate accounting for up to 10% of the accumulation rate on the glacier surface. For the last 30-50 thousand years, this evidently remained at a level of 2.2-2.4 cm of ice/a.

The main scientific results realized in 1984, but not reflected in the regional breakdown, include the following:

1. Completion of all the authors' original maps (about 1000) for the World Atlas of Snow and Ice Resources. They depict climatic conditions, snow cover and avalanching all over the world, show the areas and volumes of glaciers, volumes and specific values of snowmelt and glacier runoff, maximum snow storages, icings etc. The Atlas is an outstanding work, summarizing a vast amount of information on snow and ice collected all over the world for the last 20-25 years. It contains global evaluations of snow and ice storage, properties of their regime, variability and their utilization. A multi-stage glaciological zonation of the world permits a better understanding of the characteristics of the Earth's snow and ice resources.
2. The general structure of glaciological predictions was developed and their phases were determined. Methods of glaciological predictions are subdivided into two types: probabilistic and deterministic.
3. An hypothesis on the leading role of the natural processes of the highly active zones of the Ocean in the occurrence and development of Pleistocene ice sheets has been advanced. The idea of active interactions between glaciers and the ocean, now and in the past, was further developed and refined.
4. The predominant role of glacier transport in the formation of thick lateral and frontal moraines under conditions of maritime and continental climate was confirmed. A realistic pattern for the main characteristics in the formation of loose marine sediments under conditions of a Spitsbergen, Tien Shan and Caucasus glaciation was developed.
5. The theory of ice formation in the spray cone method of artificial rain was completed. Geographical limits on the efficiency of this method and areas of its application for the national economy were determined.

V.M. Kotlyakov and O.M. Shlyakova

ABBREVIATIONS USED IN REPORTS ON RECENT WORK *

ARIZ - Univ. of Arizona, Tucson, AZ 85721
CALIF - University of California
CALTECH - California Institute of Technology, Pasadena, CA 91125
CIP - Cryospheric Interactions Project, USGS/Tacoma, WA
CIRES - Cooperative Institute for Research in Environmental Sciences, COLO
COLO - Univ. of Colorado, Boulder, CO 80309
CSU - Colorado State University, Fort Collins, CO 80523
DRI - Desert Research Institute
FS - Forest Service
GIG - Geophysical Inst., Dept. of Glaciology, UCPH, Haraldsgade 6, Copenhagen
GLEZ - Geologisches Institut der ETH, Zürich, Switzerland
IHR - Institute of Hydraulic Research
IOWA - Univ.of Iowa,Iowa City, Iowa,IA 52242
MGS - Minnesota Geological Survey, MINN
MINN - Univ.of Minnesota, St. Paul, MN 55455
NCAR - National Center for Atmospheric Research, Boulder, CO 80307
NDAK - University of North Dakota, Grand Forks, ND 58202
NEV - University of Nevada, Reno, NV 89557
NOAA - Nat. Oceanic and Atmospheric Admin.
NWS - National Weather Service, NOAA,
OLAF - St. Olaf Coll., Northfield, MN 55057
OSU - Oklahoma State University, Stillwater, OK 74078
PICO - Polar Ice Coring Office, University of Nebraska, Lincoln, NB
PSF&RES - Pacific Southwest Forest and Range Experimental Sta., FS/USDA, Berkeley, CA
QRC - Quaternary Research Center, WASH
RICE - Rice University, Houston, TX 77251
RMF&RES - Rocky Mountain Forest and Range Experiment Station, FS/USDA, Laramie, WY
TX A&M - Texas A & M University, College Station, TX 77843
USC - University of Southern California, Los Angeles, CA 90089
USDA - U.S. Department of Agriculture
UTAH - Univ.of Utah, Salt Lake City,UT 84112
VPI - Virginia Polytechnic Institute and State University, Blacksburg, VA 24061
WISC-M - Univ.of Wisconsin,Madison, WI 53706

* see also **ICE**, Nos. 72 & 73, 1983, p.36

DEPARTMENT OF GLACIOLOGY

V.A. BUGAEV CENTRAL ASIAN REGIONAL RESEARCH INSTITUTE (SANII)

USSR STATE COMMITTEE ON HYDROMETEOROLOGY AND CONTROL OF NATURAL ENVIRONMENT

The Department of Glaciology, as an independent scientific subdivision, was established at the V.A. Bugaev Central Asian Regional Research Institute (SANII) in 1971. It brought together scientists from the Institute's Glaciological Expedition (organized in 1964) and Department of Hydrology who studied glacial phenomena, as well as specialists from the Snow and Avalanche Group of the Uzbek Hydrometeorological Service. At present it consists of two scientific laboratories (Snow Avalanche Laboratory and Laboratory of Glaciers and Snow Cover), the Glaciological Expedition, a specialized snow avalanche expedition and two contract groups, carrying out investigations financed by various institutions. This combination of scientists and operational workers provides the necessary scientific expertise and support for high-mountain investigations.

The content and direction of the Department's activities are determined by the various economic needs of the mountainous areas of Central Asia and other regions of the country; they are of an applied nature.

SANNI has the lead role in glaciology; it coordinates and conducts scientific investigations, providing methodological guidance on snow avalanche events, snow cover in the mountains and on glaciers. These studies form part of the overall programme of the USSR Committee on Hydrometeorology and Control of Natural Environment.

The main work of the Department on the snow cover includes: developing methods for estimating mountain snow resources; determining the nature of snow cover distribution; using snow information for hydrological forecasts; and other national economic applications.

Snow avalanche studies include research into avalanche behaviour, prediction and protection methods, compilation of multipurpose maps of avalanche hazard areas, and the design of instruments for remote collection of snow avalanche information.

The main purpose of research on glaciers is to study their regime and evolution, their water and ice balance, develop forecast methods for glacier runoff and identify potentially dangerous surging glaciers.

Great attention is paid to developing standards, handbooks, manuals and guides with recommendations for conducting different types of glaciological observations.

The Department did not begin from scratch. Investigations of the high-mountain areas of Central Asia began 100 years ago. At the turn of the century they were of episodic character, by enthusiasts and small expeditions trying to obtain general information on the environment and glaciation. This was a period of discovery, because knowledge about the region was so limited.

The intellectual centre of the Orient was Tashkent, where numerous research institutes later appeared.

Following creation of the Soviet Union, the range and character of glaciological investigations in this region changed greatly. A new level of investigation followed the 1921 establishment of the Turkestan (later Central Asian) Meteorological Research Institute (CAMRI) in Tashkent. CAMRI began regular observations of the glaciers, snow cover and precipitation in mountains, to develop methods for forecasting river runoff.

Significant contributions to the knowledge of glaciation in Central Asia were made by E.M. Oldekop, L.K.Davidov and, particularly, N.L. Korjenevsky, who compiled the first glacier inventory of the Pamir and Tien Shan, published in 1930. The Bureau of High-Mountain Research, formed within CAMRI in 1934, played an important part in the development of glaciological studies. It participated in the construction of a number of high-mountain meteorological stations, including ones in the Tien Shan and Pamir.

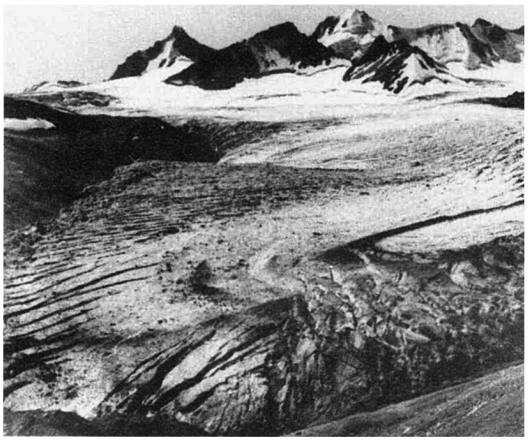
The large Tadjik Pamir expedition (1928-

1934) was a very important event as were the investigations made for the II International Polar Year. Large-scale studies of glacierized areas in the Pamiro-Alai mountain system were conducted then, which provided valuable data on meteorology, hydrology and the geomorphology of mountain glaciation.

One of the highlights of the early years was the 1928-1932 study of the largest glaciological unit in the Pamir - the Fedchenko Glacier system. Outstanding Soviet scientists such as O.Yu. Schmidt, D.I. Shcherbakov, D.V. Nalivkin, N.P. Gorbunov, D.I. Mushketov, S.B. Kolesnik, K.K. Markov and others participated in this expedition. The research was repeated by scientists from Uzbekistan, Moscow and Leningrad 25 years later during the International Geophysical Year (1957-1959). This marked a qualitatively new stage in glaciological investigations, now aimed at a comprehensive study of the present glaciological regime. Results were published in the two-volume monograph "The Fedchenko Glacier" in 1962 and in many scientific papers. V.A. Bugaev, M.A. Petrosiantz, V.I. Gubin, N.L. Korjenevsky, V.L. Schultz, O.A. Drozdov, V.F. Suslov, V.K. Nozdrukhin and I.G. Dorofeev took an active part in these later investigations. A group of geodesists from East Germany, under G. Ditrich, also worked at the glacier.

Scientists from the SANII Department of Glaciology, having Arctic and Antarctic experience, participated in many of these glaciological investigations and became the successors of those early researchers.

Another very important scientific event in the development of glaciological investigations was the International Hydrological Decade (IHD), from 1964-1975.



The Abramov Glacier

The Abramov Glacier basin was chosen as one of seven representative glacier basins in the USSR. It is situated on the southern slope of the Alai Range, 3600-4600 m a.s.l., at the head of the Koksu River. The SANII Glaciological Expedition organized the programme, built the station and has carried out year-round observations there since 1967.

Abramov Glacier station (SANII)

The detailed studies of the Abramov Glacier regime, its water and ice balance, have permitted an assessment of the development of glaciation in the vast Pamiro-Alai mountain system, solving many problems about the relationships between glaciation and climate.

Radiation measurement at the glacier surface

A considerable part of the programme at the high-mountain station is concerned with observations of the state of background pollution of the environment and its dynamics, in response to anthropogenic factors.

Logistic support by helicopter

Many other research institutes collaborated with SANII in the investigations carried out at the Abramov Glacier: Institute of Applied Geophysics, Arctic and Antarctic Research Institute, Institute of Geography of the USSR Academy of Sciences, Institute of Geology and Geophysics of the Uzbek Academy of Sciences, Leningrad State University, etc. Scientists from Bulgaria, Czechoslovakia, USA, Canada, Sweden and Japan have also visited this glacier.

The main results of the expedition's investigations were published in the monograph "The Abramov Glacier", in 1980.

The more important results obtained by the Glaciological Department in its investigation of mountain glaciation are as follows:
- development of methods for long-term prediction of glacial runoff, based on a split calculation of ice and snow components;
- development of a method for calculating variations in glaciological parameters and glacier runoff for a given change in climate;
- development of mapping techniques and compilation of maps of ice resources for inclusion in the World Atlas of Snow and Ice Resources;
- estimation of the development of glacierization throughout the USSR, using glacier mass balance data.

In recent years, the Department of Glaciology has considerably extended the geographical extent of its research. A major investigation is underway in the poorly-studied mountain regions of Siberia and the Far East. These are mainly snow avalanche surveys, in the areas scheduled for new development according to the economic plans of the country. Snow avalanche surveys along the Baikal-Amur main railway line are an important part of this work.

Avalanche surveys in Central Asia began in 1949, along the mountain highway routes. Since then, a network of snow avalanche stations has been established. From the late 1960s, the Hydrometeorological Service became responsible for providing national economic organizations with basic, regular long-range avalanche forecasts.

A number of regional methods for predicting avalanche hazards have been developed by specialists in the Department, using multifactor statistical models. Other studies involve mapping avalanche-prone sites; automating the system for collecting, transmitting and processing snow avalanche information; and compiling a complete Inventory of Avalanches of the USSR.

Remote sensing of snow, using a helicopter-borne gamma survey system and the development of methods for calculating snow cover characteristics in poorly-studied regions, has contributed greatly to knowledge of the mountain snow cover.

In the future, it is hoped that three main trends in the activities of the Department - investigation of the mountain snow cover, avalanches and glaciers - will be maintained.

Thermal drilling of the glacier

The main focus will be on modification of methods for computing and predicting glacial events, knowledge of the physical processes and development of better instrumentation for glaciological remote sensing.

The scientific production of the SANII Department of Glaciology consists of many volumes of proceedings, published annually in the series "Glaciology of Mountainous Areas". Also included are a number of monographs and guides, as listed below:

1. Moskalev, Yu.D. (Editor), 1965. Guide on Avalanche Operations.
2. Moskalev, Yu.D., 1966. Origin and Movement of Avalanches.
3. Konovalov, V.G., 1972. Ablation of Glaciers in Central Asia.
4. Kamalov, B.A., 1974. The Present-day Glaciation and Glacial Runoff in the Syrdarya River Basin.
5. Shchetinnikov, A.S., 1976. Glaciers of the Pskem River Basin.
6. Moskalev, Yu.D., 1977. Dynamics of Snow Avalanche and Snow Avalanche Computations.
7. Konovalov, V.G., 1979. Computation and Forecast of Glacier Melting in Central Asia.
8. Kanaev, L.A. (Editor), 1979. Practical Manual on Avalanche Forecasting.
9. Krenke, A.N. and Suslov, V.F. (Editors), 1980. The Abramov Glacier.
10. Shchetinnikov, A.S., 1981. Glaciation of Gissaro-Alai.
11. Suslov, V.F. (Editor), 1984. Avalanches along the Baikal-Amur Main Line.

V.F. Suslov

ANNUAL GENERAL MEETING 1985

MINUTES OF THE ANNUAL GENERAL MEETING OF THE INTERNATIONAL GLACIOLOGICAL SOCIETY

29 August at the University of Iceland, Reykjavík, Iceland

The President, Dr Hans Röthlisberger, was in the Chair. 35 members from 14 countries were present.

1. The Minutes of the 1984 Annual General Meeting, published in ICE No.76, 3rd Issue 1984, p.20-23, were approved and signed by the Chairman.

2. The President gave his report for 1984-85: Iceland, with 7 members of the IGS, ranges number-wise near the middle of the countries that have members at all, but if we compute the per capita percentage, it stands at the top. It is therefore appropriate that we hold our AGM here in Iceland. The importance of Jökulls (and those who take care of them) has been reflected by the presence of the President of Iceland, Madam Vigdis Finnbogadottir, at the opening ceremony of the Symposium of Glacier Mapping and Surveying. It is remarkable that the Icelanders have taken the burden upon themselves to organize a fair size international conference, and I want to express, on your behalf, our thanks to the local organizers. At the symposium we have now 95 participants who have come from 13 different countries as far away as Australia, Argentina, Japan and China.

Looking at the total membership of the Society, I can report that we are still close to 800, but as of 1 August, a substantial number had not paid up, and 35, who had not done so for 2 years, were removed from the list. The library subscriptions stand at 547 who have paid up for 1985, from a possible total of 611. It is to be hoped that our main publication, the **Journal of Glaciology**, will, now that the transition period for printing and editing is coming to an end, bring back former subscribers and attract new ones. A membership drive, however, is needed.

This year we all had the possibility to vote on the new Constitution that had been drawn up by the previous Council. I would kindly ask the Secretary General to present the results. (The numbers given by Mrs. Hilda Richardson were: 97% for the first group of rules, 98.5% for the second one, and 99% for the third one.)

The year has seen the production of 3 issues of the **Journal** and a change from the old system of editing to the new one, as approved by the Council at its meetings in Japan,with a House Editor based in Cambridge and 18 scientific editors from various parts of the world, including Japan and Australia. The Council is very much in favour of spreading the load of scientific editing worldwide, while having an efficient administrative and house-editing control-point at our Cambridge office. The term of the majority of scientific editors has been renewed for one to three years. This means that few new editors only will be added now, but that a balanced staggering of retirements and renewals, bringing in more young blood, will start with next year.

Dr R.J. Adie began his job as House Editor at the beginning of March, upon his retirement from the British Antarctic Survey. Prior to that the Secretary General had begun the process of introducing the new editing system, which Dr Adie then took over in March. During January our new word processors and a small laser printer came into operation. The results can be seen in the latest issue of the **Journal** (No.108). The typeface is Times, the right-hand margins are justified, and the setting of mathematics will, I think, satisfy all but the most critical of our mathematicians. The timing for publishing articles already is showing signs of improvement: publication times for No.107 - 13.4 months; for No.108 - 11 months; and we hope that when we have achieved our target of + 8 months, we shall find many authors returning to us.

The **Annals** series is certainly thriving, with volumes planned for publication up to and including the year 1989. And in some of those years there will be two volumes! Most of them arise from symposia that we are organizing; one will result from a SCAR Symposium on Antarctic Glaciology that we have been asked to help with in the same way as their previous one in 1981. Our major publications are therefore in good health. We shall continue to strive for further improvements and to take advantage of refinements in technology.

Three issues of **ICE** have come out again to bring news to you, thanks to Simon Ommanney. He told me that he is consistently in need of material from you, meaning the National Correspondents in the first place; but worthwhile news is appreciated from anyone! You have also received the blue newsletter from the Secretary General dated May 1985. The advantage of this carrier is to let the members in distant countries have by air the news about, say, meetings, before they are

over. To save costs the mailing is done together with the other circulars etc. It is the Head Office's intention to continue and expand this type of service.

The year 84/85 brought the retirement of Doris Johnson; we thank her very much for her competent services as editor during all the time from the beginning of the **Journal** in 1947. Ailsa Macqueen has resigned, first finishing **Annals** Vol.7. She has edited six **Annals** volumes, and we are sorry to see her leave. Otherwise the staff at HQ has grown. In 1979 it consisted of two full-time people and one quarter-time person. Now there are two full-time people and seven part-timers, spending from one-quarter to three-quarters of a normal working week on editing or keying-in articles for our two publications. The head office is still hosted at the Scott Polar Research Institute - thank you, David Drewry! The mail is received there, the Secretary General's office is there, and the staff look in there in the morning before going to the more spacious "satellite" office. Phone links assure that either the Secretary General or the others can be reached most of the time to get an answer. I want to express our thanks to Pat Lander, Mary Parker, Beverley Baker and Sally Stonehouse; also to Sylva Gethin who does the reference checking and editing at the Scott Polar.

Thanks to the long-range planning by our Secretary General, IGS members can arrange their travel programmes for many years to come; it will be a busy schedule!. In 1986 the Second Symposium on Remote Sensing in Glaciology will be held in Cambridge, England; in 1987 the Symposium on Ice-Core Analysis takes place in the spring in Bern, Switzerland, while the Annual General Meeting is scheduled for September in Bremerhaven, Germany, when SCAR convenes. Plans for symposia in the spring of 1988 in Australia, in the fall of the same year in Norway, and in 1989 in the Pacific Northwest are progressing.

Just before Easter 1985 we were saddened to learn of the sudden death of Valter Schytt, our first non-British president. It is our small consolation that only half a year previous Valter thoroughly enjoyed the IGS tour to China, in particular the visit to the Tien Shan Mountains and the journey across the Gobi Desert. For some of us this was the last time we saw him. The Society does not have the custom of memorial issues; I am confident, however, that Valter's achievements will be marked in that kind of way in countries nearer to his home.

Later this evening it will be my great pleasure to present the Seligman Crystal to Mark Meier, awarded to him by the Council a year ago in Sapporo. I have the further pleasure to announce that the Council,at its meeting on Saturday 24 August has accepted the recommendation of the Awards Committee and has unanimously decided to award the Seligman Crystal to Dr Gordon de Q. Robin. The crystal will be presented during the week of the Symposium on Remote Sensing in Glaciology in Cambridge, England, 6-12 September 1986. Gordon has repeated enriched glaciological knowledge and know-how by his creative geophysical contributions. His pioneering work with the seismic method during the Maudheim Expedition 1949-52, his seminal paper on the temperature distribution in the great ice sheets, his initiation of deformation studies in ice shelves, his contributions to the assessment of the mechanisms of surging and his straight-forward approach to problems of water effects in crevassing and sliding at the bed are examples of his ability to see the problems and find solutions. Stan Evans, a former Scott Polar scientist, was recipient of the Seligman Crystal in 1974 for his contributions to the development of radio echo sounding; Gordon has since been influential in developing the method further, in applying it in a broad sense in Antarctica and in advancing interpretation. As fruitful as Gordon Robin's research were his 24 years of directorship at the Scott Polar Research Institute in Cambridge, his activities in the Scientific Committee on Antarctic Research, and the successful guidance of his students.

With due acknowledgement to the Secretary General, Hilda Richardson, and her staff, I have now the satisfaction to let you have the details of a "cautiously optimistic outlook" reported by the Treasurer.

3. The Treasurer, Dr J.A. Heap, submitted a report which was presented by the Secretary General:

"I regret that, once again, I cannot be with you to present my report. As you will see from the audited accounts for 1984 there was a surplus of £3,831 for 1984 following a deficit in 1982 of £2,120 and a surplus in 1983 of £6,136. Over the last 3 years the Accumulated Fund has moved from showing a deficit of £13,251 in 1982 to a surplus of £5,098 in 1984. In my report for 1982 I emphasised the need for action to reverse the downward trend in the Society's finances. In my report for 1983 I noted that the downward trend appeared to have been reversed but I sounded 'a strongly cautionary note'. Following the financial outturn for 1984 I would describe my attitude as having moved to the 'cautiously optimistic'. This, however, should not be seen as giving any scope for a reduction in the need for financial vigilance. We do not have money to play with.

Following are some features of the Accounts to which I should draw your attention:
(a) Annals Fund. Although there has been a drop in the Annals Fund from £26,696 in 1983 to £21,216 in 1984, account needs to be taken of the purchase in 1984 of a multi-font text processing system, printer and ancillaries at a cost of £13,560.

(b) Printing of Journal number 104-6. There has been a saving of the nearly £6,000, that is, one-third of the 1983 costs, following on the change to in-house preparation of the text.
(c) Fees, salaries etc. Note the very small rise in this figure.
(d) Rent etc. Note the rise in this figiure, brought about by the move of our satellite office to premises large enough to provide for in-house editing and preparation of both Journal and Annals.

Considering the 1984 accounts in the light of the overall strategy for the Journal adopted by the Council in 1982, it can be said that:
(a) the costs of printing have been reduced;
(b) editing expenses are already being reduced and will be significantly lower in the 1985 accounts;
(c) the time taken from receipt of a revised manuscript to its publication is being reduced, and will be further reduced now that all articles will be processed under the new editing system.

Lastly, I recommend that Council adopt the Audited Accounts for 1984:"

4 Election of Auditors for the 1985 accounts. C.S.L. Ommanney proposed and R.J. Adie seconded that Messrs. Peters, Elworthy and Moore of Cambridge be elected auditors for the 1985 accounts. This was carried unanimously.

5. Elections to the Council 1985-88: After circulation to all members of the Society of the Council's suggested list of nominees, no further nominations had been received. The following people were therefore elected unanimously.

Vice-President	H. Kohnen
Elective Members (4)	K. Higuchi
	C. Jaccard
	Shi Yafeng
	B. Wold

The President thanked retiring Council members, and, in particular, the retiring Vice-President, K. Kusunoki, for their service over the past three years.

Hans Röthlisberger
12.9.86

SYMPOSIUM ON ICE-CORE ANALYSIS

Bern, Switzerland, 30 March - 4 April 1987

FIRST CIRCULAR, MAY 1985

The Society will hold a symposium on ice-core analysis in Bern, Switzerland in 1987. Registration will take place on Sunday 29 March and sessions will be from Monday 30 March to Friday 4 April in the Physical Institute, University of Bern.

TOPICS
The symposium will be concerned with analytical techniques, results and interpretations related to studies on ice cores from polar areas and from mid-latitude glaciers.

PAPERS
The Papers Committee will be happy to consider papers on these topics. Details about the summaries and final papers will be given in the Second Circular, to be published in May 1986. Dates for submissions are firm ones and must be adhered to. The Committee may decide to invite review papers on some of the topics if submitted contributions do not give sufficient coverage.

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

SESSIONS
Sessions will be held on four full days and one half-day. A half-day excursion will be held during the week.

ACCOMMODATION
Accommodation will be available in various price categories: details will be given in the Second Circular.

FURTHER INFORMATION
You are invited to attend the symposium and to return the attached form as soon as possible. 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, Int. Glaciological Society, Lensfield Road, Cambridge CB2 1ER, England.

*Note: Members of the IGS will automatically receive a copy.

SYMPOSIUM ORGANIZATION
H. Richardson (Secretary General, I.G.S.)

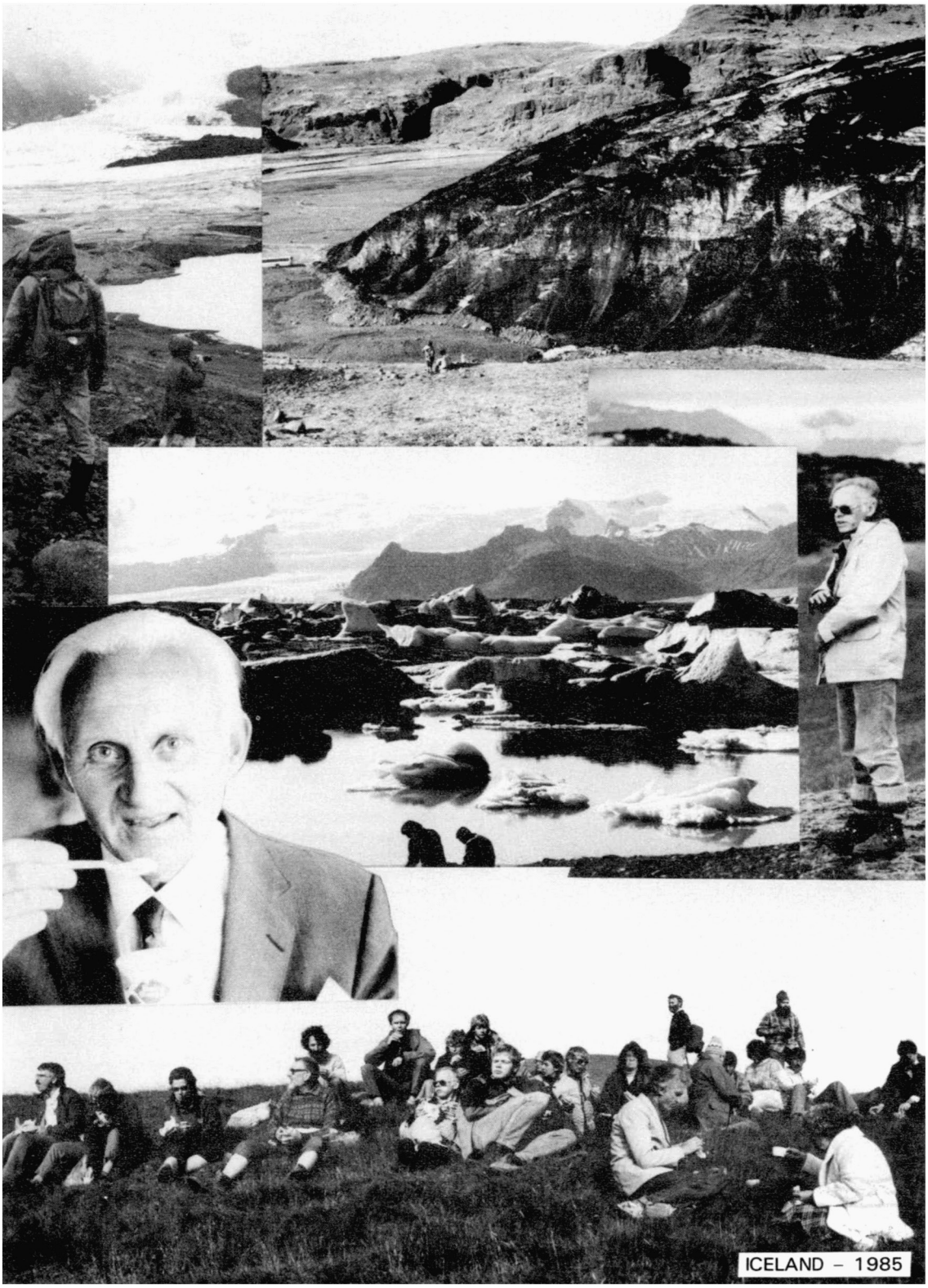
LOCAL ARRANGEMENTS COMMITTEE
Chairman - B. Stauffer

International Glaciological Society
SYMPOSIUM ON ICE-CORE ANALYSIS

Family Name . . . . . .
First Name. . . . . .
Address . . . . . .
. . . . . .
. . . . . .

*I hope to participate in the symposium in 1987 [ ]
*I expect to submit a summary of a proposed paper [ ]
*without obligation

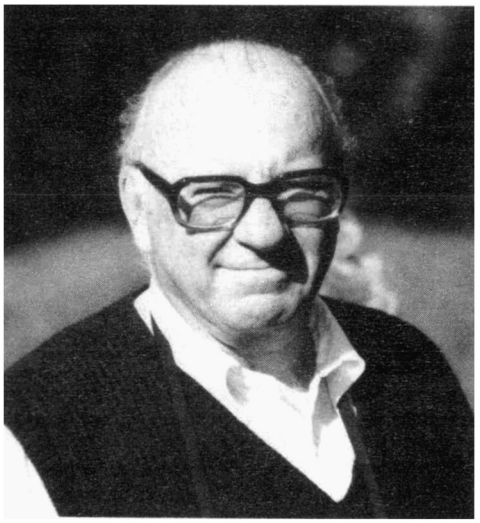
TO BE SENT AS SOON AS POSSIBLE TO:
Secretary General, Int. Glaciological Society, Lensfield Road, Cambridge CB2 1ER, U.K.


ICELAND – 1985

SELIGMAN CRYSTAL RECIPIENT – DR MARK F. MEIER

29 August 1985, Reykjavfk, Iceland

Mark F. Meier was born in Iowa City on 19 November 1925. He owes his early interest in mountains to the enthusiasm for geology of his father, who was by profession a psychologist. In 1949, Mark received a B.Sc. from the University of Iowa in electrical engineering and in 1951 an M.Sc. in geology. For his Ph.D. he moved to the California Institute of Technology to study under R.F.Sharp. His dissertation on the flow of the Saskatchewan Glacier in Alberta was accepted in 1957. During his student years, he worked summers in the U.S. Geological Survey. In 1955, he led the Crevasse Study Expedition to the North Greenland Ice Cap, then went on to Innsbruck with a Fulbright grant to study under Herfried Hoinkes. Since 1956 Mark has been Chief of the Glaciology Project Office of the U.S. geological Survey in Tacoma, Washington, retiring in November. In 1964 he was Visiting Professor of Geology at Dartmouth College and since 1965 Research Professor of Geophysics at the University of Washington. He has served, and still serves, on many different national and international committees, working groups and commissions. He was Vice-President of the IGS in the '60s and President of ICSI (1967-1971) to become from 1979 to 1983 President of the International Association of Scientific Hydrology (of which ICSI is a commission). This reflects that one of Mark Meier's major research efforts was directed towards the hydrological aspects of glaciers and snow. With the mass balance study of South Cascade Glacier since 1957, including co-ordinated surface, geodetic amd hydrological mass balance and flow measurements, he made a major contribution to the understanding of the hydrological processes relating runoff to meteorological and glaciological factors. Together with Wendell Tangborn he brought order into the confusing jungle of nomenclature concerned with the measurement of mass balance - the confusion being due to moving surfaces and shifting time periods. Going with the time, the USGS Project Office under Mark's guidance initiated programs to use remote sensing in hydrology. In the mid-1960s, the office operated the first snow and ice test site for the developing NASA program of remote sensing of earth resources.



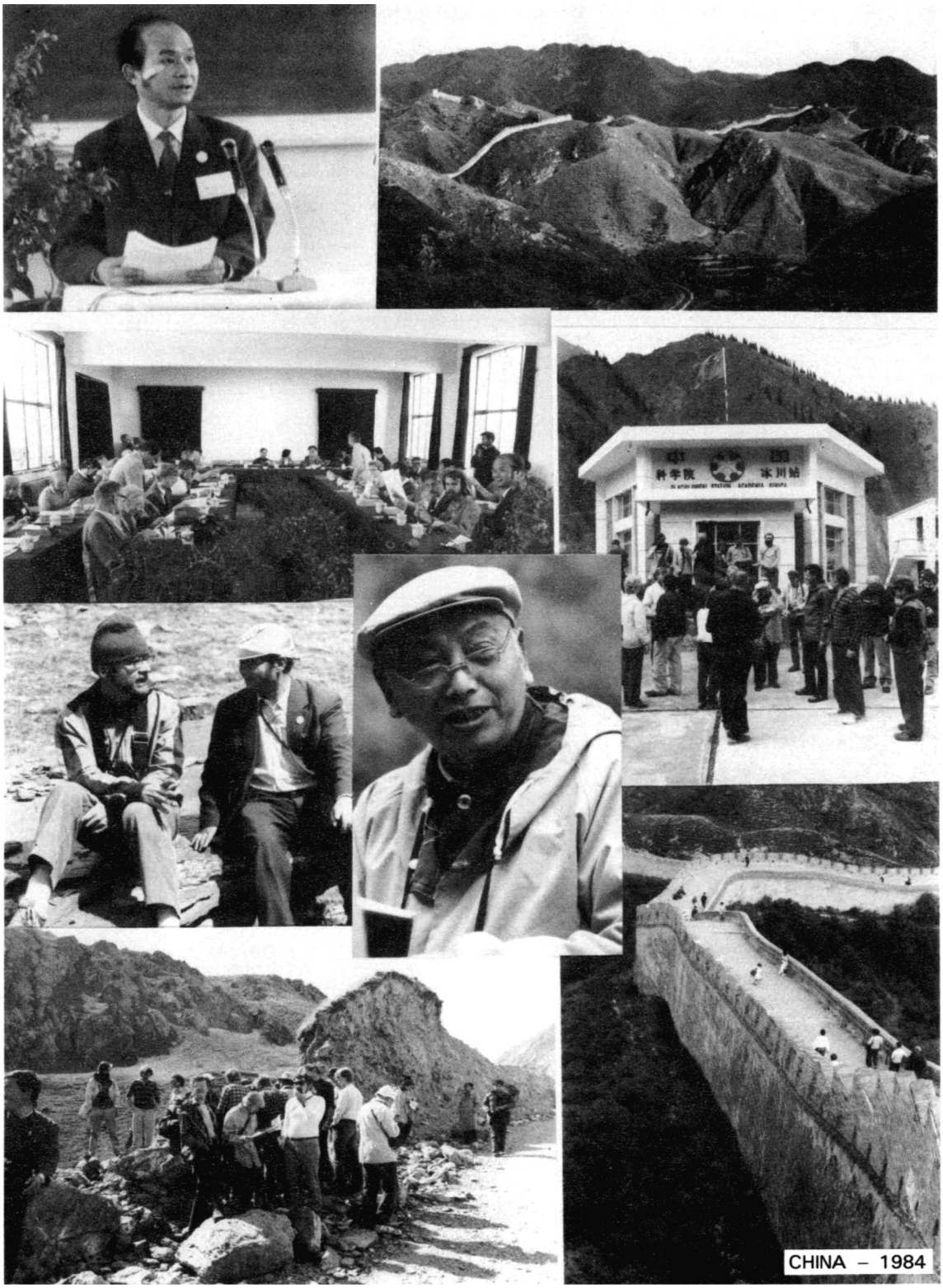
Pioneering work was done to realize the great potential for sensing snowpack distribution and water equivalent from passive microwave emissions in cooperation with industry.

In spite of Mark's international prominence in hydrology, in his heart he has always been a true "glacier man" who takes a direct interest in ice apart from the fact that it may turn into water. Mark's "Profile" printed in ICE No.26, in 1968, tells that his early field work has produced the first structural map of a glacier (Dinwoody Glacier, 1950). The wish to explain structures propagated early attempts to extract flow-law data from strain-rate observations in the field.

During the years in Tacoma, Mark's scope has broadened: he paid attention to a wide range of individual glaciers,types of glaciers and glacier phenomena. This includes ice-capped volcanos - Mount Rainier can be seen from Mark's house (weather permitting) - especially after the eruption of Mount St. Helens. Under the leadership of Mark many unique tasks have been tackled by the Tacoma group of people, among them - besides Wendell Tangborn - Austin Post, Al Rasmussen and Bob Krimmel. The major acheivements are:

- the successful prediction, based on numerical models, of the rapid retreat of Columbia Glacier, which is thought to have been stable since Captain Vancouver's visit in 1792;
- the development with the USGS in Denver, and the prolific use, of a portable monopulse radar depth sounder;
- the interpretation of LANDSAT images for the assessment of the snow cover and for the detection of glacier surges and other glacier hazards;
- the collection of a unique archive of glacier photographs of the Pacific Northwest;
- the collection, sorting and interpretation of data from numerous surges.

Mark's major scientific achievement is to have repeatedly sensed, at a crucial moment, what is needed in a specific domain of the vast field of glaciology, how this can be done and who is goint to do it. He has thereby influenced the development of glaciology in multiple fashion, thus in a unique - Mark Meier way.


CHINA – 1984

SECOND SYMPOSIUM ON REMOTE SENSING IN GLACIOLOGY

Cambridge, England, 7-12 September 1986

SECOND CIRCULAR, MAY 1985

The Society will hold a symposium on remote sensing in glaciology in Cambridge, England, in 1986. Registration will take place on Sunday 7 September and sessions will be held from Monday 8 to Friday 12 September in the University of Cambridge. The 50th anniversary of the founding of the Society will be celebrated with a special day of lectures and a Banquet, and with a post-symposium tour of Switzerland. The Council of the Society will meet on Saturday 6 September, in King's College.

1. PARTICIPATION AND ACCOMMODATION

This circular includes a booking form, which should be sent to the Secretary General before 1 June 1986 with the appropriate deposits, as indicated. Accommodation has been booked from 7 through 12 September in King's College, where the Icebreaker and Banquet will also be held. The package fee includes: bed, breakfast, lunch, dinner from Sunday (7th) evening dinner to Saturday (13th) breakfast, the extra cost for the Banquet on Wednesday (10th), the Icebreaker party (7th), organization costs, provision of summaries and one copy of the proceedings volume. (Accompanying persons are not charged for summaries and volume.)

For people not staying in King's College, the fee includes, organization costs, Icebreaker party, full cost of the Banquet, provision of summaries and one copy of the proceedings volume. (Accompanying persons are not charged for summaries and volume.) Note: - people not staying in King's may not take meals there (part from the Banquet) as the college caters only for residents.

Payments should be made in accordance with the instructions on the last page of the circular.

RESIDENTS IN KING'S COLLEGE
A deposit of £130 (£90 for accompanying persons) must be paid when booking.

NON-RESIDENTS
A deposit of £80 (£40 for accompanying persons) must be paid when booking.

The deposits will be returned in full if notice of cancellation is received before 1 August 1986. After that date, a proportion will be returned, in accordance with the expenses incurred up to the date of cancellation.

2. TOPICS

The symposium will be concerned with the application of remote sensing to the measurements of glaciological parameters. It will include such topics as:

1. Studies of sea ice, glaciers, ice sheets, snow and ground ice using remote sensing information.
2. Utilization of remote sensing data in numerical ice models.
3. Analysis and interpretation of data (satellite, aircraft, and field).
4. Advances in remote sensing instrumentation, parameter-extraction methods, and presentation techniques.

The symposium will also include a summary discussion of key problems in glaciology and potential future contribution of remote sensing.

3. PAPERS

(i) SUBMISSION OF PAPERS
Those participants who would like to contribute to the Symposium should first submit a summary of their proposed paper in English; this summary should contain sufficient detail to enable the Papers Committee to form a judgement on the likely merit of the proposed paper, but should not exceed two pages of typescript on international size paper A4 (210 x 297 mm).

Summaries should be sent to:
Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, England.

LAST DATE FOR SUBMISSION OF SUMMARIES
- 1 JANUARY 1986 -

(ii) SELECTION OF PAPERS
Each summary will be assessed by the members of the Papers Committee, acting independently of each other, taking into account scientific quality and relevance to the theme of the Symposium. The Papers Committee will then invite a strictly limited number of papers for presentation and thorough discussion at the Symposium (not necessarily confining themselves to authors who have submitted summaries). It is hoped to notify authors of papers during April 1986.

(iii) DISTRIBUTION OF SUMMARIES
The summaries of the accepted papers will be distributed to all participants before the Symposium.

(iv) SUBMISSION OF FINAL PAPERS AND PUBLICATION

The Proceedings will be published by the International Glaciological Society in the Annals of Glaciology. Papers presented at the Symposium will be considered for publication in these proceedings, provided they have not been submitted for publication elsewhere. Final typescripts of these papers should be submitted to the Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, England, by 30 June 1986. They should be written in English and prepared in accordance with the instructions that will be sent to authors when they are notified about acceptance of papers for the Symposium. Authors will be told the maximum length for their papers when they receive notice of acceptance of their summaries. The papers will be refereed according to the usual standards of the Society before being accepted for publication. Speedy publication of the proceedings will depend upon strict adherence to deadlines.

LAST DATE FOR SUBMISSION OF FINAL PAPERS - 30 JUNE 1986 -

4. SESSIONS

Sessions will be held on Monday, Tuesday, Thursday and Friday in the University Chemical Laboratory, Lensfield Road, next door to the Scott Polar Research Institute, where the Society's office is located.

5. 50th ANNIVERSARY CELEBRATIONS

To mark the Society's Golden Jubilee, Wednesday 10 September will be devoted to invited papers covering the various aspects of snow and ice research, with special reference to their development during the past half-century. In the evening a special banquet will be held. In the week after the symposium, beginning on Saturday 13 September, a tour of Switzerland (see section 6) will take place. Priority booking will be given to those people who have registered for the Symposium. A separate circular about the celebrations will be published in due course.

6. GOLDEN JUBILEE TOUR

The Golden Jubilee Tour to Jungfraujoch and the western part of the Swiss Alps will be held from 13 to 19 September, 1986. The visit to Jungfraujoch serves to keep alive the memory of Gerald Seligman, founder of the IGS, and the work he carried out with distinguished collaborators at the international research station.

Points of glaciological interest, such as spectacularly advancing glaciers, will be visited and magnificent scenery will be enjoyed. Parallel tours for mountaineers, hikers and sight-seers will be organized. The estimated cost will be between Sfr.600 and 1000 according to choice of accommodation (youth hostels or hotels) and itinerary.

SYMPOSIUM ORGANIZATION

I.G.S. Headquarters office

PAPERS COMMITTEE

R.S. Williams (Chairman)
D.J. Drewry
P. Gudmandsen
R.O. Ramseier
K. Steffen
G. Wendler
H.J. Zwally

BOOKING FORM

SYMPOSIUM ON REMOTE SENSING IN GLACIOLOGY

7-12 September 1986

Mail to: Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, England.

BEFORE 1 JUNE 1986

See below for methods of making payment

. . . . . ./ . . .
Family Name (print or type) Initials

Address . . . . . .

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Accompanied by

Name. . . . . .

I send deposits as follows:

RESIDENTS IN KING'S COLLEGE
Participant/s (£130 each) . . . . . .£ . .
Accompanying persons (£90 each) . . .£ . .

NON-RESIDENTS
Participant/s (£90 each). . . . . .£ . .
Accompanying persons (£40 each) . . .£ . .

PAYMENT SENT. . . . . .£ . .

METHODS OF MAKING PAYMENT IN £ sterling

By cheque payable to: International Glaciological Society, and sent to the Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, England.

By Bank transfer to International Glaciological Society Symposium, Account No. 08102112*, and sent to National Westminster Bank plc, 56 St Andrew's Street, Cambridge CB2 3DA, England.

*Note: it is important to include the account number in your instructions to your bank, because the Society has several accounts.

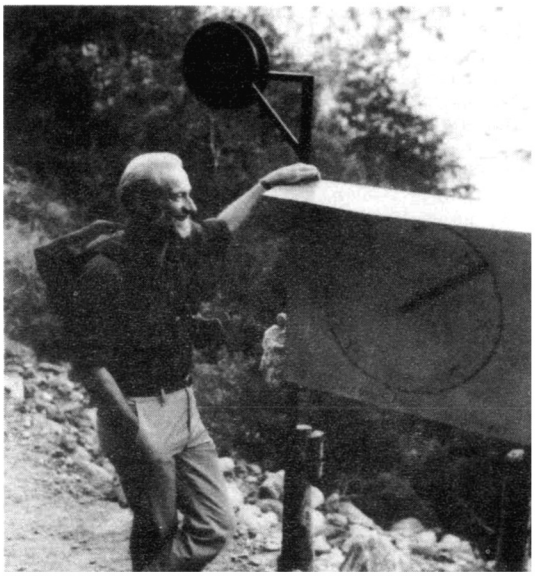
WORKSHOP ON HYDRAULIC EFFECTS AT THE GLACIER BED AND RELATED PHENOMENA

16-19 September 1985, Interlaken, Switzerland

This highly successful meeting was conceived and organized by the Versuchsanstalt für Wasserbau, Hydrologie und Glaziologie, ETH, Zürich. Originally intended as a small workshop, it in fact attracted some 65 participants from 10 countries. The younger generation of glaciologists was well represented. Attendance remained high throughout, in spite of the splendid weather and the rival attractions of Kleine Scheidegg and the Jungfraujoch. Some 40 papers were presented, in addition to several in a poster session. The last afternoon was devoted to a general discussion with background noise provided by the Swiss Air Force. Because nearly all the participants were staying in the Hotel Mattenhof, where the sessions were held, those so inclined could begin discussions at breakfast and continue until the bar closed late at night.

Major topics were the sub-glacial drainage system, sliding (in the broad sense of all movement other than deformation within the ice), and surges. Recent field programs on Findelen, Columbia, and Variegated Glaciers each resulted in several papers. Several speakers described subglacial observations of sliding, sediment deformation, water flow, and temperature. Yet more measurements of short-period velocity fluctuations were presented; interesting differences appeared between the behaviour of a floating tongue (Jakobshavn) and a grounded one (Columbia). There were also some theoretical papers, including more developments in sliding theory. One analysis showed that not all variations in sliding velocity produce similar changes at the surface.

Much attention was focussed on the distinction between "hard" and "soft" beds, that is, between the rigid impermeable bed assumed in classical sliding theory and a layer of permeable sediments in which most of the deformation may occur. Water plays a vital role in both cases, but in different ways. Both types of bed exist, but what is their relative frequency? Seismic observations suggesting that West Antarctic ice streams have deformable beds give this topic new importance. Processes in subglacial sediments were also invoked to explain surges on Trapridge Glacier. In contrast, the recent surge of Variegated Glacier was attributed to the destruction of subglacial tunnels so that drainage became controlled by narrow passageways connecting basal cavities. Some mathematical skill is helpful in understanding this explanation. The remark by a well-known glaciologist, that most surging glaciers appear to be in National Parks, opens up a potential new line of research.



Roger Hooke making short-term velocity measurements of Oberer Grindelwaldgletscher

The two days following the workshop were spent on field trips. One group had a guided tour of part of Aletschgletscher while others, primed with wine provided by the **Gommerkraftwerke,** entered the James Bond-like world of a hydroelectic tunnel carrying run-off from Fieschergletscher. All were reunited on the second day at the snout of Findelengletscher for wine and snacks, compliments of the Grand Dixence Co., presented with Gallic flair by M. Albert Bezinge. Afterwards we inspected traces of subglacial cavities marked by solution deposits, a pressure transducer awaiting burial by the advancing glacier, potholes formed subglacially, and even a Nye-channel. A dripping ice tunnel gave access to a basal debris layer.

Almut Iken and her colleagues at ETH are to be congratulated on organizing such a stimulating meeting. Abstracts of the papers and a summary of the results are to be published as a VAW/ETH report that will be sent to participants and to all members of the **International Glaciological Society.**

Stan Paterson

FUTURE MEETINGS (of other organizations)

THE PHYSICAL BASIS FOR ICE SHEET MODELLING

Two-day Symposium at the IUGG General Assembly, Vancouver, B.C., 9-22 August 1987

OBJECTIVE
To focus on a complete physical description of ice sheets in a form suitable for modelling, and to present data suitable to both calibrate and test increasingly complex ice sheet models. The Symposium will NOT deal with ice sheet model results.

SCHEDULE
Full papers are due by 30 November 1986 and will be prepublished in the IAHS red series. Send extended summaries (300-500 words) by 15 May 1986 to:

PROGRAM
1. Constitutive laws for ice
2. Basal boundary conditions
3. Long time-scale interactions with ocean, atmosphere and mantle
4. Hard facts to calibrate or test ice sheet models

E.D. Waddington, Convenor,
Physical Basis of Ice Sheet Modelling
Geophysics Program AK-50
University of Washington
Seattle, WA 98195, U.S.A.

CHEMICAL DYNAMICS OF SEASONAL SNOWCOVERS

13-27 July 1986, Seminarc, Les Arcs, Savoy, France

A NATO Advanced Study Institute will be presented on snow physics and chemistry to exchange information on the techniques and theory of snowcover studies, its chemical dynamics and evolution. Principal lectures will be presented by W.P. Adams, S.C. Colbeck, T.D. Davies, R. Delmas, H.G. Jones, N. Klever, J. Martinec, E.M. Morris, W. Stichler and R. Wright. The proceedings will be published in the NATO ASI series by the Reidel Publishing Company.

Applications should be received by 27 March 1986 and acceptance will be notified by 25 April 1986. Limited support is available to citizens of NATO countries. Those wishing to present a paper should submit a 250-word abstract with their application. For further information contact:

Prof. H.G. Jones
INRS-EAU, Université du Québec
C.P. 7500, Sainte-Foy, Québec
G1V 4C7, Canada

NEWS

REVISED IGS CONSTITUTION
The proposed changes to the Constitution of the International Glaciological Society were agreed to by majorities of 97% for the first group of rules, 98.5% for the second one, and 99% for the third one. The revised Constitution has been mailed to all members.

IGS SYMPOSIUM IN 1989
The Council accepted an invitation from members in the U.S. Pacific Northwest for a symposium on "Ice and Climate", with possible tours to Mt. St. Helens and coastal Alaska. More detailed proposals will be presented to Council in 1986.

MARK MEIER MOVES TO INSTAAR
Mark Meier, long-time Chief of the Glaciology Project Office, USGS in Tacoma and this year's recipient of the Seligman Crystal (see p.48), has been appointed Director of the Institute of Arctic and Alpine Research (INSTAAR) and Professor of Geological Sciences, at the University of Colorado in Boulder (Campus Box 450, CO 80309). He will direct an institute of about 20 researchers, in addition to graduate students, in scientific research on high-altitude and high-latitude environmental phenomena and on former cold environments during the Quaternary period. INSTAAR's facilities include laboratories and headquarters on the Boulder campus of the University of Colorado and a Mountain Research Station in the Front Range, east of Boulder. In addition, a new Geochronology Center is being developed on campus.

MARGINAL ICE ZONE
A special collection of papers dealing with physical processes in the MIZ will be published in JGR-Oceans. It will focus on results from the E.Greenland Sea (MIZEX-East), but results from other MIZ-related programs are welcome. Manuscripts are required by 1 May 1986. For further information contact R. Muench, SAIC, 13400B Northrup Way #36, Bellevue, WA 98005 (tel: 206-747-7152).

INTERNATIONAL ASSOCIATION OF HYDROLOGICAL SCIENCES

TECHNIQUES FOR PREDICTION OF RUNOFF FROM GLACIERIZED AREAS

Edited by
Gordon J. Young

149 + ix pages
price $18 (US)
IAHS Publ. no. 149
(published March 1985)
ISBN 0-947571-30-2

The **IAHS** *International Commission on Snow and Ice* **(ICSI)** designed and encouraged the snow and ice programmes of the **UNESCO** sponsored *International Hydrological Decade* **(IHD)** and *International Hydrological Programme* **(IHP).** As a result of the **IHD** and the **IHP** very considerable advances have been made in our understanding of hydrological processes in high mountain areas, and several good integrated data sets are now available for further research analysis.

This new **IAHS** publication has been produced by the **ICSI** Working Group on Prediction of Runoff from Glacierized Areas and edited by Gordon J. Young, the working group chairman. The publication opens with an overview by Gordon Young (Ottawa, Canada) which discusses the worldwide distribution of glacierized areas; how predictive techniques for runoff serve water supply and flood control; and climate and hydrological response. An overview of contemporary techniques then follows by Andrew G. Fountain (Tacoma, USA) & Wendell Tangborn (Seattle, USA). This second overview summarizes current techniques for predicting runoff from glacierized basins with emphasis on techniques for estimating the drainage of water from glaciers. The next section presents case studies as illustrations in an attempt to bring together the current knowledge and practices in hydrological predictive techniques. The wide-ranging case studies include studies of river basins of various sizes and having substantially different climatic regimes, and are separated into case studies for water supply (from Switzerland, Canada, Greenland, USSR, China and Pakistan) and case studies of catastrophic floods (USSR, Nepal, Pakistan and Canada).

ORDERS This **IAHS** publication may be ordered from any of the following addresses:
Office of the Treasurer IAHS, 2000 Florida Avenue NW, Washington, DC 20009, USA
IUGG Publications Office, 39 ter rue Gay Lussac, 75005 Paris, France
IAHS Press, Institute of Hydrology, Wallingford, Oxon OX10 8BB, UK
Please note that unless instructed otherwise the publication will be sent by surface mail and delivery to some destinations outside Europe and North America may take up to six months. Air mail postage is extra. Prepayment is welcomed but not obligatory.

A catalogue of all IAHS titles may also be obtained free of charge from any of the above addresses.

8-11 April
14th International Polar Meeting, German Society of Polar Research. Bremerhaven, FRG. (H. Miller, Alfred-Wegener-Institut für Polarforschung, Columbus-Center, 2850 Bremerhaven, F.R.G.)

13-17 April
Fifth International Symposium on Offshore Mechanics and Arctic Engineering (OMAE). Tokyo, Japan. (Dr V.J. Lunardini, US Army CRREL, 72 Lyme Road, Hanover, New Hampshire 03755, U.S.A.)

15-17 April
Western Snow Conference. Camelback Sahara, Phoenix, Arizona, U.S.A. (Robert T. Davis, Secretary, Western Snow Conference, P.O. Box 14884, Spokane, Washington, WA 99214, USA.)

24-26 April
15th Annual Arctic Workshop. Boulder, Colorado. (J.T. Andrews, INSTAAR, Campus Box 450, University of Colorado, Boulder, CO 80309, U.S.A.)

4-8 May
Fast Glacier Flow: Ice Streams, Surging and Tidewater Glaciers, A.G.U. Chapman Conference. Whistler Village, B.C., Canada. (Dr G.K.C. Clarke, Dept. of Geophysics and Astronomy, Univ. of British Columbia, 2075 Wesbrook Mall, Vancouver, B.C., V6T 1W5, Canada)

17-20 June
Fourth Workshop on Hydraulics of River Ice and Short Course on Ice Engineering. Montréal, Quebec, Canada. (M. Marc Drouin, Head, Hydraulics Dept, Société d'énergie de la Baie James, 20th Floor, 800 de Maisonneuve Blvd E., Montréal, Québec, H2L 4M8, Canada)

2-10 July
I.A.H.S. 2nd Scientific Assembly, Symposium on Modelling Snowmelt Induced Processes. Budapest, Hungary. (Dr A. Szöllösi-Nagy, VITUKI, H-1453 Budapest, Pf 27, Hungary)

13-27 July
Chemical Dynamics of Seasonal Snowcovers, NATO Advanced Study Institute, Savoy, France. (H.G. Jones, INRS-Eau, C.P. 7500, Sainte-Foy, Québec, G1V 4C7, Canada)

22-25 July
Cold Regions Hydrology Symposium, American Water Resources Association. Fairbanks, Alaska, U.S.A. (Douglas L. Kane, Institute of Water Resources, Engineering Experiment Station, Univ. of Alaska, Fairbanks, AK 99701, USA)

18-22 August
* 8th Symposium of the I.A.H.R. Section on Ice Problems. Iowa City, U.S.A. (Dr R.Ettema, Inst. of Hydraulic Research, Univ.of Iowa,Iowa City, IA 52242, USA)

30 August - 5 September
* VII Symposium on Physics and Chemistry of Ice. Grenoble, France. (VII Symposium on Physics and Chemistry of Ice, Laboratoire de Glaciologie,BP 68,38402 Saint Martin-d'Hères Cedex, France)

6-12 September
** Symposium on Remote Sensing in Glaciology and 50th Anniversary of the IGS. Cambridge, England. (Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, UK)

14-19 September
* International Symposium on Avalanche Formation, Movement and Effects. Davos, Switzerland. (C. Jaccard, Symposium 1986, EISLF, Weissfluhjoch, CH-7260 Davos-Dorf, Switzerland)

27-30 October
Polar Tech '86, Inter. Offshore and Navigation Conf Helsinki, Finland. (Technical Research Centre of Finland, Lab. of Structural Engineering, Betonimiehenkuja 3, 02150 Espoo, Finland)

1987

** March
North East North American Branch meeting, International Glaciological Society. Location to be announced. (Dr S. Ackley, U.S. Army CRREL, 72 Lyme Road, Hanover, New Hampshire 03755, U.S.A.)

**30 March - 4 April
Symposium on Ice-Core Analysis. Bern, Switzerland. (Secretary General, IGS, Lensfield Road, Cambridge CB2 1ER, UK)

31 July - 9 August
12th Congress of the International Union for Quaternary Research. Ottawa, Ontario, Canada. (Mrs L. Baignée, Secretariat, XII INQUA Congress, c/o National Research Council of Canada, Ottawa, Ontario, K1A 0R6, Canada)

31 July - 9 August
Holocene Glacier Fluctuations, 12th INQUA Congress. Ottawa, Ontario, Canada. (P.T. Davis, Dept. Geology, Mount Holyoke College, South Hadley, MA 01075, U.S.A. or G. Osborn, Dept. Geology, University of Calgary, Calgary, Alberta, T2N 1N4, Canada)

* co-sponsored by the International Glaciological Society ** IGS Symposia

9-22 August
Symposium on the Physical Bases of Ice-sheet Modelling, IUGG General Assembly. Vancouver, BC, Canada. (E. Waddington, Geophysics Program AK-50, University of Washington, Seattle, WA 98195, USA)

9-22 August
Symposium on Marginal Ice Zone Processes. IUGG General Assembly. Vancouver, BC, Canada. (R.D. Muench, Science Applications Inc., 13400 B, Northrup Way, Suite 36, Bellevue, Washington 98005, USA or K. Davidson, Dept. of Meteorology, Naval Postgraduate School, Monterey, California, U.S.A.)

9-22 August
Symposium on Large Scale Effects of Snow Cover, IUGG General Assembly, Vancouver, BC, Canada. (Dr B.E. Goodison, Atmospheric Environment Service, Environment Canada, 4905 Dufferin St., Downsview, Ontario, M3H 5T4, Canada)

9-22 August
Workshop on River Ice, IUGG General Assembly. Vancouver, BC, Canada. (Dr K.S. Davar, Department of Civil Eng., Univ. of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada)

7-12 September
* Fourth SCAR International Symposium on Antarctic Glaciology. Bremerhaven, FRG. (Dr H. Kohnen, Alfred-Wegener-Inst. for Polar Research, Columbus-Center, D-2580 Bremerhaven, F.R.G.)

1988

14-19 February
** Symposium on Ice Dynamics. Hobart, Australia. (Secretary General, IGS, Lensfield Road, Cambridge CB2 1ER, UK)

September
** Symposium on Applied Glaciology. Norway. (Secretary General, IGS, Lensfield Road, Cambridge CB2 1ER, UK)

1989

21-25 August
23rd IAHR Biennial Congress. Ottawa, Ontario, Canada. (Dr T.M. Dick, NWRI, CCIW, P.O. Box 5050, 867 Lakeshore Rd., Burlington, Ontario, L7R 4A6, Canada)

September
** Symposium on Ice and Climate. Seattle, Washington, U.S.A. (Secretary General, IGS, Lensfield Road, Cambridge CB2 1ER, UK)

NEW MEMBERS

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INTERNATIONAL GLACIOLOGICAL SOCIETY

Founded by G. Seligman

c/o SCOTT POLAR RESEARCH INSTITUTE, LENSFIELD ROAD, CAMBRIDGE CB2 1ER, ENGLAND
Secretary General, H. Richardson

The Society is registered as a charity in the United Kingdom,
with the Charity Commissioners - number 231043.

INTERNATIONAL GLACIOLOGICAL SOCIETY

Lensfield Road, Cambridge CB2 1ER, England

DETAILS OF MEMBERSHIP

Membership is open to all individuals who have scientific, practical or general interest in any aspect of snow and ice study. Payment covers purchase of the *Journal of Glaciology* and *Ice*. Forms for enrolment can be obtained from the Secretary General. No proposer or seconder is required.

ANNUAL PAYMENTS 1986

Private members	Sterling: £22.00
Junior members	Sterling: £11.00
Institutions, Libraries	Sterling: £65.00 for Volume 32 (Nos. 110,111,112)

Annals of Glaciology – prices vary according to size of volume. For further information, apply to the Secretary General.

Note – Payments from countries other than Britain should be calculated at the exchange rate in force at the time of payment. Please ensure that sufficient money is included to cover the bank charges. The Society needs the full payment, so bank charges should be paid by you. Thank you.

ICE

Editor: Simon Ommanney

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