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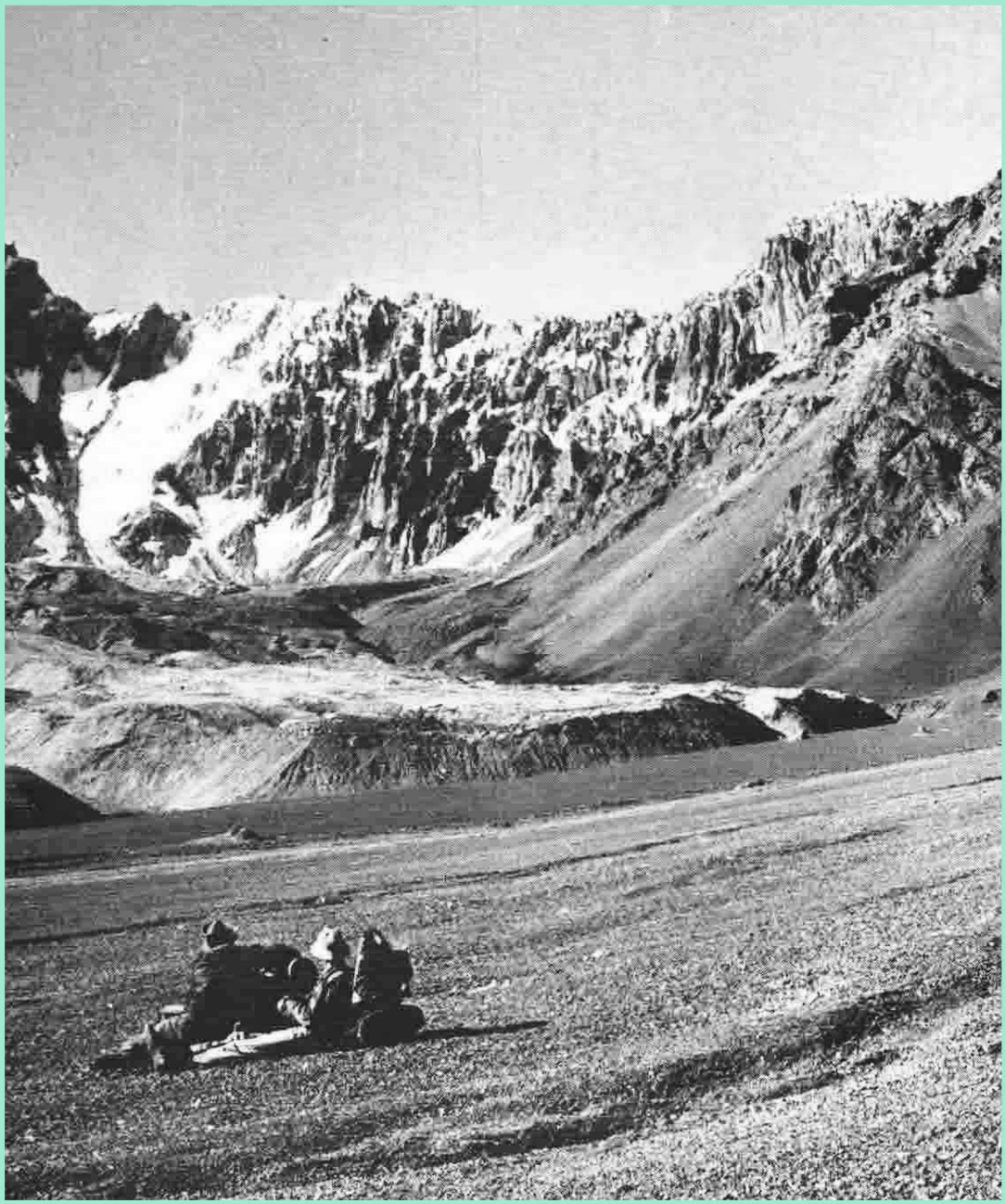

INTERNATIONAL GLACIOLOGICAL SOCIETY

REYKJAVIK,
ICELAND

1985
26-29 AUGUST

Symposium on
GLACIER MAPPING
AND SURVEYING

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GOLDEN JUBILEE

The Society's fiftieth anniversary will be celebrated in 1986 during the symposium in Cambridge and afterwards with a special tour of Switzerland. It was on the Jungfraujoch in 1936 that the Founder of the Society, Gerald Seligman, and colleagues studied the metamorphosis of snow into glacier ice.

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ICE

NEWS BULLETIN OF THE

INTERNATIONAL GLACIOLOGICAL SOCIETY

NUMBER 76 3rd ISSUE 1984

CONTENTS

The President announced at the recent meeting in Sapporo that the Society's highest award, the Seligman Crystal, is to be awarded to Mark Meier for his contributions to glaciology. A photo story on the Japanese/Chinese meetings and tours will appear in the next issue of ICE.

COVER PICTURE: Rock glacier "Tres Dedos" derived from glaciers being covered by debris, Cordillera Central de los Andes; lower snout at 3,500 m a.s.l. Photo by A.E. Corte, 1976.

AUSTRIA

In 1982 a privately financed avalanche research institute was established in St.Anton am Arlberg. It will carry out applied research by working with existing experts and cooperating with avalanche forecast offices in the Tyrol and with universities. Some 30 observations sites have been established over an area of 30 x 20 km within which instruments are checked three times a day. Data is stored and analyzed using a microcomputer. After a five-year period of data collection an avalanche forecast model will be developed and then tested during the subsequent two years. An online computer system permits the daily reduction of snow pit data and makes this data immediately available to the investigator in the field. The system is simple enough that it can be used by the non expert. In addition, an avalanche course is offered that besides improving the state of knowledge about snow and avalanche research generates financial support for the institute. The long-term objective is to improve the level of accuracy of avalanche forecasts and aid in the reduction of the avalanche hazard.

Further information on this programme can be obtained from Lawinenbeobachtungsstelle Vallugagrat, Dr rer. nat. Claus E. Rink, A-6580 St. Anton am Arlberg, Tirol, Austria.

Claus E. Rink

CHINA

This report deals with glaciological investigations in China from 1980-1984 and supplements that published previously in ICE (No. 68, 1982, 15-18) on work from 1978-1980.

The Tian Shan Glaciological Station, which was reopened in 1980, has greatly enlarged its role in glaciological research becoming not only a school for training post-graduate students but also a base for testing and experimenting with new apparatus and equipment and for international cooperative research. In addition to regional studies of contemporary and Quaternary glacierization in the Qilian Mountains and the Tian Shan, new field studies are being carried out in the Altai Mountains (1980), in the eastern section of the Kunlun Mountains (1981), in the Hengduan Mountains (1982-84 in cooperation with Lanzhou University), and on Mount Nanjiabawa at the eastern end of the Himalayas (1982-83).

In the field of snow and ice hydrology, apart from the measurements at the Tian Shan Station, a new hydrological station was established in the upper reaches of the Heihe River, in the Qilian Mountains, mainly for the observation of snow-melt runoff. New investigations were started in the Hengduan Mountains, in the southeastern part of Xizang, and in the Tanggula Mountains of the Qinghai-Xizang Plateau on the prevention of avalanches and snow drift hazards, in addition to continuing cooperation with the Xinjiang Institute of Geography. Studies of glacial geology and geomorphology as well as of Quaternary glaciation were carried out cooperatively with the Departments of Geography of Lanzhou University and Beijing University in the valley of the Ürümqi River in the Tian Shan, in the Hengduan Mountains, in the East Kunlun Mountains and in the Taibai Mountains of Shaanxi Province. To clarify some of the problems with the Quaternary glaciation of East China, work was done in Lushan, Huangshan and in the lower reaches of Changjiang.

Some notable joint international investigations were the Sino-British-Pakistan Joint Expedition in the Karakorum (1980),the Sino-Japanese Joint Investigation in the Bogda Peak area (1981)(ICE, No.69, 1982, p.2-3) and the Chinese-Australian Investigation at Casey Station (1982). In addition,important progress was made in the sea ice study of the Bohai area by the Sea Ice Division of the Institute of Oceanic Environment, National Bureau of Oceanography, and on the observation and prevention of ice jamming in several sections of the Songhuajiang and the Huanghe rivers, by the hydrological departments of the Ministry of Water Conservancy.

Some of the most notable results of recent investigations are listed below:

SNOW AND ICE RESOURCES

According to preliminary statistics from maps and LANDSAT images, the total area of mountain glaciers in west China is about 56,500 km^2, half that of Central Asia, with a total water storage estimated at 5,000 km^3 and an annual melt-water volume of 5.5 km^3, which is of great significance for the arid region of northwest China.

The glacier inventory of China is being carried out by the Lanzhou Institute of Glaciology and Geocryology. Data for the Qilian and Altai Mountains have been published, those for parts of the Tian Shan and the Pamirs are in press and those for the Kunlun Mountains, the interior basin regions of the Qinghai-Xizang Plateau, the Hengduan Mountains and the Himalayas are in process. In support of the programme, the depth of 22 glaciers was determined using a radio-echo

sounder designed by the Lanzhou Institute. With the data obtained, the empirical formula for the relationship between glacier depth and area for the Swiss Alps was applied to the determination of water storage in the Chinese glaciers.

The total number of glaciers in the inland river basins of northwest China (excluding those south of the Kunlun Mountains on the Qinghai-Xizang Plateau) is 19,874 covering 24,629.96 km^2 and constituting 1788.42 km^3 of water and an annual glacier melt volume of 17.37 km^3, or 19.4% of the total amount of the inland river basins. Several large glaciers and glacierized areas, previously unknown, have been discovered such as the Dungde flat-topped glaciers in the southwestern section of the Qilian Mountains (57.07 km^2), a large glacierized area in excess of 4000 km^2 in the west Kunlun Mountains, the Kungai Mountain glacierized region of 968 km^2 with an average snowline about 4700 m a.s.l. and a minimum of 4370 m a.s.l. never before reported for the northern part of the Chinese Pamirs and the Yinsugaidi Glacier, 41.5 km long with an area of 329.2 km^2 on the north slope of the Karakorum.

Precipitation in the high mountains of western China has been estimated from rough values of ablation and accumulation inferred from the summer temperature near the equilibrium line obtained from the glacier inventory. The annual precipitation in the glacierized areas of the Tian Shan is generally 600-800 mm, reaching a maximum of 1070 mm.

A map of snow distribution in China has been compiled by Li Peiji. Some 4,200,000 km^2 of China is covered by seasonal snow for more than 2 months and 4,800,000 km^2 by partial snow cover for less than 2 months. A maximum snow depth of 80-90 cm was found in the Altai and the Yili River valley of the Tian Shan. In the northern and eastern parts of northeast China, snow cover reached a depth of 40-50 cm similar to that found in the lower reaches of the Changjiang. The volume of water represented by the seasonal snow cover is estimated at 30 km^3. Snowmelt runoff in northeast China and in the northern part of Xingjiang has the potential for causing major floods.

GLACIER PHYSICS

Results of investigations of Batura Glacier showed that there is a type of large glacier in Central Asia with complicated physical properties that fits into neither the maritime nor continental category but should be considered a complex type. Li Jijun has provided more detailed descriptions of the maritime glaciers of the southeastern part of Xizang. Thorough investigation of the temperature regime of continental glaciers in the Qilian and Tian Shan Mountains has shown that heat released by refreezing of meltwater frequently creates a warm layer in the accumulation area and that in some regions the base of these "cold glaciers" may reach melting point and exhibit basal sliding. The continental glacier has been shown to be polythermal rather than monothermal.

Ice core and oxygen isotope analyses have shown that the firn to ice transition may take over ten years and that an annual layer might be lost in a year of strong ablation. In the Mount Bogda region annual accumulation can exceed 1000 mm.

A summary of data on movement of continental type glaciers shows that their velocity is decreasing. The average annual flow of Glacier No.1, at the Tian Shan station, from May 1980 to May 1981 was 31-73% slower than from 1959-1962; this is in agreement with the thinning and retreat of most glaciers. The emergent flow vector compensated for up to half the thinning caused by ablation. Strain rates in the crevasse zone of Glacier No.1 were in the order of 0.1/a, they were higher at the terminus where the velocity was about 2 m/a.

Chinese scientists extended their activities to research on ice caps in Antarctica. Xie Zichu studied the ice formation and fabric of Law Dome (66-77°S, 111-114°E). Fabric analysis of ice cores from two bore holes (300 m and 350 m) revealed the following layers - depositional, transitional, first fine-grained, second fine-grained, first coarse-grained and second coarse-grained. The two fine-grained layers, with a strong single-maximum fabric, corresponded to two layers of high ice shear and the coarse layers, with multi-maxima fabric, to layers of loose ice shear. The second fine-grained layer belongs to the Late Pleistocene glaciation. Experiments by Huang Maohuan et al. on repeated recrystallization of polycrystalline ice with no original preferred orientation showed a gradual tendency to an optimum orientation, transformation to cyclic structures and then disintegration into a three and even four maxima fabric. It is possible that such optimum orientation is the result of repeated superimposition in the process of recrystallization.

GEOCHEMICAL STUDIES OF ICE AND SNOW

Preliminary chemical analysis of water from Ürümqi Glacier No.1 by Luo Hongzhen et al. showed that the degree of mineralization of new snow, firn and glacial ice was generally between 10-40 mg/l; HCO_3^- was predominant in the anion and Ca and Mg in the cation. The number of ions increased from new snow to glacial ice and from the firn region to the terminus. Watanabe et al. showed that this is due to the concentration and infiltration of the surface meltwater and they found the concentration of ions in the dirty layer was 2-7 times higher than in other ice and snow. Trace element analysis proved that K, Mn, Ca, Fe, and Al were present, rather than Na and Mg, showing that the glaciers in the interior of the continent are less affected by

the sea and coastal air masses. Comparison of trace element concentrations from a number of samples in different glacierized regions showed that the Ürümqi River headwaters, Tuomur Peak, the Kunlun Mountain Pass in Qinghai, and Batura Glacier in the Karakorum were all Ca>Mg>Na types, while Hanas Glacier in the Altai Mountains was a Na>Mg>Ca or Mg>Na>Ca type and Rongbuk Glacier at Qomolangma Peak (Mt. Everest) was a Ca>Na>Mg type, showing that the latter two areas are more deeply affected by oceanic air currents. One special case was found in the ice and snow sample at Qomolangma Peak where the concentration coefficient of Cr reached 70 (EF_1), far exceeding other areas. This may be due to the lithologic character and extremely strong weathering in the area.

The average value of tritium concentration of 12 new snow samples in the summer of 1980 from several glacierized areas north of the Tanggula Mountains on the Qinghai-Xizang Plateau to the Altai Mountains was about 100 TU (minimum 56.9, maximum 168.6) with peak values in the summer months of July to August from which annual accumulation layers could be distinguished. Analysis of 95 ice and snow samples from the East Rongbuk Glacier, Qomolangma, Tian Shan Glacier No.1, three glaciers in the Qilian Mountains and also on the Qinghai-Xizang Plateau for 1978-1980 showed that the deuterium values fluctuated between -46°/$_{oo}$ and -208°/$_{oo}$, with the lowest value (-158 to -208°/$_{oo}$) at the East Rongbuk Glacier and the highest (-46.2 to -52.5°/$_{oo}$) at the tongue of the Yanglonghe Glacier in the Qilian Mountains, having an evident, but by no means strict, altitudinal effect. The seasonal variations of δ(D) and $\delta^{18}O$ were both lower in the winter season but higher in the summer. From the relationship between the two values in ice, snow, groundwater, melt water and river flow, the following empirical formula was obtained:

$$\delta^{18}O = 2.195 + 0.115\delta D \quad (r = 0.9665)$$

The average value of $\delta^{18}O$ in precipitation, ice and snow for the summer of 1981 in the east Tian Shan glacierized area was -10 to -11°/$_{oo}$, varying from -1 to -16°/$_{oo}$. The average value in daily precipitation decreased with the lowering of daily air temperature; that for ice and snow was lower than that for precipitation.

GLACIER VARIATION AND PREDICTION

Careful investigation of Batura Glacier in 1975 led to a prediction that an advance of 180-240 m would turn to retreat beween 1991 and 1997 and a 20-30 year period of recession. A subsequent forecast by Ding Dewen et al. was for a 209-303 m advance stopping between 1994 and 1996. Between 1975 and 1980 the glacier advanced an average of 40 m and the snout surface lowered from 3.3-11.8 m. These figures are slightly smaller than the 1975 forecast and may warrant some adjustment to the basic parameters in the model.

Between 1966 and 1981, several lobes of the Dungde flat-topped glacier, Qilian Mountains, retreated 38-130 m. An advance of 250 m in the 20 years before 1980 has been reported for a glacier in the Dadumahe River basin, Zhangyi region, Hexi Corridor.

Among 40 glaciers in the Anyemaqen Mountains (34-35°N, 99-101°E), in the eastern section of the Kunlun Mountains, between 1966 and 1981, 15 (38%) were obviously advancing, of which the Halong Glacier advanced 790 m in 15 years, two glaciers were evidently retreating and the remaining 23 were either stationary of fluctuating slightly. Among 31 medium- and small-sized glaciers in the Kunlun Mountains, Qinghai Province, 14 were advancing, 11 retreating and 7 stationary. Comparison of July 1973 and November 1976 LANDSAT images revealed a surging glacier that had advanced 600 ± 200 m.

According to various sources of data, mainly the comparison of maps and LANDSAT images, among the 116 sample glaciers on the Qinghai-Xizang Plateau, 35 were advancing, 62 retreating and 19 stationary.

In the Tian Shan Mountains, 39 glaciers have been surveyed over a period varying from 10-30 years. 24 were retreating, 5 advancing while the remainder were indeterminate. Comparatively systematic mass balance data have been obtained for Ürümqi Glacier No.1. In the 24 years from 1959 to 1983, 14 years were negative and 10 positive; this has been reflected in the slow thinning and retreat of the glacier and the reduction in its velocity. Glaciers in the Altai Mountains, since the air photo coverage of 1959, have been retreating. The Hanas Glacier retreated 424 m between 1959 and 1980.

Shi Yafeng

NETHERLANDS

UNIVERSITY OF UTRECHT

Modelling of ice sheets and glaciers has only a short history in the Netherlands, commencing around 1976 when J. Oerlemans, at the Royal Netherlands Meteorological Institute, started working on the ice-age problem. Since 1980, when Oerlemans moved to the State University of Utrecht, most numerical work has been carried out at the Institute for Meteorology and Oceanography. At present there are four researchers (W. Greuell, M. Lindeman, J. Oerlemans and C.J. van der Veen) working on the following subjects:

a) Interaction of ice sheet and planetary waves. Mass balance data are used to find a relation between planetary waves and the accumulation rate on glaciers. Using an atmospheric circulation model to compute planetary waves, the feedback between a growing ice sheet and its mass balance (through the planetary waves generated by the ice sheet) can be studied.

b) Numerical modelling of glacial erosion. Glacial erosion can be included schematically in numerical models to study its effect on glaciers and the interaction between ice flow, erosion and bedrock adjustment. Also, the effect of erosion on the stability of ice sheets will be investigated.

c) The use of glacier fluctuations for detecting climate changes. Using past observations, an inventory of (recent) glacier fluctuations (mainly European glaciers) will be made. With the aid of numerical models, the reaction of glaciers to climate changes can then be verified against these observations. The purpose of this study is to see whether glaciers can be used to detect climate change.

d) The stability of the West Antarctic Ice Sheet (WAIS). The dynamics of marine ice sheets and the ice shelf/ice sheet interaction are being studied by means of numerical models.

As one can infer from the short descriptions given above, the accent lies on the large-scale behaviour of ice masses and their role in climate. In particular, attention is paid to the CO_2 problem: how do glaciers and ice sheets (most notably the WAIS) react to a climatic warming?

C.J. van der Veen

NEW ZEALAND

GLACIER SNOWLINES ANNUAL PHOTOGRAPHIC SURVEY
(T.J.Chinn, Ministry of Works & Development)
The annual end-of-summer glacier snowline survey was made on a one-day flight of the Southern Alps at the end of March 1984, although a large section of the southern western alps was lost to cloud. In addition to annual variations of snowline altitude, this survey provides data for the glacier inventory and provides an opportunity to photographically record numerous other alpine features. It was found this year that an increase in altitude of the flight from 2500 m to 3000 m gave a more useful coverage of the glacier snowlines which occur around 1800 m.

SNOW HYDROLOGY
Dan Moore (University of Canterbury <CANT>) has just completed his Ph.D. thesis on snow hydrology in a rain-on-snow environment in the Waimakariri catchment. Blair Fitzharris (University of Otago <OTAGO>) has been developing a method to index the size of the seasonal snowpack using standard climate observations.

SNOW AVALANCHE RESEARCH
Peter Weir (Forest Research Institute, NZ Forest Service) has been working on use of a remote weather station for avalanche forecasting in the Craigieburn Range. Howard Conway (CANT) is continuing his Ph.D. studies of avalanche release mechanisms in the Mt. Cook area. Glen McGregor (CANT) has completed his Ph.D. thesis on factors influencing avalanching in the Craigieburn Range. Ian Owens and Blair Fitzharris (CANT & OTAGO) have completed an avalanche atlas of the Milford Track and have adapted techniques used for highways for assessing the degree of avalanche hazard. Jon Wyles (CANT) has undertaken an M.Sc. study on avalanche terrain and level of hazard in Nelson Lakes National Park.

NEW ZEALAND — ANTARCTICA

GLACIOLOGY AND HYDROLOGY
(T.J.Chinn, Ministry of Works & Development)
A monitoring programme on hydrology and glaciology in the Dry Valleys region, Antarctica, is continuing. Mass balance measurements were continued on one glacier while ablation measurements were made on the snouts of three. A number of glacier margins are being assessed for advance or retreat by measurements and photographs from fixed points.

Work is currently concentrating on correlations between temperature and melt water discharge. Flow measuring flumes and thermographs have been installed close to the glaciers of three tributaries to the Onyx River. Results from these experiments are expected to provide temperature - discharge relationships.

PILOT STUDY OF ICEBERGS
(H. Keys, Commission for the Environment)
A combined Commission for the Environment and Department of Scientific and Industrial Research Project (DSIR) has commenced a pilot study of icebergs in McMurdo Sound. Measurements and samples have been taken of 264 bergs stranded in fast ice, and results compared with satellite images. Numerous radiometer measurements have also been made to compare with the various satellite image spectral bands.

PHYSICAL PROPERTIES OF ICE
(W.H. Robinson, Physics & Engin. Lab., DSIR)
A DSIR project is making studies of sea ice at the McMurdo sea-ice airfield to measure the strain caused by a moving load. Vehicles are used as moving loads and it has been found that strain reaches a maximum with the load travelling at 45 mph.

Elastic and plastic strain measurements are also being conducted on the floating Erebus Glacier tongue.

T.J. Chinn

SWEDEN

GLACIOLOGICAL RESEARCH AT TARFALA, 1984

During the past summer we continued our surveys of a 32-stake network covering most of Storglaciären. These surveys were begun in June 1982, and have been repeated since then at intervals of 7 to 14 days during the four summer months and 30 to 60 days during the rest of the year. Summer velocities on the glacier are sensitive to water input to the subglacial hydraulic system, which in turn is dependent primarily on summer temperature, and secondarily on rainfall. Thus the pattern of acceleration varies markedly from year to year. For example, a stake near the middle of the ablation area with a mean velocity of 35 mm/d, reached peak velocities (averaged over 7 days) of 43 mm/d in mid July 1982, 63 mm/d in early July 1983, and 49 mm/d in mid June 1984. The accelerations are systematically larger in the lower part of the ablation area, where peak 7-day average summer velocities may be more than twice the mean winter velocity. In the accumulation area, in an area of comparable ice thickness, summer velocities exceed those in the winter by only 15 to 20%.

Five 4-stake strain nets within this 32-stake network have been used to obtain principal strain rates at the glacier surface. From these, the vertical strain over the known thickness can be obtained. By subtracting the vertical velocity due to flow over a known bed slope and that due to the vertical strain from the measured vertical velocities, we have calculated rates of cavity opening at the bed. Integrating these rates over time yields the mean separation of ice from the bed as a function of time. Preliminary calculations for 1983 suggest a maximum cavity volume under the entire glacier of 5 x $10^5 m^3$, which is consistent with estimates of maximum summer water storage on other glaciers.

Bore hole deformation measurements in an area about 70 m down-glacier from the crest of a riegel yielded a surprising result. Over a 7-day period in July the velocity at the surface near the hole was about 45 mm/d while that at the bed was nearly 300 mm/d. The velocity vector at the bed deviated from that at the surface by about 60°. The acceleration occurred gradually over the bottom 50% of the 132 m ice thickness. Given the measured surface velocities, this acceleration is basically consistent with requirements for conservation of mass flux through the constricted cross sectional area over the riegel.

Some detailed dye-trace measurements this past summer also produced interesting results. Tests in the same moulin at different times yielded quite different concentration vs time curves in outlet streams. On one occasion there was a single peak in each of two outlet streams, and some days later a single injection of dye yielded three peaks in each of these streams. We suppose that the latter result reflects either englacial or subglacial braiding of the flow from the moulin before it split into the two branches leading to the two separate outlet streams.

Other measurements this year included the usual mass balance studies, extending our mass balance record to 39 years; daily ablation measurements over a 10-stake net near the middle of the glacier, and weekly measurements on a 50 to 60 stake network over the entire glacier; and water and suspended sediment discharge measurements in the streams draining the glacier. We hope to be able to use these measurements to calculate water storage in the glacier for comparison with 1984 cavity volume measurements. Finally, surveys of a 23-stake network on nearby Rabots Glaciär were done roughly every two weeks during the summer.

Valter Schytt and Roger LeB. Hooke

UNITED KINGDOM — ANTARCTICA

BRITISH ANTARCTIC SURVEY

Ice shelves and their grounding lines

Calculations by J.R. Potter, J. Loynes and Dr J.G. Paren confirm that George VI Ice Shelf, if it is in equilibrium with its catchment, loses an average of about 2 metres of ice per annum from its bottom surface. The losses from this ice shelf alone represent as much as one sixth of the total ice shelf melt of Antarctica. In the 1983-84 field season, M. Pedley and Dr J.G. Paren observed the physical properties of sea water under the ice of George VI Sound to help identify the processes involved in this melting. Such studies are needed to develop a circulation model for the marine environment beneath the ice shelf. Evidence from two 13-month current meter recordings and other recent work by J.R. Potter suggest that there is a submarine constriction under George VI Ice Shelf which prohibits oceanographic communication between its two ice fronts. An explanation of this feature is important both for understanding the mass balance of the ice shelf and for a structural explanation of the origin of George VI Sound.

Tidal analysis of long-term current meter measurements at the northern end of George VI Sound show the same principal features as tidal height records: a marked reduction in the relative amplitude of the main lunar component, the M_2 tide, and a large change in phase across the semi-diurnal band. The current records also show that order 3 components are present. This type of behaviour is usually associated with energy absorption and dissipation which, near ice shelves, may

be the result of tidal flexing across the grounding line. Long base-length tiltmeters have been used by S.N. Stephenson on Rutford Ice Stream to define the tidal flexing zone in detail. A two component system was used to measure the amplitude and direction of bending as a function of distance from the grounding line. A simple elastic bending model developed by Dr C.S.M. Doake can describe qualitatively the bending profile, but in order to fit quantitatively it was found necessary to use a reduced value for the flexural rigidity. We are therefore learning about the response of ice to deformation at tidal frequencies, when the behaviour lies between that of an elastic material over very short time intervals and that of long term plastic deformation associated with creep flow in ice sheets.

Ice cores and their chemical composition

Ice cores from the Antarctic Peninsula are a particularly valuable asset for long-term records of past climate because relatively long instrumental climatic records are available to calibrate them. Dr D.A. Peel has found that the transfer function between stable oxygen isotope ratios and temperature from an ice-core-derived series differs from the theoretically predicted value. The discrepancy arises mainly from a biasing which inevitably occurs in an ice core record, where the atmospheric environment is sampled only during periods of snowfall.

Remote from industrial centres, Antarctica is well placed to obtain evidence for the extent of global-scale pollution by industrial effluents such as the heavy metals. Recent work by E.W. Wolff has confirmed the extremely small concentrations of contemporary lead reported by other investigators using an entirely different analytical approach. Parallel results for zinc and cadmium indicate that virtually all published data from the Antarctic interior are contaminated by up to a factor of ten. These data suggest that, in modern snow, lead and zinc are not enriched by large factors (probably less than 5-fold) over values expected for unenriched rock-dust in the ice. Evidently Antarctica has been substantially less influenced by airborne pollution than has Greenland.

The extremely small concentrations found in snow are paralleled by measurements of trace elements in samples of the atmospheric aerosol which A.L. Dick collected during a recent combined aerosol and snowfall sampling programme. Our data now cast serious doubt on the findings of all previous investigations of the Antarctic aerosol. These studies are making it possible to evaluate the relative importance of wet and dry deposition processes in fixing trace elements in snow. Such information is basic to an interpretation of ice core impurities as indicators of change in the atmosphere.

C.W.M. Swithinbank

U.S.A.

(*For abbreviations used see ICE, No.72 & 73, 1983, p.36)

GLACIOCHEMISTRY OF HIMALAYAN GLACIERS

(P.A. Mayewski, GRG/UNH*)

Results of several seasons of investigation into the glaciochemistry of glaciers in the Himalayas reveal that the region provides suitable glaciers. Documentation of subseasonal and multi-year climate events, specifically tracking of the Asian monsoon, can be achieved from these studies. Potential for records extending over several hundred years exist.

THERMAL STATE OF SURGING GLACIERS

(G.K.C. Clarke, Dept.of Geophysics & Astronomy, Univ.of British Columbia; S.G. Collins, Dartmouth-Hitchcock Medical Center, Hanover, N.H.; D.E. Thompson, NASA/HQ)

Measurements of Trapridge Glacier (61°14'N, 140°20'W), Yukon, Canada, reveal an unambiguous association of thermal structure and flow evolution in a surge-type glacier. Basal ice is found to be frozen to the bed in the lower glacier, but temperate in the upper glacier. A large wave-like surficial bulge has formed at the boundary between the two zones where ice from the more rapidly flowing upper zone is effectually impounded by stagnant ice of the lower zone. Bed topography does not account for the surface bulge. Thermal structure appears to be the major factor influencing present flow, but we doubt that thermal instability is the trigger for the surge. A hydraulic drainage system at the glacier bed-water upstream of the bulge is indicated. There is evidence that some substantial portion of subglacial drainage is via permeable materials underlying the glacier. We believe that disruption of flow through this permeable zone may be expected as the preconditions for surge development and that this could constitute a triggering mechanism for glacier surge.

COLUMBIA GLACIER

(M. Meier, A. Rasmussen, R. Krimmel, A. Fountain, C. Driedger, C.S. Brown, B. Vaughn, D. Miller and R. Walters, GPO/USGS)

The retreat of Columbia Glacier accelerated in 1984, during which there was an 800 m retreat. By November of 1984 the glacier had vacated 7 km^2 between the submarine terminal moraine and the terminus. This area was packed with icebergs, often 10^6 t or larger, most of 1984. The shoal zone over the terminal moraine acted as an effective filter, allowing only relatively small icebergs into Prince William Sound. The terminus thinned,

and retreated into deeper water, allowing local areas of the terminus to float, for the most part though, the entire glacier remained grounded. The velocity of the lower glacier nearly doubled, from 6-8 to 10-15 m/a, between late 1983 and late 1984. Measurements during August of 1984 demonstrated a strong correlation of lower glacier velocity with heavy rain and tidal cycle.

Temperature, precipitation, ice ablation, and discharge from a nearby river were measured as inputs to a basin runoff model. Airborne radar data from 1978 was used to produce a bedrock map of the lower glacier.

CASCADE VOLCANOES

(C. Driedger and P. Kennard, GPO/USGS)
The volume of ice on Mount Baker, Mount Rainier, Mount Hood, Three Sisters, and Mount Shasta was determined by using empirically derived formulae. The thickness of some glaciers on these volcanoes had been measured using a ground-operated monopulse radar, these data were then used to calculate volumes of glaciers for which only surface geometry was available.

The ice volumes were subdivided into drainages, to allow modelling of volcanically induced flood hazards.

OLYMPIC PENINSULA

(R. Spicer and C.S. Brown, GPO/USGS)
An inventory of the glaciers on the Olympic Peninsula has been completed.

SOUTH CASCADE GLACIER

(A.Fountain, R.Krimmel & B.Vaughn, GPO/USGS)
Mass and water balance measurements were continued at South Cascade Glacier. In addition the amount of water stored seasonally in the firn, about 10 cm averaged over the glacier, was determined by measuring the firn porosity (.15), hydraulic conductivity (7.5 m/d), and water level changes in shallow boreholes of approximately 150 cm penetrating firn/ice material with a very low hydraulic conductivity.

RHEOLOGY OF GLACIER ICE

(K.C. Jezek, USACRREL; R.B. Alley, Univ. of Wisconsin; R.H. Thomas, NASA/HQ)
We studied the rheology of glacier ice using measured strain rate data from the Ross Ice Shelf and stresses inferred from the measured heights of bottom crevasses. Our analysis is an improvement over earlier studies using ice shelf data because we account for the restraining effect of grounded ice on the stress field. We found that our data were consistent with power law creep and that the exponent, N, in the flow law equalled 3.3. Taking N = 3, we found that the flow law constant equalled $2.32 \times 10^{-25} s^{-1} (Nm^{-2})^3$ which corresponds to an average temperature of -15.9°C over the ice shelf.

WEST ANTARCTIC GLACIOLOGY

(R. Bindschadler, GSFC/NASA; D. MacAyeal, Univ. of Chicago; H.J. Zwally, GSFC/NASA; R.H. Thomas, NASA/HQ)
The 1983-84 austral summer saw the initiation of a multi-year joint NSF/NASA program in the Siple Coast area of Antarctica. The overall goals of this program are to determine the mass balance of the portion of West Antarctica which drains into the Ross Sea, to study the ice dynamics in the vicinity of the grounding line, and to study the interaction between an active ice stream and the ice shelf.

Three sites were occupied: near the grounding line of Ice Stream B (DNB: 84°10.6'S, 154°16'W) and Ice Stream C (DNC: 82°49.4'S, 152°27'W) and approximately 120 km southeast of the summit of Crary Ice Rise (CIR: 83° 47.5'S, 165°59'W). At each site a network of survey stakes was established; stake lines and strain rosettes extending more than 400 km in total. Optical leveling was completed over 185 km of these lines. The topography of the ice streams appears to consist of ridges as high as 13 m oriented along the direction of flow while on the ice shelf elevations varied less than 5 m in magnitude. From leveling and other tiltmeter measurements, DNB appears to be on ice shelf with the grounding line many kilometers upstream. If so this does not agree with the grounding line mapped by the Scott Polar Research Institute based on radio echo sounding data. The camp DNC was definitely on grounded ice while 25 km north of camp a ramp with the relatively high slope value of 5×10^{-3} agreed well with the SPRI grounding line.

At CIR the strain rates were large enough to produce measurable strain over the period of just a few days. The preliminary strain rate pattern is consistent with ice compressing in the direction of Crary Ice Rise ($2 \times 10^{-10} s^{-1}$ at CIR) and under tension ($1 \times 10^{-10} s^{-1}$ at CIR) perpendicular to this direction.

Firn studies at each camp site included obtaining a 10-m deep core,10 m temperatures (-26.25°C at DNB, -29.85°C at DNC, -25.70°C at CIR), and detailed stratigraphy over the upper 2 m. The stratigraphy showed the presence of numerous high density layers suggestive of radiation melt crusts.

COMPUTER MODELING OF ATMOSPHERIC ICE ACCRETION AND AERODYNAMIC LOADING OF TRANSMISSION LINES

(K.Z. Egelhofer & S.F. Ackley, Thayer School of Engineering,Dartmouth College & USACRREL)
In this work the development of a time-dependent computer model capable of predicting the accretion of rime ice on a wire free to rotate is described. A finite element technique is used to obtain the air velocity field adjacent to the wire. This technique is a very effective method of

analyzing this problem because the ice accretion shape is not limited to a simple geometric shape. A local collision efficiency is calculated for several radial sectors of the wire by tracking supercooled water droplets of various sizes until they collide with the wire. A heat balance is performed at the freezing surface to determine whether the liquid water droplets freeze upon impact. The asymmetric buildup of ice causes the wire to rotate, changing the flow field around the wire and the rate of ice accretion. The drag force is computed as a function of time to investigate the forces acting on the wire during an icing event.

ICING STUDIES AT MT. WASHINGTON
(J. Howe, Mt. Washington Observatory, Gorham, N.H.)
The Mt. Washington Observatory conducted a variety of tests and experiments during the 1983-84 icing season. Anemometers made by the R.M. Young Co. (propellor type) and by Environmental Instruments Inc. (hot wire type) are being evaluated for their performance in high winds and icing. Ice detectors by Rosemount and by Dataproducts New England are being evaluated for reliability and, in conjunction with rotating multicylinder exposures, for their usefulness as indicators of icing intensity. We hope also to make simultaneous measurements of cloud droplet size with the PMS FSSP and the multicylinders under icing conditions.

We are continuing the study of ice and wind loads on a wire simulating a section of high-voltage transmission line. The test installation this season includes single-axis load cells at each end of a 30-ft length of 1/4 inch wire rope, a Rosemount ice detector, and a vaned pitot-static anemometer. We are also experimenting with techniques for measuring the density of complexly-shaped ice accumulations, and for making molds of the accumulations so that replicas can be made for use in wind tunnel measurements of drag coefficients.

PRECIPITATION PROCESSES AT THE SOUTH POLE
(A.W. Hogan, Atmospheric Sciences Research Centre, SUNY-Albany)
The austral summer 1983-84 was meteorologically unusual in the Polar Plateau. The surface temperature remained cold throughout November and large hoar frost needles formed on the cold firn surface when slightly warmer air was advected to South Pole in December. These frost crystals continued to accrete, achieving lengths of 2-3 cm by early January.

The hoar frost appeared quite dense, and covered most of the surface. A one meter square area was measured on the surface in the clear air sector of 6 January, and hoar frost carefully scraped from the surface with a spatula. The frost crystals filled three one-liter sample bottles, but weighed only 130 gm. This is equivalent to 130 g/cm^2, or .13 mm of precipitation, a very small amount in relation to appearance, and to the .4 mm found to accrete in a few hours during a supercooled fog in 1976 by Kikuchi.

The hoar crystals were also unusual in that they were quite resistant to erosion by wind. Past observations have shown surface hoar to begin eroding and drifting at wind speeds of 6 to 7 m/s, but these deposits did not erode in winds of 9 to 10 m/s on 13 and 14 January. On 14 January, very warm air was advected onto the Polar Plateau, accompanied by winds in excess of 10 m/s, and relatively heavy snow. This snow continued through 15 January, and the hoar frost crystals provided surface roughness which trapped the snow to prevent its drifting. The new snow was scraped from the surface at 0200 15 January by the same technique. The 2 to 3 cm of accumulated snow was equivalent to 1.85 mm of water, which is one of the largest falls observed at South Pole.

ANISOTROPIC RANDOM MEDIUM MODEL FOR ACTIVE REMOTE SENSING OF SEA ICE
(J.K. Lee, MIT)
In the microwave remote sensing of earth terrain, the terrain medium such as snow, ice and vegetation has been modeled as a dielectric medium with random permittivity of fluctuations. However, it has always been assumed that the medium is isotropic whereas the actual medium may be anisotropic in nature. An example is the dielectric behaviour of sea ice. Due to the development of brine inclusions inside ice crystals, it has been found that the dielectric loss of sea ice is greater when the electric field is parallel to them, implying an electrical anisotropy. It has also been observed that the c-axis of the crystal structure of sea ice has a preferred azimuthal orientation.

Here we develop a model of an anisotropic random medium to be applied to active remote sensing of sea ice. The anisotropic random medium is characterized by its permittivity tensor $\bar{\bar{\varepsilon}}(\bar{r}) = \bar{\bar{\varepsilon}}_m + \bar{\bar{\varepsilon}}_f(\bar{r})$ where $\bar{\bar{\varepsilon}}_m = \langle\bar{\bar{\varepsilon}}(\bar{r})\rangle$, $\langle\bar{\bar{\varepsilon}}_f(\bar{r})\rangle = 0$ and both $\bar{\bar{\varepsilon}}_m$ and $\bar{\bar{\varepsilon}}_f(\bar{r})$ are uniaxial with the optic axis by some angle. The dyadic Green's function formalism is introduced and the first order Born approximation is taken to calculate the first order scattered intensity. Introducing the correlation functions of permittivity fluctuations in both the vertical and lateral directions, the analytic expressions for backscattering cross-sections are shown to include depolarization effects (σ_{HV}) in the single-scattering approximation.

The theoretical results are applied to interpret the experimental data by matching with the radar backscattering measurements of the Arctic sea ice at different frequencies, polarizations and viewing angles for both the first-year ice and multiyear ice.

THEORETICAL MODELS FOR INTERPRETATION OF EXPERIMENTAL DATA FROM SNOWPACKS & SNOWFALLS

(Y.Q. Jin and J.A. Kong, MIT)

A strong fluctuation theory for wave propagation through random medium is applied to the active remote sensing of snowpacks and snowfalls. Snowpacks and snowfalls are modeled as a bounded layer of random discrete spherical scatterers. Dry snow is a mixture of ice particles and air, and wet snow has an additional constituent of water drops. Gunn-Marshall size distribution is used for snowfall. Using the distorted Born approximation and the mean dyadic Green's function, we have calculated the backscattering cross sections, the bistatic scattering coefficients, and the cross-polarized backscattering cross section for active remote sensing of snowpacks, and the reflectivity factor, the attenuation and transmission coefficients through snowfalls. Various functional dependencies on wave-length, observation angle, wetness, precipitation rate and so on are established. All theoretical results are favorably matched with experimental results.

SCATTERING EFFECTS IN REMOTE SENSING OF SNOWPACK

(R.T. Shin and J.A. Kong, MIT)

In the microwave sensing of snowpack, the scattering effects due to medium inhomogeneities and surface roughness are shown to play a dominant role. Two theoretical models have been developed to characterize snowpacks. We can account for the volume scattering effects by modeling snowpack as a random medium or a homogeneous medium containing discrete scatterers. The snowfield is then modeled as layers of such scattering media bounded by rough interfaces with air above and homogeneous half-space below. The radiative transfer theory has been widely used to solve for thermal microwave emission from such media. The development of theoretical approaches has been guided by the motivation that the data set obtained in the field and plotted as functions of frequency, angle and polarization must be matched with the same set of parameters characterizing the field. The three-layer model, which includes a thin top layer caused by sunlight illumination, has been developed to explain the data collected from snow-fields displaying a diurnal change. The radiometric measurements of snowpacks in northern Vermont exhibit strong coherent interference effects caused by layering in the snowpack. Due to the weather cycles in the area, there were prominent ice layers embedded in the snowpacks. These ice layers are observed to be quite different from that of more homogeneous snowpacks. A model of multi-layered scattering medium, which accounts for the effect of coherent interference, is being developed for the interpretation of data collected from snowpacks containing ice layers.

THERMAL CONVECTION IN SNOW

(D. Powers and S. Colbeck, Thayer School of Engineering, Dartmouth College & USACRREL)

The fundamentals of natural convection in saturated porous media was reviewed and applied to snow. The present theoretical understanding of convection in porous media was extended to include phase change between solid and fluid, inclination of the layer, and uniform heat flux and permeable boundary conditions. The effects of each of the above was quantified by solving the governing partial differential equations with a finite difference scheme. Experiments were performed which confirm our modeling of heat transfer in a snow layer with a uniform heat flux bottom.

ICE COVER EFFECTS ON RIVER WAVE BEHAVIOUR

(M.G. Ferrick, USACRREL)

Rapidly varying flow waves are a primary cause of ice cover breakup on rivers. Due to the presence of ice and the difficulties involved in determining conditions in the field, analyses of river waves during breakup are subject to much uncertainty.

We conducted laboratory experiments to determine the effects of the ice cover upon these waves, and to identify the physical processes that produce these effects. The dimensionless friction scaling parameter of the St. Venant equations provides a quantitative estimate of the friction/inertia balance that dictates river wave behaviour. Knowledge of this balance is essential to interpretation and analysis of flow wave data. We apply the friction parameter in our interpretation of laboratory data.

CONFINED COMPRESSION TESTS ON SEA ICE

(J. Richter-Menge, USACRREL)

Instrumentation and equipment for performing confined compression tests on ice is being developed at CRREL. The equipment is designed to provide a constant ratio between radial confining pressure and the axial compressive stress. Comparison of instrumentation techniques indicates the importance of making axial displacement measurements directly on the ice sample.

A BRITTLE TO DUCTILE TRANSITION IN ICE UNDER TENSION

(E.M. Schulson, P.N. Lim & R.W. Lee, Thayer School of Engineering, Dartmouth College)

Experiments have revealed a brittle to less brittle transition in polycrystalline ice Ih slowly strained (10^{-6} s^{-1}) under uniaxial tension at temperatures from -20°C to -5°C. The transition occurs at a "critical grain size" ($\simeq$ 1.5 mm) where the stress to nucleate cracks equals the stress to propagate them. The tensile strength of coarser-grained aggregates is controlled by crack nucleation and obeys an expression of the Hall-Petch type; viz.

$$\sigma_T^N = \sigma_1' + k'd^{-1/2}$$

when σ_1' and k' are experimentally determined materials parameters and d is grain size. The strength of finer-grained material appears to be controlled by crack propagation and is given by the expression of the form

$$\sigma_T^P = Kd^{-1/2}$$

where K is another materials parameter.

S.F. Ackley

U.S.S.R.

In 1983 glaciological studies were conducted in the Caucasus, Central Asia, Siberia, Kamchatka, and in the Arctic and Antarctic.

CAUCASUS

The **Institute of Geography, USSR Academy of Sciences,** conducted glaciohydrometeorological studies on the glaciers of the southern slope of the western and central Caucasus. Repeated photo-theodolite surveys of the Yuzhniy Marukh and Klych glaciers were carried out. Surface velocities of the glaciers, position of their termini and the values of ablation were determined by geodetic and pseudo-parallax methods. Measurements of ice, firn and snow melting were made on Tbilisa Glacier at the glacier foot (2600 m asl) and on its tongue (3200 m asl).

The **Transcaucasian Hydrometeorological Institute** and the **Transcaucasian Hydrometeorological Service** continued observations of ablation, ice velocity, fluctuations of the termini, surface level and meltwater runoff on the Gergeti, Yuzhniy and Yugo-Vostochniy glaciers, in the Bogosskiy Range. Data from the last 10-12 years suggests that, with small changes in total ablation, the thickness of glaciers grew by 3-7 m, reaching 14 m on the Devdoraki Glacier. The increasing influence of seismic activity on Dagestan glaciers, from 1970-1974, has been revealed.

The **Alpine Geophysical Institute** carried out laboratory investigations of the relaxation and elastic properties of snow. Elastic deformation relaxed relatively quickly in snow of any density and structure within a wide range of negative temperatures. The time of stress relaxations was found to depend on snow temperature and thus provided a physical explanation for the mechanism of avalanching. Methods for improving the efficiency of impacts on the snow cover for artificial avalanche release were developed. The chemical and aerosol composition of glaciers in the Central Caucasus was analysed. A tendency for decreasing concentration of aerosols and some microelements (Ag, Ni, Cr, Pb and Mn) was revealed.

The **University of Kharkov** continued its studies of mudflows in the Baksan, Terek, Belaya, and Aragvi River basins. Maps have been compiled showing the relation of the density of mudflow sites to neotectonics and relief. The problem of the formation of mudflow basins must necessarily be considered in the context of the development of the natural environment in general.

Moscow University's Avalanche and Mudslide Laboratory carried out studies on the Dzhankuat Glacier and Dzhantuganskoye Firn Plateau. Mass balance components were computed and repeated surveys of the most active central part of the Dzhankuat Glacier were made. Two core holes were drilled to a depth of 45 and 93 m on the Dzhantuganskoye Plateau. The core was sampled for structural petrographic analysis.

The development of methods for long-range prediction of climatically-induced changes of avalanche activity was continued. A long-term forecast of avalanche activity in the Baksan River basin was prepared.

The **Geological Institute, Estonian Academy of Sciences,** began isotope investigations of an ice core from the Dzhantuganskoye Plateau that showed preservation of primary isotope information in the firn sequence.

CENTRAL ASIA

The **Central Asia Hydrometeorological Institute** developed methods for the numerical classification of dry and wet avalanches and 24-hour forecasts of wet avalanches. The characteristics of glacierization and glacier runoff under changing climatic conditions were studied. The degradation of glaciers in some regions of Central Asia has been evaluated for the last 30 years. An assessment of the general evolution of glacierization over the territory of the USSR was carried out, based on glacier mass balance data. An avalanche-danger map of the USSR has been compiled.

The Institute continued to develop and install a new telemetric system "Lavina" (Avalanche) which provides information on snow cover and meteorological elements directly from avalanche sites. Experiments were made in recording the acoustic emissions of snow avalanche-prone areas. Investigation of heat- and mass-balance components of Abramov Glacier were continued together with observations on the natural pollution of the environment under alpine conditions.

The **Institute of Geography, the Kazakh Academy of Sciences,** completed an evaluation of snowiness and avalanche hazards in the northern Tien-Shan, in the mountains of eastern Kazakhstan and around Lake Issik-kul. Dendrochronological studies of the Tien-Shan have been completed. The results have been used to reconstruct climatic conditions for the last 300 years.

Investigations in the Zailiyskiy and Dzhungarskiy Alatau have led methods for estimating the firn line altitude, water storage in glaciers and the calculation of glacier mass balances from the air temperature. Changes in the surface features of glaciers were measured on the Tsentralniy Tuyuksu, Igly Tuyuksu, Zoi Kosmodemyanskoy and Shokalskiy glaciers. The characteristics of an imminent surge were observed on the right-hand branch of Shokalskiy Glacier. The continuous advance of the Talgar Yuzhniy Glacier was recorded.

The **Kirgiz Hydrometeorological Service** continued field observations on the Golubin Glacier. The 1982/83 balance was negative at - 22.2 g/cm^2 with a winter balance of +56.7 g/cm^2 and a summer balance of -78.9 g/cm^2. The results of observations along the lower boundaries of glaciers were interpreted. Measured rates of glacier retreat were as follows: Dzhukchak Glacier 14 m, Kugandy Glacier an average of 90 m for the last 17 years (1966-1983), Golubin Glacier 10 m (1981-1983), Aksu-Zapadniy 20 m. The Chongtur, King-Tur, Aksu-Vostochniy, Ponfiliv and Aksay glaciers were stationary in 1981-1983. However, the Aksay Glacier tongue continued to degrade, developing a substantial morainic mantle. The following glaciers advanced: Davidov 15 m (1982-1983), Dolon-Ata 50-60 m (on its right), 6-8 m (on its left).

The **Tien-Shan Station, Kirgiz Academy of Sciences**, conducted observations of precipitation distribution and glacier melting in the Koilu River basin (the right tributary of the Sary-Dzhaz River) and in the Chon-Kyzylsu River basin. This region combines areas of low humidity and high precipitation. An average of 97 cm of ice melted from the glaciers of the Koilu River basin. The year-round observations of mass- and heat-balance components on the Karabatkak Glacier were continued. A map was compiled depicting the glacier's terminus and the abutting morainal lake.

The **Geological and Geophysical Institute, the Uzbek Academy of Sciences**, investigated glaciers on the northern slope of the Alai Range - upper reaches of Shakhimardansai and the Karakyzik Glacier basin. Glacier movement and mass balance observations were conducted and included differential melt rates as a function of debris cover. The composition, distribution and dynamics of rock fragments were determined. The nature of debris formation and glacier regimes under different geological and geomorphological conditions was studied.

The **Institute of Geography, the USSR Academy of Sciences**, continued to observe the surging Medvezhiy Glacier. Components of water/ice balance, type of ice formation and surface flow on the glacier tongue were determined. Discharge of the Khirsdara River was measured and studies made of hydrological and glacio-geomorphological characteristics of a season with abnormally high melting. Large amounts of accumulation (over 150 g/cm^2) and water percolation deep into the firn sequence were observed in accumulation areas of the Central Pamirs at the altitudes of about 5000 m. Data on selected mountain-glacier basins have shown it possible to use the year-to-year annual similarity of accumulation-ablation fields in the computation of glacier runoff. The relationship between quality of glacial water and types of ice-formation was revealed.

Lichenometric and phyto-indicative surveys of terminal moraines were carried out on the glaciers of the central Tien-Shan. Peat samples were collected for radio-carbon and biostratigraphic analyses aimed at reconstructing glacier dynamics during the Holocene. Glaciospeleological surveys were conducted in the limestone region of the south-eastern Pamirs. Thirteen caves with ice bodies and snow have been revealed.

The **Tadzhik Hydrometeorological Service** observed 13 glaciers. Results suggest the Medvezhiy, Zeravshanskiy, RGO, Garo, Mazarskiy, Scogach, Khadyrsha and Rama glaciers are retreating; the Shagazy, Kyzylkul and Mushketov glaciers continue to advance; and the Tro and N-507 glaciers are stationary. Hydrological, meteorological and snow surveys were carried out on Dikhadang Glacier. Changes in the glacier limit, melting and ice flow were also observed on this glacier.

The **University of Kharkov** computed meteorological conditions in the area of the Sarkand Station, Dzhungarsky Alatau, using the annual rings of Tien Shan fir trees for the period from 1865 to 1975.

SIBERIA

The **University of Tomsk** continued to investigate the Altai. Tacheometric surveys were made at the beginning and end of the ablation season on the Maliy Aktru Glacier tongue and on tongues of some other glaciers. In the 1982/83 balance year the Maliy Aktru Glacier retreated 8.5 m and the Sophyskiy Glacier 37 m (1979-1983). Values of snow accumulation in the Aktru basin appeared to be close to the mean perennial value. Mass balance of all the glaciers in the Aktru basin was determined and appeared positive for the first time in the last six years.

Radio-echo profiling of some glaciers was carried out in the Yuzhno-Chuyskiy Range. The maximum thicknesses of glaciers were as follows: Bolshoi Taldurinskiy - 80 m, Sophyskiy - 112 m, Udachniy - 84 m and Nekrasov - 96 m. A core drilling was undertaken for the first time on the Maliy Aktru Glacier.

Altai University continued glacier investigations in the Severo-Chuyskiy, Yuzhno-Chuyskiy, Terektinskiy, Zapadno-Sayanskiy and Katunskiy Ranges as well as in the northeastern Altai. The growing tempo of glacier retreat for the last decade was found to be 2-3 times greater than previously thought.

Areas of growing avalanche activity and aufeis formation were identified. Additional data on the characteristics of snow cover distribution in the lower mountain belt of the northeastern Altai were obtained.

The **Novosibirsk Institute of Railway Transport** developed recommendations for snow drift and avalanche protection along the main transportation routes of Siberia, the Far East and the Far North. Properties of the snow cover were measured and the dynamics of snow accumulation observed at avalanche sites in Krasnoyarsk, the Far East and along the Baikal-Amur Railway. Techniques and programs were developed for erecting protective snow retardation devices along avalanche-prone slopes of Krasnoyarskaya and the Far East Railways. Experimental studies of streamline flow conditions over avalanche protection constructions were performed. The dynamics of drifting snow and avalanching were studied together with the processes of snow transport and deposition, revealing the significance of pulsations in the snow/wind flow. An expected increase in stream velocity when flowing over embankments was found. New data were gathered which indicated the impact of gentle slopes in excavations on the distribution of snow drifts within and around them. The compilation of an album of avalanche protection and snow retardation devices was initiated.

The **Institute of Permafrost, Siberian Branch of the USSR Academy of Sciences**, continued studies of the composition and spreading of permafrost over the Laptev Sea shelf. Outcrops of ice wedges and underground ice masses were studied in the Lena River delta. A theory of thermal abrasion as a cryogenic process was developed. Forecasts of thermal abrasion along the banks of large reservoirs were prepared. Aspects of placer formation under the long-term impact of seasonal and perennial underground ice in mountain rocks, in the course of phase transition, were revealed. The electrical conductivity and the dynamics of the electrical field under pingos were identified. An atlas of predictive permafrost cartograms for the north of western Siberia was compiled and published. With it one can forecast the depth of seasonal thawing and freezing of soils under different climatic conditions and also predict the development of thermokarst and assess man-made impacts on the terrain.

The **Institute of Siberian and Far Eastern Geography, Siberian Branch of the USSR Academy of Sciences,** developed the theoretical basis for obtaining ice of a loose structure and investigated the metamorphism, thermophysical and some physico-mechanical properties of artificially granulated ice. Experiments were performed on the erection of complex ice structures. The Institute also studied the problem of water desalination using the drop-freezing method. A formula was developed for determining the rate of drop-freezing of water on horizontal surfaces. A genetic classification of aufeis on rivers, covering all the existing types of ice formed in the course of layered water freezing, was developed. Aspects of the occurrence and spreading of river icings in the south of eastern Siberia were studied. Data on observations of the regime of icing body deformations in the Eastern Sayans were generalized. Characteristics of the occurrence of the ice deformation field on freezing-through rivers were revealed. The formation of the electromagnetic field in the ice cover was studied during the period of icing formation. The mechanism of the impacts of cryogenic processes on rock fragments, constituting aufeis fields, was revealed. The role of cryogenesis in the spreading of aufeis areas of river valleys was also shown.

Snow and ice resources of the Angara River basin and the prospects of their utilization in the national economy were evaluated. 99.7 km^3 of ice or 213 mm of water equivalent are formed annually in the basin, making up about 35% of the annual amount of atmospheric precipitation.

The **Institute of Geography, the USSR Academy of Sciences,** carried out paleoglaciological investigations in the north of western Siberia in the vicinity of Gudan Peninsula and in the lower reaches of the Yenisei River (the region of Igarka). Studies of underground ice, including its structure, genesis and the relationship of different types of ice with relief, were conducted. Samples were taken for isotope-chemistry and palynological analyses and the absolute age of the deposits was determined.

The **Geological Institute, Estonian Academy of Sciences,** made isotope-oxygen analyses of underground ice masses in the north of western Siberia. The potential of this method for the study of buried ice was demonstrated. Correlations were revealed between variations in oxygen isotopes and the climatic conditions during their formation.

KAMCHATKA

The **Institute of Volcanology, Far East Branch of the USSR Academy of Sciences,** continued investigations of the regime of the Mutnovskiy Volcano glaciers. In 1982/83 accumulation was about 270 g/cm^2 and ablation about 280 g/cm^2. Aerial stereophotogrammetric surveys of the volcano's craters were made to estimate the dynamics and redistribution of ice masses in the inter-craterial glacier system. Glaciological and isotope-geochemical investigations were conducted on the glaciers of the Mutnovskiy and Kozelskiy volcanoes. Stratigraphic and isotope-oxygen measurements were made in the crater of the Ploskiy Tolbachik Volcano to study fluctuations in the regime of the glacier and volcanic activity for the last 100-130 years.

Secondary ejection of the Klyuchevskoy Volcano was studied in the Piyipa Glacier. The place of the outburst was identified. Lava flows destroyed 2.5 km^2 of the area of the Piyipa and Kellya glaciers; the volume of melted snow and ice was over 80 million m^3 of water. A lava field of specific surface morphology resulted from the interaction of lava and ice.

The **Institute of Geography, the USSR Academy of Sciences,** conducted phototheodolite surveys and velocity measurements of the Bilchenok and Eulchenok surging glaciers, and of some other glaciers of the Klyuchevskaya system and Mutnovskiy Volcano. The **Geological Institute, Estonian Academy of Sciences,** obtained the first samples needed for complex isotope-geochemical investigations of the stratification of vertical glacier profiles in a region of active volcanism.

THE ARCTIC

The **Arctic and Antarctic Institute** and **Leningrad University** continued meteorological, radiation and mass balance investigations on the Vavilov Dome (Severnaya Zemlya). An experimental prototype gas sampler for drill holes was tested. The age of ice at a depth of 100 m was determined to be 280 ± 60 years. Temperature and inclinometer measurements of the 410 m deep borehole drilled in 1982 were made. The results established the temperature profile of the Vavilov Dome and showed the time changes in the spatial position of the borehole.

The main parameters of the radiation field and radiation properties of the internal structure of snow strata were obtained. The dependence of snow sequence albedo and the attentuation ratio on surface albedo and the structural characteristics of the snow was determined. Methods for calculating the radiation field in a snow cover were proposed. Its attenuation, absorption and scattering in layers was calculated, as well as the thickness of the layer of active radiation for different types of snow sequences.

The **Institute of Geography, the USSR Academy of Sciences,** continued studies of West Spitsbergen glaciers. Mass balance was measured on four selected glaciers and stereophotogrammetric surveys of the Nordenskjöld and Fon-Post glaciers' lobes were made. Snow and ice samples were selected for studies of chemical contamination. The age of moraines was determined by lichenometric methods. The Institute continued to study Holocene stadial moraines and peat bogs. The total ice storage of Spitsbergen was calculated as 7.5 x 10^3 km^3. The decreasing tempo of glacier retreat when moving away from their sources of nourishment was revealed as well as the role of surging glaciers in the evolution of glacierization on the archipelago over the last 100 years. The structural-stratigraphic and isotope-geochemical properties of firn-ice sequences, typical of different ice-formation zones, were established. It was then possible to reconstruct changes in glacio-climatic conditions of the glaciers for the last 500 years from the ice cores of deep bore holes.

Complex hydrological measurements were made on the Merimer River and its tributaries in order to design a dam and reservoir to supply water for the Soviet mine "Pyramida". Stemme Lake was studied.

The **Geological Institute, Estonian Academy of Sciences,** completed isotope-geochemical analysis of the ice core from Vestfonna Ice Dome, Nordaustlandet. The data indicated that the rate of sedimentation has been nearly stable for the last 800 years and climatic conditions are in good agreement with the earlier data.

The **Institute of Mechanics, Moscow State University,** carried out numerical modelling of the evolution of the Greenland Ice Sheet. Results suggest that it is unstable. Changes in glacierization are now underway, evidently caused by abrupt changes in external conditions. In the next thousand years the area of glacierization will shrink although the ice volume will grow.

ANTARCTIC

The **Arctic and Antarctic Institute** made a tractor traverse from Mirnyy to Dome B where four polygons were established for radio echo measurements of ice flow velocity. On one of the polygons, near the ice divide, the velocity appeared to be 0.2 m/a. The drilling of a new deep bore hole, which has now reached 240 m, was started at Vostok Station. Geophysical studies were continued in a 2083 m borehole. Detailed studies of ice structure were made to a depth of 1415 m. Changes in some parameters of air inclusions and ice crystals were detected. It was concluded that the volumetric structure of ice bears genetic information that can be used for paleoclimatic reconstruction. Systematic snow surveys were continued at the Molodezhnaya, Novolazarevskaya, Vostok and Leningradskaya stations.

Physico-geographical and glacio-hydrological aspects of the formation and development of ice coasts were studied near Molodezhnaya for their use as natural moorings. The necessary work was done for selecting a new airfield for heavier planes "Il-76". Data from airphoto and terrestrial topographic surveys of three sites along the western coast of Enderby Land made in 1962, 1968, 1976 and 1978 were interpreted. Stable deglaciation over the last 16 years was revealed.

Observations on the chemical composition of atmospheric precipitation and snow cover were continued near Mirnyy. Methods for applying seismic data to the evaluation of iceberg discharge have been developed.

The **Institute of Geography, the USSR Academy of Sciences,** continued investigations under the IAGP Programme; including structural-petrographic and isotope-geochemical studies of the core from a deep hole at Komsomolskaya. A core sampling from the Ross Ice Shelf was made in cooperation with American scientists from SUNY-Buffalo. Abrupt changes in the shape and crystallographic orientation of ice and inclusions in the lower horizon of the ice shelf were revealed. Results indicate significant time variability of the oceanographic properties under the ice shelf.

A model was developed for mapping areas of extreme basal melting under the Antarctic Ice Sheet. Calculations were made of iceberg melting in transit from Antarctica to low latitudes. They were also made of longitudinal rates of ice deformation, horizontal velocity of ice flow averaged over its thickness, ice discharge through the transverse cross-section of a glacier and the residence time of an ice particle in the Antarctic Ice Sheet.

Interpretation of 6-year long observations along the Pionerskaya - Dome C route indicated a rapid decrease in the accumulation rate towards the central part of the ice sheet and its greatest spatial and time variability in the transection area from the ice slope to the high Antarctic Plateau. The data from 1977-1982 suggested a surplus of accumulation over drainage by 28% in the large watershed of East Antarctica. Observations from the last 20 years indicate an increase in surface elevation in the central part of east Antarctica and a lowering in the coastal areas. Supersaturation (up to 150%) of the atmosphere at extremely low temperatures was revealed along with the important role played by deposited ice, engendered by it, in the nourishment of cold glaciers in Central Antarctica.

Ancient glaciation sediments were revealed in the Prince Charles Mts (East Antarctica) and their age was estimated as Early Miocene. Conclusions about the active cryogenic processes occurring on the glacier bed were confirmed. The following succession of events is implied: frost fracturing and disintegration of the bedrock, cryohydration weathering under the impact of wedge-like pressure of thin water films in micro-fissures of the rock, chemical dissolution and new formations.

The principal scientific results in 1983, not reflected in the regional breakdown, include the following:

1. Compilation of the World Atlas of Snow and Ice Resources is nearing completion. Maps depicting climatic conditions for the winter period over many plains and mountain regions of the world have been finished along with maps covering summer climatic conditions of the alpine zones. These are the first presentations of the fields of liquid and solid precipitation and temperature at representative altitudes and permit calculation of the glacioclimatic resources of these territories. Snow cover duration and maximum snow storage maps for the majority of natural areas have been compiled giving the first global picture of snow cover and enable correction of the calculations of snowmelt runoff resources.

New methods for mapping accumulation at the equilibrium line altitude have been introduced. They were used to evaluate precipitation, snow cover, avalanche hazard and runoff in insufficiently studied and unstudied alpine and high-latitude regions. They allowed the first plotting of realistic fields of precipitation, runoff and snow cover in the mountains with due regard to various local conditions, based on information on the altitudinal position of glaciers. The programme and draft of the second volume of the World Atlas of Snow and Ice Resources have been compiled. The latter will be a monograph containing the scientific and methodological bases of snow/ice resource investigations and the possibilities for their utilization.

2. A hypothesis has been advanced relating the occurrence of ice sheets to precipitation and pressure variations, generated by zones of high energy in the ocean and atmosphere and showing the role of the ice sheets in preserving such zones under conditions of climatic fluctuations.

3. It was proved that riegels in trough valleys can be due to exaration instability of glacier flows; the thermal mechanism in such instability was evaluated. Studies in the Caucasus and Tien-Shan indicated the decisive contribution of bed exarations by glaciers to the formation of terminal and lateral moraines.

4. The problem of the reconstruction of the bedrock configuration of a subisothermal quasistationary glacier from its surface profile along the fixed flow line has been analyzed. It was possible to reconstruct the subglacial topography of mountain glaciers and that of the marginal area of ice sheets. A mathematical model of the thermo- and hydrodynamic processes in the centre of large ice sheets has been developed. It analyzes the impact of paleoclimatic conditions on a glacier on the basis of internal processes of heat- and mass-transfer occurring in it.

5. The spray-cone freezing method for desalination of mineralized waters has been refined. Identification of geographical aspects of artificial ice formation related to climatic and water resources of the territory is nearly accomplished. The interrelations between shear properties of snow cover and trafficability of snow on virgin soils were studied.

V.M. Kotlyakov and O.M. Shlyakhova

SNOW, ICE AND PERMAFROST GEOPHYSICS PROGRAM

GEOPHYSICAL INSTITUTE
UNIVERSITY OF ALASKA
FAIRBANKS, ALASKA, U.S.A.

High-latitude research forms the focus for most of the activities of the Geophysical Institute,where the Snow,Ice and Permafrost Geophysics Program is based; up to one-fifth of the Institute's research is specifically in this realm. Much of the research involves field studies in Alaska. Ice, in its various forms, affects almost every facet of life in high latitudes. Sea ice covers the waters of the Beaufort, Chukchi and Bering seas for up to ten months of each year. Alaska has more glaciers than any other region outside of Antarctica, the high Canadian Arctic and Greenland. Rivers and lakes may be ice covered for nine months of the year; the seasonal snow cover blankets the state annually. Permafrost underlies about three-fourths of the State and most of the continental shelf under the Beaufort Sea. For snow, ice and permafrost research, Alaska is a vast and magnificent natural laboratory.

Research and teaching in snow, ice and permafrost geophysics at the Geophysical Institute can be said to have started in 1960, with the arrival at the Institute of Dr Carl S. Benson, whose reputation as a glaciologist was already well established by his investigations of snow stratigraphy and characteristics of the inland ice sheet during his traverses of Greenland in the 1950s. There had been some previous interest and involvement by other staff members in snow and ice research, but it was rather isolated and sporadic. For example,Keith Mather,Institute director from 1963-1976, had studied snow sastrugi on Antarctic traverses, and Charles (Bucky) Wilson,who turned his attention to atmospheric research at the Institute, was a glaciologist at Little America during the IGY, taking part in the 1600-mile Victoria Land Traverse. The most significant of these isolated studies was perhaps the first detailed investigation of the structural and mechanical properties of sea ice, carried out by the late Harold Peyton between 1959 and the mid-1960s. His data set eventually formed the basis for designing the offshore petroleum drilling platforms in seasonally ice-covered Cook Inlet in Alaska and similar structures in the Arctic Ocean.

Carl Benson brought with him a breadth in outlook and activities, characterized by his definition of glaciology as being anything having to do with frozen water substance. With typical abandon he plunged into"glaciological"research involving ice fog, glacier-volcano interaction on Mt. Wrangell, the seasonal snow cover of northern Alaska and the freezing of turbulent streams, among others. Graduate students in glaciology began to emerge, such as Larry Mayo and Dennis Trabant; they now monitor most of the glaciers being studied in Alaska for the U.S. Geological Survey in Fairbanks.

In the second half of the sixties two new staff members arrived, both basically micrometeorologists, but with a strong interest in snow and ice. Dr Gerd Wendler arrived from the University of Innsbruck where he had studied under the late Professor Herfried Hoinkes, and served his glaciological apprenticeship on the glaciers of the Austrian Alps. Dr Gunter Weller came from the University of Melbourne with experience on energy balance measurements over sea ice and snow-fields at Mawson and Plateau Station in Antarctica.

Weather station on McCall Glacier

The first big glaciological project at the Geophysical Institute was funded by the National Science Foundation in 1969. Wendler, Benson and Weller managed the project, which led to a six-year study of the McCall Glacier in the Brooks Range, a glacier that

had been briefly investigated during the IGY. Heat, mass and water balances were studied, together with glacier movement, ice foliation and aufeis formation below the glacier. In the meantime, other glaciological projects proceeded, including Benson's diverse schemes already listed, plus new ones: Wendler's and Weller's energy balance studies over snow and tundra at various locations, and a joint effort with the meteorologists at the Institute, primarily Glenn Shaw and Bjorn Holmgren (a visitor from Uppsala), to examine radiation-ice interactions in the Arctic Ocean at Ice Island T-3, at the AIDJEX (Arctic Ice Dynamics Joint Experiment) stations, and at Barrow. This led to (among other things) the discovery or rather rediscovery of Arctic haze by Glenn Shaw.

A big boost to the glaciology program occurred during the early to mid-1970s when six new members joined the Geophysical Institute's glaciology group, bringing considerable diversity and expertise to the program. Dr Will Harrison, originally a nuclear physicist, began working on surging glaciers. He quickly became involved in a major project on Variegated Glacier in southeast Alaska, with researchers from the University of Washington and Caltech. Dr Thomas Osterkamp who had come to the University of Alaska in 1968 and had initiated the teaching of ice physics in the Physics Department joined the Institute and started research projects on permafrost and river ice. Dr William Sackinger and Dr Lewis Shapiro began research on sea ice dynamics, using a shore-based radar at Barrow, and on the mechanical and structural properties of sea ice. Two graduates who received their PhD degrees in the early seventies, Dr Sue Ann Bowling and Dr William Stringer, became involved in research on ice-climate interactions and sea ice remote-sensing by satellite,respectively.

Sea ice override of the beach at Pt. Barrow

The Outer Continental Shelf Environmental Assessment Program (OCSEAP) started by NOAA (National Oceanic and Atmospheric Administration) in Alaska in the mid-seventies provided excellent opportunities for sea ice and permafrost research. An objective of this program, among others, was to assess the hazards posed by sea ice and permafrost to offshore petroleum development. The Institute's staff was heavily involved in research on sea ice characterization by remote sensing, ice override of Arctic beaches, the mechanical properties of sea ice using in situ measurements, stress measurements in ice using transducers and in the pioneering work on an entirely new field of investigation, that of subsea permafrost. These latter investigations, including the detection and characterization of permafrost under the ocean floor by seismic methods, drilling, probing and development of coupled heat-salt flux models, was carried out by a group that included CRREL (Cold Regions Research and Engineering Laboratory) and the U.S.G.S. (United States Geological Survey). Dr John Morack of the Physics Department and Dr James Rogers of the Engineering Department of the University of Alaska-Fairbanks, both with joint appointments at the Institute, also participated in these studies. A post-doctoral fellow, Dr Jerome Johnson, joined the staff to work on sea ice problems. He was also interested in avalanche studies and is now with CRREL.

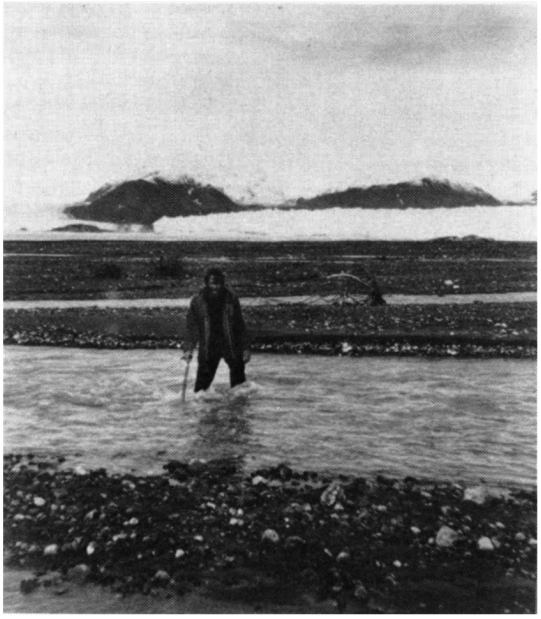
Using magnetic induction methods to detect ground ice

More recent staff additions include Dr Joan Gosink, a hydrodynamicist and numerical modeler interested in ice-covered lakes and rivers, and Dr Koji Kawasaki, whose expertise lies in using geophysical methods to detect permafrost. Dr Keith Echelmeyer has recently joined the Institute as a post-doctoral fellow to work with Will Harrison on the Jakobshavns Glacier Project in Greenland. Dr Echelmeyer played a key role in the initiation of this project. The expertise of the staff has been deliberately allowed to remain very broad, covering all frozen water substances, as envisioned by Carl Benson 25 years ago.

Recent research activities by Institute staff involve the major areas and projects listed below. More details are contained in the report on recent work in Alaska published in ICE, No. 72 & 73, 2nd & 3rd Issues, 1983, p.23-31.

GLACIERS

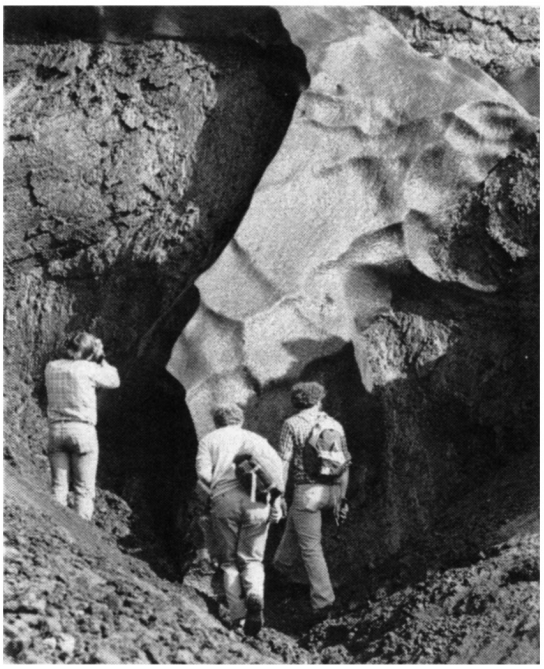
The largest glacier project at present is the study of movement and deformation of Jakobshavns Glacier, a major ice stream flowing out from the Greenland Ice Sheet. When Variegated Glacier, in southeast Alaska, surged again in 1982-83, it was fully instrumented; data analysis is still underway. Glacier-volcano interaction studies continue in Alaska on Mt. Wrangell and Mt. Redoubt and deep drilling is planned for the near future to determine isotope ratios on Mt. Wrangell. Jökulhlaups of Standline Lake, dammed by the Triumvirate Glacier, are being investigated as are the effects of glaciers on the hydrology of basins proposed for some major hydroelectric developments in Alaska.



Institute glaciologist on his way to work, Hubbard Glacier, SE Alaska, in background

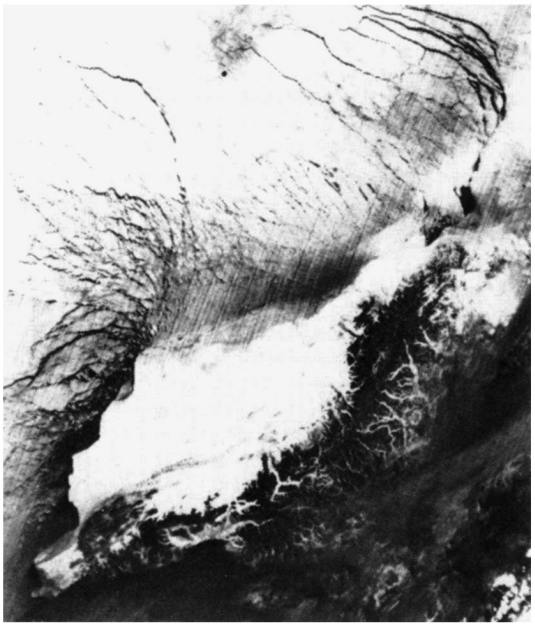
PERMAFROST

The major emphasis by the Institute in snow, ice and permafrost research is now on permafrost. A variety of geophysical detection methods are being tested, including EM, resistivity, and telluric currents. For calibration, an ice mass of known characteristics and size has been created by filling a ditch in permafrost terrain with water and allowing it to freeze. Climatic changes recorded in the temperature regime of permafrost are being investigated, for short-term



Exposed ice mass near Fairbanks, Alaska

time scales and for pre-Holocene times. Studies of offshore permafrost in the Arctic Ocean continue, using drilling, probing, temperature analysis and the on-going development of coupled heat and salt transfer models.



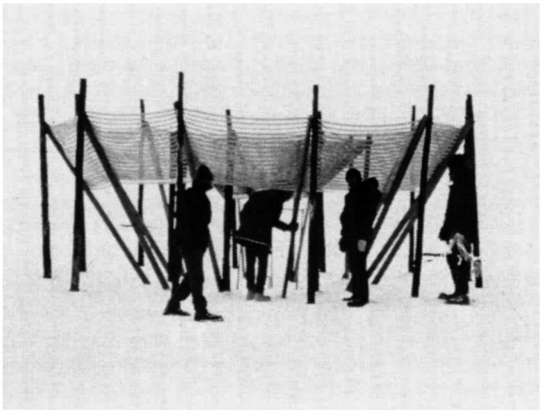
NOAA satellite photo of sea ice off the northern coast of Alaska, Point Barrow is in the centre left half

SEA ICE

Sea ice studies, which were most intense during OCSEAP, continue. Characterization of sea ice around the coast of Alaska occurs by satellite remote sensing which aids in determining ice extent, floe sizes, ridges and movements. A Landsat Quick-look read-out station operated by the Institute allows real-time access to ice imagery. Ice islands are being tracked by satellite-interrogated buoys, and studies of spray ice accretion on structures and ships, and of ice electrical resistivity continue.

SNOW

The seasonal snow cover of Alaska continues to be the subject of various studies. Winter precipitation along the Arctic coast is difficult to estimate because of horizontal snow drift; use of Wyoming-style precipitation gauges has corrected previous estimates of precipitation by a factor of three. Convection in the low-density, depth-hoar dominated snow pack of interior Alaska is being



Wyoming snow gauge used on the North Slope of Alaska to measure precipitation

investigated, and studies on the use of various materials to reduce snow albedos and accelerate spring snow-melt continue. Katabatic winds and snow drift are being studied jointly with the French in Antarctica between Dome C and Dumont-d'Urville.

RIVER AND LAKE ICE

A major project on the study of frazil and anchor ice in streams is investigating nucleation, growth, characteristics and evolution. Large-scale processes include the study of freeze-up and breakup dynamics of rivers, ice forces on bridges, and stream icings (aufeis). Models of the hydrodynamic and thermal regime in stratified lakes with and without ice covers are being developed with a view to applying them to thaw lakes on the Arctic Coastal Plain and to manmade reservoirs. Other problems associated with large reservoirs in high latitudes are being investigated, including frazil ice jams and the entrainment of frazil and anchor ice into turbine intakes, ice cover flexure during water draw-down, and the creation of open water and ice fog downstream from reservoirs.

Tail section of buried LC-130, Antarctica, near D-57 automatic weather station used for katabatic wind and snow drift studies

The University of Alaska offers graduate study programs leading to the M.S. and Ph.D. degrees through the Department of Geology and Geophysics. Courses taught by Geophysical Institute staff in the Snow, Ice and Permafrost Option include the following:

- Geos 614 - Snow and Ice in the Environment
- Geos 615 - Sea ice
- Geos 616 - Permafrost
- Geos 694 - Glaciers

A large number of other courses are offered at the University of Alaska-Fairbanks in various departments, addressing scientific aspects of snow, ice and permafrost in the Arctic and subarctic regions. They include courses in glacial geomorphology and geology, remote sensing, meteorology, atmospheric dynamics and physics of the lower atmosphere, also in physical oceanography and ocean engineering, and in frozen ground and ice engineering, Arctic hydrology and Arctic heat and mass transport.

In addition to the senior teaching and research staff already mentioned, the Institute has an active program in which visiting professors teach and participate in the research on snow, ice and permafrost geophysics.

Gunter Weller

ANNUAL GENERAL MEETING 1984

MINUTES OF THE ANNUAL GENERAL MEETING OF THE INTERNATIONAL GLACIOLOGICAL SOCIETY

7 September in Hokkaido Koseinenkin Kaikan, Sapporo, Japan

The President, Dr C.W.M. Swithinbank, was in the Chair. 90 members from 15 countries were present.

1. The Minutes of the 1983 Annual General Meeting, published in ICE No. 72 & 73, 2nd and 3rd Issues 1983, p.43-45, were approved and signed by the Chairman.

2. The President gave his report for 1983-84: This is our first meeting in Japan and you may well ask why we have not been here before. There are 84 Japanese members of the Society and this is a greater number than in any other country east of the Greenwich meridian. Here in Sapporo we have 186 registered participants for the Symposium on Snow and Ice Processes at the Earth's Surface, yet Japanese glaciologists outnumber the overseas visitors by 2-1. This is a fair measure of the healthy state of glaciology in this part of the world and of the loyalty of our far-flung membership.

The **Journal of Glaciology** continues to serve as the most visible product of our corporate endeavour. The three 1983 issues totalled 524 pages. Last year the Council decided, with some regret but on the grounds of cost, that we should change the format for the first time in 37 years. You have now seen the new format with number 104 and I hope that you are pleased with the appearance. We believe that the cover picture can serve to remind us of the scope of glaciology as the Society defines it, and also perhaps of the abiding beauty of our part of the natural world. Last year I appealed to you to submit your best pictures for the cover; some have done so but we need a broader selection and in particular, good illustrations of phenomena other than glaciers.

With the new format we can publish 20 per cent more papers at a cost saving of 40 per cent, and we have removed the page limit that was necessarily imposed on the editors some years ago to balance the books. We have been able to do this partly because of the financial savings inherent in the new format and partly because of a grant-in-aid from the U.S. National Science Foundation. We are grateful to them for this help.

Last year also, Council appointed a working group to consider the implications of changes in publishing technology and whether changes should be made in the editing system. Members were Bill Budd, Sam Colbeck, Keiji Higuchi, John Glen,and Mike Kuhn, with the President, Treasurer and Secretary General. We sought the views of the Editorial Board and of the Society's membership-at-large. On the basis of responses, recommendations were made to the Council, and at its meeting on 5 September 1984 Council decided that to reflect the international character of the Society, there should be wider international involvement in the scientific editing of articles; that a House Editor should be employed to coordinate all stages of production from the Society's office; and that there should henceforth be a standing Committee to recommend to Council a policy for the Society's publications. By means of these changes we believe that it should be possible to reduce the elapsed time from submission of articles to publication to around six months. This, I think you will agree, is a consummation devoutly to be wished.

Together, these are the biggest changes that have overtaken the **Journal** since Gerald Seligman began publishing. You,and only you, can judge whether they turn out for the better. But I do think that we should take this opportunity to thank John Glen, Ray Adie, David Homer, and Doris Johnson for their tireless efforts over the years to keep the **Journal** at the head of its field. From now on we shall try to work with a longer list of scientific editors. Although each one will handle fewer articles, we intend to maintain the same high standards as before. Since continuity is important, particularly during the transition period, we hope that the existing scientific editors will bear with us. Not all of them have agreed with the changes, but it is greatly to their credit that they have accepted them and have indicated their willingness to serve under the new system. Few learned societies are blessed with such unswerving loyalty and for this we must be endlessly grateful.

The **Annals of Glaciology** continues to flourish. Volume 5, the Proceedings of the Symposium on Ice and Climate Modelling, has now been published and is available to those who have not already obtained a copy. This particular **Annals** volume placed a special burden on the editors and referees owing to the interdisciplinary nature of the subject matter. But in spite of it they have achieved a nice balance between original research contri-

butions on the one hand and authoritative review articles on the other. For this we must thank the Chief Editor Steve Schneider, the Associate Editors Ed Birchfield, Peter Kilworth, Hans Oerlemans, Uwe Radok, Dominique Raynaud, Bert Semtner, and Neil Young, the House Editor Ailsa Macqueen, and very many anonymous referees.

We now have an enviable reputation for publishing timely symposium volumes and as a result, there is every reason to be optimistic about the future of the series. We can foresee not only an annual volume resulting from our own symposia but also a continuing demand from other organizations for help in publishing their own glaciological symposia. The Cambridge office staff can comfortably handle two volumes per annum and next year we shall not only publish volume 6, the proceedings of the Sapporo symposium, but also the proceedings of the National Research Council of Canada Symposium on Snow and Ice Chemistry and the Atmosphere that was held in Peterborough, Ontario, 19-24 August 1984.

Four issues of ICE have been published in the last 12 months and for this once again we must thank the editor Simon Ommanney. Please remember that the size of each issue is critically dependent on contributions from national correspondents. We rely on our correspondents and appreciate that considerable effort is sometimes required to extract from their colleagues reports of current field work. But it remains true that many members find the reports an excellent way of keeping up with our far-flung activities.

Plans for future symposia are in a healthy state. For 1985 we have a Symposium on Glacier Mapping and Surveying to be held in Reykjavik, Iceland, 26-29 August. The second circular was distributed in May and reminds us that the meeting will be followed by a 3-day study tour of southern Iceland. In 1986 we celebrate the Society's 50th anniversary with a Symposium on Remote Sensing in Glaciology to be held in Cambridge, England, 7-12 September. One day during the week will be set aside for a series of invited review papers discussing progress in glaciology over the last 50 years. The meeting will be followed by a study tour of Switzerland.

We shall continue to hold symposia in different parts of the world. But we depend on glaciologists everywhere to lead us to the right places, and we depend on members in the host country to take on the local arrangements. Beyond 1986, discussions are in progress with a view to meetings in Switzerland Australia, Norway, western North America, and Finland.

The new Council that takes office at the conclusion of this meeting will have on it representatives of 9 different countries. This is not a bad showing for a management structure that is limited by Constitution to 12 Elective Members. The Society has 747 paid-up members and rather too many still owing for 1984. The services that we can render to members are very much affected by the total of membership income, and I ask all of you to help by recruiting new members. We have a library circulation of the **Journal** of 525 and this too represents a vital source of income. However, about 100 libraries have cancelled their subscriptions in the past two years, so we need to find new libraries to recover the lost income.

The Cambridge office has suffered some upheavals this year. I hasten to add that the headquarters of the Society is still in the Scott Polar Research Institute and will remain there thanks to the generosity of the new Director, Dr David Drewry, who has followed his predecessors in welcoming our continued presence. The connection has been of immense benefit to the Society over many years. But as we have grown,we expanded some time ago into rented accommodation across the road. Much to our regret, the lease on these premises expired in August a short time before some of us had to leave for Japan. The staff had to oversee and participate in moving most of our wordly goods into new rented accommodation. That this was accomplished at a particularly busy time of the year without seriously affecting the administrative routine or the setting of papers for publication reflects great credit not only on our Secretary General, Hilda Richardson, who had conducted all the negotiations, but also on Pat Lander and Mary Parker. Together with Ailsa Macqueen, Beverley Baker, and Sylva Gethin - none of whom works full-time for the Society - our small staff not only looks after all membership and symposium matters but now also keys in every **Annals** and every **Journal** article as soon as it arrives from the Editors. Office equipment continues to improve and we have every intention of improving the appearance of the Society's publications as soon as technology allows this to be achieved within our means.

Last but not least, I have a happy announcement to make. Your Council, acting on a recommendation of the Awards Committee, has unanimously decided to award the Seligman Crystal to Dr Mark Meier. The crystal will be presented at the Symposium on Glacier Mapping and Surveying to be held in Reykjavik, Iceland, 26-29 August 1985. The decision to reward Mark Meier in this way was based principally on his pioneering work on the flow of Saskatchewan Glacier,on seminal contributions to the understanding of heat, ice and water balances, on glacier surges, on remote sensing of snow and ice, and on the stability and dynamics of glaciers. Other factors which influenced our decision were his success in attracting an outstanding team of glaciologists to work in Tacoma and the north-west, his leadership in U.S. glaciology and in the International Commission on Snow and Ice, and his recent

apogee as President of the International Association of Hydrological Sciences. He has done sterling service as an ambassador for glaciology in high places.

This is my last report to you as President. In three years in office I have had to preside over some radical changes in parts of our affairs and it has not always been easy. But throughout I have enjoyed the support of a strong and representative Council as well as of a series of dedicated working groups whose members took immense trouble to sound out the views of other glaciologist before making clear-cut recommendations. We must continue to be guided by the needs of glaciology and the needs of our members. I would like to thank all whose wise counsel has made it generally a pleasure and always a priviledge to help in guiding the Society. And here I must point a finger at Hilda Richardson. Presidents come and go but Hilda - or so it seems - goes on forever. Her encyclopaedic knowledge of the affairs of the Society - not to mention the affairs of glaciologists - is placed at the disposal of each President on election, and is interpreted to him with tact and skill thereafter. Once we even thought of insuring her life but no company would accept the Society's valuation. So to Hilda, my heartfelt gratitude.

At this point I have to hand over the reins to Hans Röthlisberger,a distinguished glaciologist from Switzerland, the ancestral home of glaciology. He has a long record of interest in the Society, service on Council, and dedication to internationalism in pursuit of our goals. With him at the helm, and with your continued support, I have confidence in the future of the Society.

3. The Treasurer, Dr J.A. Heap, submitted a reort 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 1983 there was a deficit of £2,120 in 1982 and a surplus of £6,136 in 1983. You will also see that the Accumulated Fund shows that a deficit of £13,251 in 1982 has changed to a surplus of £1,267 in 1983. While these figures appear to suggest that the clear downward trend in the Society's finances to which I referred in my last report has been reversed, I need to sound a strongly cautionary note on two grounds. The first is that the change from deficit to surplus arises from unexpectedly higher income and not from savings on the expenditure side. The two main sources of this unexpected income were higher income from page charges and the surplus on the dollar exchange rate. We cannot plan an income from these sources at these levels in the future. The second is that the Society received a generous and unconditional grant of £8,382 from the United States National Science Foundation. Without these sums the surplus for the year and the Accumulated Fund would present a much less rosy picture.

In my last report to you I pointed out that the **Contingencies Fund** stood at £73 and that this should be increased as a matter of priority. We were not able to transfer any resources to the Contingencies Fund during 1983 and it still remains a matter of high priority that we should build up the Contingencies Fund over the next few years to about £10,000. The Society must have means of meeting the unexpected, such as the cancellation of a symposium,and consequent loss of income from the associated **Annals** volume.

I recommend that you accept the audited accounts for 1983.

Following the pattern of my last report to you, I now turn to the future. Last year I said that "the key to future financial viability, to maintaining the service to Members of the Society and to improving that service now lies in making as much use as possible of our in-house publishing facilities". At the end of 1983 we gave up having the text of the **Journal** set by the printer and moved to using our own word processing facilities and paste up of the final text for printing. As a result we shall effectively increase the length of the **Journal** by 20% at a printing cost of £10,000, a saving of ca. £8,000 on the 1983 printing costs. The Secretary General, the President and I have recently taken further decisions about the Society's word processors and facilities to produce good camea ready copy which will enable us to produce a better looking page, reduce the strain on staff and ease the problem of setting complicated mathematics.

It is my hope that the changes in editing procedures approved by your Council this week will also enable us to provide better service to members by speeding up publication of papers accepted for the **Journal**.

I am confident that the centralization of the editing process in Cambridge, in the Society's new premises, with a professional editor working alongside our word processor staff, offers a prospect of very considerably reducing the publication time of **Journal** papers; and can be achieved without spending more than at present on the editorial side of the Society's activities. I am also confident that unless the publication time of the **Journal** papers is substantially reduced the consequences for the future of the Society could be gravely prejudicial. We must be competitive."

4. Election of Auditors for the 1984 accounts. W.H. Mathews proposed and K. Kusunoki seconded that Messrs. Peters, Elworthy and Moore of Cambridge be elected auditors for the 1984 accounts. This was carried unanimously.

5. Elections to the Council 1984-87:
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:

President	H. Röthlisberger
Vice Presidents (2)	S.C. Colbeck
	P. Schwerdtfeger
Elective Members (4)	B. Hallet
	D. Raynaud
	R.S. Williams
	G.J. Young

The retiring President, Dr C.W.M.Swithinbank, invited the incoming President, Dr H. Röthlisberger, to address the meeting.

6. Acceptance speech by H. Röthlisberger:
In his acceptance speech the new President thanked the members for the vote of confidence and then commented on two aspects of the present situation. The first is the international character of the Society, which is obvious from - besides the holding of the 1984 Annual General Meeting in Sapporo - the fact that the new (Swiss) President's mother tongue is not English, and that the vice presidents come from Japan, the U.S.A. and Australia. The second point is that at the Sapporo meeting we have seen a great number of young motivated participants. It is to be hoped that the trend set by the Japanese scientific community will spread to many more countries, so that the Society will be prepared when, in a not too distant future, presidents will no longer be much older that the Society itself. Finally Dr Röthlisberger expressed his gratitude to his predecessor for passing on to him an agenda in which everything is well under control. He then thanked the Secretary General and her staff for the constant care and superb professional way in which the daily business of the Society is run.

BRITISH BRANCH MEETING

20-21 September 1984, Aberdeen, Scotland

The British Branch of the Society met for its annual meeting on September 20th and 21st, 1984, in Aberdeen. A field trip to visit some well exposed glacial features in the Cairngorm mountains followed the meeting and was well attended. The excursion coincided with some of the first snow of the winter.

The titles and authors of the papers presented were:

Ian Evans:
Cirques of Cumbria.
David Roberts:
Late Wisconsin glacial palaeoclimate of the Falkland Islands.
Chalmers Clapperton:
A late glacial event in Ecuador.
Andrew Dugmore:
Late Holocene glacier fluctuations in South Iceland.
Neil McIntyre:
Ice dynamics from Antarctic IS topography.
Eric Wolff:
A reappraisal of heavy metal concentrations in Antarctic snow.
Mark Pedley:
A summer on George VI Sound.
Eric Wolff:
A linear flow law for polar ice.
David Collins:
Electrical conductivity of meltwater in winter runoff from Alpine glaciers.
Rob Ferguson:
High mountain meltwater yield: annual variation and its forecasting.
Richard Harding:
Turbulent transfers over snow.
Liz Morris:
Hydrochemical processes during snowmelt.
Roland Souchez:
On the evolution in stable isotopes of water and ice during freezing.
Campbell Gemmell:
Facies and stable isotope characteristics of the basal ice.
Chris Durbin:
Stable isotope studies of glacial hydrology at Austre Okstindbreen.
Hermann Engelhardt:
The surge of the Variegated Glacier.
Martin Sharp:
Time/space variation in abrasion rates in a surge-type glacier.
Dominic Sharp:
Basal fragment shape and concentration: their role in lodgement.
Richard Hindmarsh:
Boulton v Hallet: not a dualism?
Adrian Hall:
The use of weathered rock as an indicator of the intensity of glacial erosion.
Brian Whalley and A.F.Gellatly:
Glaciology and glacial geomorphology of mountain icecaps in North Norway.
Julian Dowdeswell:
The distribution and character of sediment in a tidewater glacier, southern Baffin Island.

The meeting next year will take place on September 12th and 13th at the Department of Geography, University of Manchester M13 9PL (details from Dr D. Collins at Manchester).

Dougal Goodman
British Branch President

The following papers and short notes have been accepted for publication in the **Journal of Glaciology**:

R.J. Small, I.R. Beecroft and D.M. Stirling:
Rates of deposition on lateral moraine embankments, glacier de Tsidjiore Nouve, Valais, Switzerland.
B.N. Boots and R.K. Burn:
Analyzing the spatial distribution of drumlins: a two-phase mosaic approach.
D.R. MacAyeal:
Optimal measurement of ice-sheet deformation from surface-marker arrays.
V.N. Nijampurkar, N. Bhandari, D.V. Barle and U. Bhattacharya:
Radiometric chronology of Changme-Khangpu Glacier, Sikkim.
T. Hughes:
We look but do not see.
R.G.W. Ward, E.D.G. Langmuir and B. Beattie:
Snow profiles and avalanche activity in the Cairngorm Mountains, Scotland.
N.F. McIntyre:
A re-assessment of the mass balance of the Lambert Glacier drainage basin,Antarctica.
W. Ambach:
Characteristics of the heat balance of the Greenland ice sheet for modelling.
E.M. Shoemaker:
Cylindrical flow in or over channels of irregular shape.
P.G. Johnson and J.M. Power:
Flood and landslide events, Peyto Glacier terminus, Alberta, Canada,11-14 July 1983.
Jørn-Ole Andreasen:
Apparent short-term glacier velocity variations.
Gee Tsang and T. O'D. Hanley:
Frazil formation in water of different salinities and supercoolings.
A. Judson and R.M. King:
An index of regional snow-pack stability based on natural slab avalanches.
E.M. Morris and A.G. Thomas:
Preferential discharge of pollutants during snowmelt in Scotland.
D. Dahl-Jensen:
Determination of the flow properties at Dye 3, South Greenland, by bore-hole tilting measurements and perturbation modelling.
E.M. Shoemaker:
The formation of fjord thresholds.
O. Humlum:
Changes in particle size, shape, roundness, and fabric for glacial fraction load with distance from source, Mýrdalsjökull, Iceland.
S.S. Grigoryan, S.A. Buyanov, M.S. Krass and P.A. Shumskiy:
A mathematical model of ice sheets and the calculation of the evolution of the Greenland ice sheet.
N.F. McIntyre:
The dynamics of ice-sheet outlets.

Short Notes:

K. McGuffie and A. Henderson-Sellers:
The diurnal hysteresis of snow albedo.
D.R. Butler and G.P. Macanson:
A reconstruction of snow avalanche characteristics in Montana, USA, using vegetative indicators.
R.J. Braithwaite:
Can the mass balance of a glacier be estimated from its equilibrium-line altitude?

RECENT MEETINGS (of other organizations)

SYMPOSIUM ON SNOW AND ICE AND THE ATMOSPHERE

19-24 August 1984, Trent University, Peterborough, Ontario, Canada

This symposium attracted 84 delegates from eleven countries. Invited speakers included L.A. Barrie, C.F. Boutron, C.U. Hammer, S. Jossaume, and B. Stauffer.

Topics discussed included the variation in atmospheric CO_2 based on analysis of air bubbles in glacier ice, long-term variations in atmospheric pollution and climate based on deep Arctic and Antarctic ice cores, the roles of snow and ice in the regime of lakes including "acid shock" during spring melt, the impact of volcanic eruptions in ice core research etc. The meetings were structured to promote discussion between the diverse groups of scientists which were represented.

The Symposium was organized by the NRC Subcommittee on Glaciers and was sponsored by the Royal Society of Canada,Energy, Mines and Resources Canada, Environment Canada, the Commission on Atmospheric Chemistry and Global Pollution, and Trent University.

The Proceedings will be published by the IGS as an issue of the Annals of Glaciology. The Chief Scientific Editor is Dr W.P.Adams. The issue, Volume 7, will appear in 1985.

Copies of the Symposium abstracts can be obtained from Peter Adams, Watershed Ecosystems Program, Trent University, Peterborough, Ontario, K9J 7B8, Canada.

Peter Adams

FUTURE MEETINGS (of other organizations)

SNOW MANAGEMENT FOR AGRICULTURE WORKSHOP/SYMPOSIUM

9-11 July 1985, Swift Current, Saskatchewan, Canada

The theme is the role of snow management in conventional and reduced tillage systems for the production of cereal, forage, oilseed and pulse crops.

PROGRAM

There will be the following sessions:-

1. Physics, economics and viability of agricultural snow management
2. Snowcover insulation for winter crops
3. Water enrichment
4. Snow management & reduced tillage systems
5. Snow management and forage production
6. Snow management & grain cropping systems
7. Snow management in soil energy conservation efforts
8. Snow management & socio-economic benefits

PAPERS

Titles, along with a short (400 words) abstract, should be submitted by March 1,1985. Preference for oral presentations will be given to early respondents, others may be asked to make poster presentations. The proceedings will be published. Specifications and formats will be mailed to authors of accepted papers. The official languages will be English and French. Papers may be submitted in either language. Simultaneous translation will not be provided.

REGISTRATION AND ACCOMMODATION

Information on registration and accommodation will be provided at a later date. Registration fees should be low. Blocks of rooms have been reserved at motels near the center of symposium activity. A reception will be held on Monday, 8 July and the program will finish with a field tour on Thursday, July 11. For further information write to:-

Snow Management for Agriculture,
c/o Research Branch, Agriculture Canada,
P.O. Box 1030,
Swift Current, Saskatchewan,
S9H 3X2 Canada

INTERNATIONAL SYMPOSIUM ON GLACIER MASS BALANCE, FLUCTUATIONS AND RUNOFF

30 September - 6 October 1985, Alma-Ata, U.S.S.R.

The purpose of this symposium is to discuss the scientific results of recent studies (mainly part of the International Hydrological Programme <IHP>) of glacier regime, mass balance, fluctuations and glacier runoff. Applied and basic research on the following topics, which are part of the third phase of the IHP, will be considered.

1. Mass balance of glaciers as an element in their regime and an agent of fluctuations
2. Mass balance of large ice sheets and their evolution over the next few decades
3. Climatically induced long-term and short-term fluctuations of glaciers
4. Glacier surges and the occurrence of outburst floods
5. Formation and fluctuation of glacier runoff, its computation and prediction
6. Mass balance, changes in the regime and runoff from large glacier systems.

In conjunction with the symposium there will b an extended meeting of the ICSI Working Group on Snow and Ice Hydrology of Glacierized Basins (Chairman, Dr M. Kuhn, Austria). The following problems will be discussed:-

a) Methods of glacier mass balance and runoff measurement
b) Survey of glacier variations
c) Computation and prediction of glacier runoff, including outburst floods
d) Preparation of international guidelines for the computation and prediction of runoff from glaciers and glacier systems.

The Symposium will be convened by Prof. V.M. Kotlyakov, Vice-President of the International Association of Hydrological Sciences and Chairman of the ICSI Division of Glaciers and Ice Sheets.

Based on abstracts submitted, authors of acceptable papers will have been advised by March 1985. The working languages will be Russian and English with simultaneous translation. Papers submitted will by published by the Organizing Committee.

Registration will take place in Alma-Ata on 29 September 1985. Following the end of the Symposium, on 7 October 1985, there may be a three-day excursion to the Uzbek cities of Tashkent and Samarkand with the party returning to Moscow on 10 October.

A second circular will be distributed in May 1985. Further information may be obtained from:-

Prof. V.M. Kotlyakov,
Institute of Geography,
U.S.S.R. Academy of Sciences,
Staromonetny Street 29,
Moscow 109017, U.S.S.R.

INTERNATIONAL SYMPOSIUM ON AVALANCHE FORMATION, MOVEMENT AND EFFECTS

14-19 September 1986, Davos, Switzerland

This Symposium will be combined with the 50th Anniversary celebrations of Snow and Avalanche Research at Weissfluhjoch/Davos.

ORGANIZATION
The Swiss Federal Institute for Snow and Avalanche Research (SFISAR) on behalf of the Swiss Department of the Interior.

PURPOSE
To provide an opportunity for the discussion of new experimental and theoretical findings of scientific aspects in the fields outlined below.

TOPICS
1. Snow & snowpack properties and stability
2. Meteorological factors and avalanche formation
3. Vegetation effects on snowpack stability
4. Avalanche movement
5. Avalanche forecasting methods
6. Avalanche protection
7. Geographical distribution of avalanches
8. Avalanche risk analysis

PAPERS
The Papers Committee will be pleased to consider any paper on these topics. Details about the summaries and final papers will be given in the Second Circular, to be published in the summer of 1985.

PUBLICATION
Papers will be refereed according to the usual standards before being accepted for publication in the Proceedings.

PROGRAMME
All activities will take place at Davos Congress Center. Registration is on Sunday 14 September. Plenary and poster sessions will take place from Monday to Thursday. Parallel sessions are not planned. The symposium language will be English. The 50th Anniversary will be celebrated on Friday 19 September in an official session (English,German, French) and by a banquet. On Saturday 20 September, the participants will have an opportunity to visit the SFISAR-buildings on the Weissfluhjoch. An excursion is foreseen for Sunday 21 and Monday 22 September.

ACCOMMODATION:
Participants will be accommodated in hotels of different categories (25.- to 76.- SFr per night for room & continental breakfast).

FURTHER INFORMATION
You are invited to attend the symposium and request the Second Circular as soon as possible from:-

C. Jaccard,
EISLF,
Weissfluhjoch,
CH-7260 Davos-Dorf,
Switzerland
tel: 083-5-32-64, telex: 74-309

14TH ARCTIC WORKSHOP ARCTIC LAND-SEA INTERACTION

6-8 November 1985, Dartmouth, Nova Scotia, Canada

A spectrum of Arctic environments and processes will highlight the important interactions between the subaqueous and subaerial environment. The workshop, to be held at the Bedford Institute of Oceanography, aims to encourage the two-way flow of information between land-oriented and sea-oriented scientists.

SPONSORS
Arctic Institute of North America
Centre for Cold Ocean Resources Engineering
Geological Survey of Canada
Institute of Arctic and Alpine Research
Norske Polar Institutt
Ocean Science and Surveys
Scott Polar Research Institute

SESSIONS
1. Permafrost deltas and shelves
2. Arctic fjords
3. Arctic/subarctic estuaries
4. Beaches and coasts
5. Tidewater glaciers and iceberg dynamics
6. Climate-water circulation interactions
7. Transgression/regression of sea level
8. Terrestrial and marine ecosystem interactions
9. Archaeology

NOTES
Scientists are invited to participate and present a paper or poster. There will be no concurrent sessions. A Second Circular will be issued in Spring 1985 detailing abstract and poster requirements, accommodations, and field trips. A registration fee of $50 will include a banquet and receipt of published abstracts. Scheduling of excursions and field trips will depend upon the interest expressed by participants and may include a pre-workshop excursion to Baffin Island.

FURTHER INFORMATION
Copies of the Second Circular and more information can be obtained by writing to:-

ALSI 85
Bedford Institute of Oceanography,
P.O. Box 1006,
Dartmouth, Nova Scotia,
B2Y 4A2 Canada

OFFSHORE MECHANICS AND ARCTIC ENGINEERING (OMAE)

13-17 April 1986, Keio Plaza Intercontinental Hotel, Tokyo, Japan

The 5th International Symposium on Offshore Mechanics and Arctic Engineering (OMAE) will be held in the Keio Plaza Intercontinental Hotel, Tokyo, Japan, from 13-17 April 1986. It is being organized by the American Society of Mechanical Engineers (ASME), the Society of Naval Architects of Japan and 16 international co-sponsor societies. Papers will be published in the Proceedings which will be available from the ASME. 30 technical papers sessions and two panel sessions are being organized.

Papers are solicited on Arctic engineering, offshore mechanics/control, offshore technology,and ocean energy/resources particularly in the area of full-scale and model-scale experimental methods and results, analytical methods, numerical methods and modelling and component designs.

DEADLINES

Abstract (2 copies)	1 April 1985
Tentative acceptance notice	15 April 1985
Manuscript (5 copies)	15 July 1986
Final acceptance notice	1 November 1986

For more information and papers covering Arctic engineering please contact:-

Dr V.J. Lunardini,
Cold Regions Research and Engineering Laboratory,
72 Lyme Road,
Hanover,
New Hampshire 03755, U.S.A.)

2ND SCIENTIFIC ASSEMBLY OF THE INTERNATIONAL ASSOCIATION OF HYDROLOGICAL SCIENCES

2-10 July 1986, Budapest, Hungary

The principal aim of this Assembly is to promote the advancement of the hydrological sciences, to review the newest developments in a few selected fields and also to outline new directions for future research. Four Symposia will be held,each with the participation of four or more Commissions:-

S1: Modelling snowmelt-induced processes
S2: Conjunctive water use
S3: Monitoring to detect changes in water quality series
S4: Integrated design of hydrological networks

The following workshops will also be held:-

W1: Physics and stochasticity in hydrology
W2: Geomorphology and numerical modelling of catchment behaviour
W3: Recent developments in flood routing
W4: Hydrology 2000

PROGRAMME

The programme of the Symposium on Modelling Snowmelt-induced Processes, of chief interest to IGS members is as follows:

1) Dynamics of qualitative and quantitative variables of snow cover:
- Changes of snow density in time and space
- Thermodynamics of snowmelt
- Relationship between the water equivalent and the snow cover/use of remote sensing to estimate the extent of snow cover and its water equivalent

2) Modelling and forecasting snowmelt induced floods
- Model complexity vs. data availability and lead time
- The need for and methods of parameter/forecast updating
- Snowmelt and rainfall-induced mixed floods

3) Non-point source pollution accumulated in snow cover
- Accumulation of pollution in snow cover
- Pollutant concentration of surface runoff after snow melting
- Snowmelt erosion and wash-out mechanism

4) Coupling models of different sub-processes
- Scale problems
- Interfacing sub-models (input/output requirements)
- Error propagation through sub-models (uncertainty analysis)

The Scientific Assembly will take place on the premises of the Budapest University of Technology. It will open on Tuesday, 2 July 1986 and close after the technical sessions on Wednesday, 10 July 1986. The Assembly languages will be English and French: no simultaneous translation will be provided. The proceedings of each symposium will be prepublished. One volume will be included in the registration fee and others may be purchased at a reduced price. Several excursions are being planned.

IMPORTANT DATES

Submit extended abstracts	30 March 1985
Authors notification	1 July 1985
Receipt of full papers	30 October 1985

All correspondence relating to the Assembly should be directed to:-

Dr A. Szöllösi-Nagy,
Executive Secretary,
2nd IAHS Scientific Assembly,
Water Resources Reserach Centre (VITUKI),
H-1453 Budapest, P.O. Box 27,
Hungary
(Tel: 361-338-160; Telex: 22-4959 h)

REVIEWS

Lance Tufnell. Glacier Hazards. Topics in Applied Geography, Longman Inc., London and New York, 1984, 97 p.,18 figures, 12 tables. £5.95 or $10.95.

Any interference with human activity by a glacier is viewed as a glacier hazard in this book, even when it is related only to a relatively slow glacier advance or retreat. A large part of the book is therefore devoted to glacier fluctuations and climatic changes. Examples from various part of the world are given on how fields and settlements became buried under the ice and communications were disrupted at times of strong glacial expansion, like during the Little Ice Age. Many different economic effects of glacier fluctuations are listed.

Glacier floods and ice avalanches, with their immediate impact on life and property, are treated in a separate chapter. Many examples are given, including the most disastrous catastrophies on record, and the typical situations that have led to either avalanches or floods are described. In these classical types of glacier hazards glacier variations can also be a major factor. This is pointed out to be important for planners, as the potential, as well as the actual, hazards should be taken into account.

In the concluding chapters particular attention is given to glacier fluctuations and hazards in the Canton of Valais, Switzerland. In this case-study, aspects of planning and accident prevention are considered.

The author deals with the subject of glacier hazards in a broad sense and views an impressive number of events from different angles. His sources are numerous, but not all are equally reliable. Second-hand information is occasionally used where more informative original reports are available. Not wanting to burden his geographic readers with glaciological theory, Tufnell approaches the problem deliberately in a strictly descriptive, occasionally statistical manner. However, without a proper understanding of the physical processes that cause and influence glacier floods and ice avalanches, the evaluation of risks and the short-term predictions of an event, which are so very important for practical purposes, is hardly possible. Although the more physically inclined glaciologists will miss these aspects in Tufnell's book, it is worthwhile for them to have it on their shelf because of the wealth of information it contains with related references.

Hans Röthlisberger

NEWS

RECENT PUBLICATIONS

Barry, R.G. (Editor), 1984. Snow and Ice. Chapter 9, CODATA Directory of Data Sources for Science and Technology, E.F. Westrum, ed. New York, Pergamon Press. CODATA Bulletin No.53, 87 pp.

This Bulletin provides an overview of the principal agencies and institutions involved in glaciological data collection. It covers information relating to all forms of terrestrial snow and ice - snow cover, freshwater and sea ice, glaciers,ice sheets, and ground ice. The principal listing is by country, and subject and name indexes are provided. The information was compliled from a survey distributed by the World Data Center A for Glaciology <Snow and Ice> (WDC-A) addressed to centers,agencies, and institutions listed in mailing lists of the WDC-A and the International Glaciological Society. Individual copies of "Snow and Ice" are available for US$10 from Pergamon Press Inc,Maxwell House, Fairview Park, Elmsford, NY 10523, USA. Outside North America, inquiries or orders should be addressed to Pergamon Press Ltd., Headington Hill Hall, Oxford, OX3 OBW, U.K.

Glacial Lake Agassiz, Special Paper 26, Geological Association of Canada, edited by J.T.Teller and L. Clayton, provides an overview of Lake Agassiz, summarizing all major aspects of the lake - its history, stratigraphy, hydrology, biology, and post-glacial legacy. A large coloured map of the lake and related glacial margins is included. Each chapter is a synthesis of a particular major component of the lake and is written by one or more of the recognized experts. For thousands of years, Lake Agassiz was the largest lake in North America, and deposits extend over nearly a million square kilometres of North America. Sedimentation, from the Great Lakes and Saint Lawrence region to the Gulf of Mexico to the Arctic, was influenced by this lake.

The report is available for CAN$34 (US$29) plus $2.50 for postage and handling from Geological Association of Canada Publications, Business and Economic Services, 111 Peter Street, Suite 509, Toronto, Ontario, M5V 2H1, Canada.

A report on the Workshop on Antarctic Climate Data, sponsored by SCAR and convened by WDC-A, is contained in the latest volume in the Glaciological Data series, GD-15. The report includes the recommendations of the participants, preliminary inventories of data available, and a bibliography. GD-15 and others in the series are available at US$5.00 a copy, or on an exchange basis in return for copies of snow and ice publications, data sets, etc. supplied to WDC-A. Inquiries about Glaciological Data should be sent to WDC-A for Glaciology, Campus Box 449, University of Colorado, Boulder, Colorado 80309, U.S.A.

A separate issue of Geografiska Annaler, 66A(3), 1984, has been devoted to the proceedings of the workshop on Glacier Mass Balance and Runoff, held in Hamburg in 1983. Because the issue contains a wealth of information on glacier mass balance and runoff studies around the world, as well as numerous references to papers and publications, it has been decided to make this one issue available to glaciologists at the reasonable price of 40 SEK (about US$5). Order from Dr L.E. Åse, Dept. Physical Geography, University of Stockholm,S-106 91 Stockholm,Sweden. Method of payment, account No. etc. will be given in detail on the invoice. Regular subscribers to Geografiska Annaler will receive the issue as part of Vol.66A. The issue includes the following papers:-

Roots, E.F.: Glacier mass balance measurements - an honourable past, an important future.
Young, G.J. and Ommanney, C.S.L.: Canadian glacier hydrology and mass balance studies - a history of accomplishments and recommendations for future work.
Weidick, A.: Studies of glacier behaviour and glacier mass balance in Greenland - a review.
Collins, D.N.: Water and mass balance measurements in glacierized drainage basins.
Mayo, L.R.: Glacier mass balance and runoff research in the USA.
Kuhn, M.: Mass budget imblances as criterion for a climatic classification of glaciers.
Reynaud, L., Vallon, M., Martin, S. and Letrequilly, A.: Spatio-temporal distribution of the glacial mass balance in Alpine, Scandinavian and Tien Shan areas.
Ageta, Y. and Higuchi, K.: Estimation of mass balance components of a summer-accumulation type glacier in Nepal, Himalaya.
Tangborn, W.V.: Prediction of glacier derived runoff for hydro-electric development.

CHINESE SOCIETY OF GLACIOLOGY AND GEOCRYOLOGY

Membership in the Chinese Society of Glaciology and Geocryology, a branch of the Geographical Society of China, is open to all interested glaciologists for an annual membership fee of US$10. The Society is based in the Lanzhou Institute of the same name and publishes the Journal of Glaciology and Geocryology. Articles generally appear in Chinese with English abstracts. Those appearing in the most recent issue covered the following topics:-

- Quaternary glaciation in the Mts. Tomur-Hantengri area, Tian Shan
- Periglacial development in the northeast marginal region of the Qinghai-Xizang Plateau
- Quantitative analysis of snowline zonality
- Avalanches and glaciers at Hailuogou in the Mt. Gongga area
- Characteristics of a glacial flood
- Preliminary observations on Neoglaciation in the Qilian Mountains
- Features of the Wangfeng glacial moraine at the headwaters of the Ürümqi River
- Frost damage on slopes of reservoir dams
- Glacial traces in the Tanzhesi area, Beijing

Those interested in joining the Society should send their name and address, details of their academic and professional career, publications and reports and annual dues to: Chinese Soc. of Glaciology & Geocryology, Lanzhou Inst. of Glaciology & Geocryology, Academia Sinica, Lanzhou, China

WORKING GROUP ON THE PREDICTION OF RUNOFF FROM GLACIERIZED AREAS

During the 1978 Symposium on the Computation and Prediction of Runoff from Glaciers at Tbilisi, USSR, the Working Group on Heat, Ice and Water Balances at Representative Basins met and recommended the formation of a new working group. At the December 1979 meeting of the ICSI Bureau in Canberra, a Working Group on Prediction of Runoff from Glacierized Areas was officially formed. It was disbanded in August 1983. Similar work is now being carried on by the new Working Group on Snow and Ice Hydrology of Glacierized Basins (ICE, No.72 & 73, 1983, p.54).

The 22 members of the Working Group were chosen to represent countries or regional groupings of countries having concerns with runoff from glacierized areas. Many were drawn from lesser developed countries. They provided considerable input but few were able to attend the Working Group meetings which were held in conjunction with major symposia (Norway, 1980; England, 1982; and Germany, 1983).

The main objective was to produce a state-of-the-art report on the prediction of runoff from glacierized areas focusing on

operational forecasting requirements. In 1982 a bibliography on Glacial Hydrology was published through the World Data Center A for Glaciology. A text on Techniques for Prediction of Runoff from Glacierized Areas is in the final galley proof stage prior to publication in 1985 as an IAHS redbook.

A second objective was the development of basic knowledge and understanding of hydrological processes in glacier basins to be accomplished by compiling a series of up-to-date review papers by leading scientists.

Although no such publication has been prepared by the Working Group, members were very active in promoting more general activities of benefit to the snow and ice community. In particular, they took active part in the Symposium on Hydrological Aspects of Alpine and High-Mountain Areas (Exeter,1982; IAHS Publication No.138) and in the Workshop on Glacier Mass Balance and Runoff (Hamburg, 1983; Geografiska Annaler, 66A(3), 1984).

G.J. Young

EASTERN SNOW CONFERENCE

The Eastern Snow Conference (ESC) is a joint US/Canadian organization which was founded in the 1940's. It is an association of people interested in research and applied aspects of the study of ice in all its forms, especially snow. The principal activities of the ESC are the organization of an annual meeting, in the US or Canada in alternate years, and the production of the annual Proceedings of the Eastern Snow Conference, which now form more than thirty volumes deposited in libraries throughout North America and Europe. The annual meetings are sometimes held in major cities such as Washington, Montréal, Toronto or Boston and sometimes in smaller cities such as Peterborough, Oswego, Portland or Fredericton.

The members of the ESC are a very diverse and, over the years, fluctuating, group. They include professional snow surveyors, engineers and technologists (of various stripes), professors and students, hydrologists and biologists, people responsible for keeping roads clear of snow and rivers free of ice, and others interested in snow and agriculture. The members are drawn from all parts of eastern North America, they live and work in places which extend from Maryland to the High Arctic. The line between the territory of the ESC and its counterpart in the other half of the continent, the equally venerable Western Snow Conference, is not a precise one. Residents of the Mid-West and of the Prairie Provinces seem to join one or the other organization on the basis of personal whims such as a preference for Reno, Nevada over Bangor, Maine as a desirable meeting place.

In recent years, the annual ESC meetings have included sessions on snow and small mammals, snow and buildings, river ice, permafrost, remote sensing of snow and ice, biology of sea ice, snow and ice on lakes, measuring snow and ice, hydroelectricity and snow and ice, glaciers, icebergs, snow and farming, etc.

Anyone interested in joining the Eastern Snow Conference should contact Barry Goodison, Atmospheric Environment Service, 4905 Dufferin Street, Downsview, Ontario, M3H 5T4, Canada. It is also possible to join simply by showing up and registering at the next meeting.

DEEP DRILLING IN GREENLAND

In response to an open Workshop on Analysis of Deep Ice Cores from Greenland, sponsored by the National Academy of Science Polar Research Board and held in Washington, D.C., on January 30-31, 1984, a committee has been formed to draft a science plan for U.S. involvement in another deep drilling program in Greenland (GISP II). Two meetings have been held in Columbus, Ohio (July 12-13 and September 20-21, 1984). This committee is addressing two primary issues: (1) potential scientific and logistic involvement in a new multinational ice core drilling and core analysis program, and (2) the advancement of glaciological research in the United States through this science program, in Greenland. On October 8-9, 1984 representatives from Denmark, Switzerland and the U.S. met in Bern to discuss the progress made by each country toward securing financial and scientific support for GISP II. Note that the GISP II program is still in proposal form and has not been approved by NSF as an official program. This committee continues to receive letters from U.S. scientists expressing support and interest in this potential deep drilling effort.

The members of this committee would be pleased to receive comments or ideas related to possible science programs utilizing the ice core, the bore hole, or the logistics facilities at the drill site. The committee members are Ellen Mosley-Thompson (Chair), Institute of Polar Studies, Ohio State University, Columbus, OH 43210; Anthony J. Gow, U.S. Army CRREL, 72 Lyme Road, Hanover, NH 03755; Michael Herron, Schlumberger-Doll Research, Ridgefield, CT 06877; Kenneth Jezek, U.S. Army CRREL, 72 Lyme Road, Hanover, NH 03755; Barclay Kamb, Department of Earth and Planetary Sciences, California Institute of Technology, Pasadena, CA 91109; and Aslam Khalil, Oregon Graduate Center, Oregon State University,Beaverton, OR 97006.

The American Meteorological Society has recently received a donation of some 70 slides and other negatives taken by Wilson Bentley, the Vermont farmer who is well known in glaciological circles for a lifetime devoted to the photography of snow crystals and the publication of some 2500 pictures of these in the book entitled Snow Crystals" co-authored with W.J. Humphreys. The donation was made by a Mrs. Rice whose husband was professor of art history at Nassau Community College. The gift is considered important as it will enable the AMS to supply Bentley photomicrographs of ice crystals and frost for use in both technical and popular articles. Bentley's entire collection of original and duplicate slides were sent to the Buffalo Museum of Science after his death, and they are there today.

GLACIOLOGICAL DIARY

1985

16-18 April
53rd Annual Western Snow Conference. Boulder, Colorado, U.S.A. (Bruce VanHaveren, Bureau of Land Management, Building 50, Denver Federal Center, Lakewood, Colorado 80225, U.S.A.)

28 April - 1 May
IAWPRC International Conference on Water and Ice Pollution in Arctic Regions. Yellowknife, N.W.T., Canada. (K. Charbonneau, Conference Services Office, National Research Council of Canada, Ottawa, Ont., K1A OR6, Canada)

6-8 May
Workshop on the Stability of the West Antarctic Ice Sheet. Institute for Meteorology and Oceanography, Utrecht, Netherlands. (J. Oerlemans, Institute for Meteorology and Oceanography, Princetonplein 5,Utrecht, Netherlands)

6-7 June
42nd Annual Eastern Snow Conference. Montréal, Québec, Canada. (Hilda Snelling, Meteorology Section, USAF/ETAC, Building 859, Scott AFB, Illinois 62225, U.S.A.)

1-5 July
BOSS '85, 4th International Conference on Behaviour of Offshore Structures. Delft, Netherlands. (BOSS'85 c/oKIvI, P.O. Box 30424, 2500 GK The Hague, The Netherlands)

9-11 July 1985
Snow Management for Agriculture. Swift Current, Saskatchewan, Canada. (Snow Management for Agriculture, c/o Research Branch, Agriculture Canada, P.O. Box 1030, Swift Current, Saskatchewan, S9H 3X2, Canada)

5-7 August
The Fourth International Symposium on Ground Freezing. Sapporo, Japan. (ISGF 85, Institute of Low Temperature Science, Sapporo 060, Japan)

21-23 August
Symposium on the Paleoenvironmental Reconstruction of the Late Wisconsin Deglaciation and the Holocene. University of Lethbridge, Alberta, Canada. (Dr R.W. Barendregt, Department of Geography, University of Lethbridge, 4401 University Drive, Lethbridge, Alberta, T1K 3M4, Canada)

26-29 August
Symposium on Glacier Mapping and Surveying, Reykjavik, Iceland. (Secretary General, Inter. Glaciological Society, Lensfield Road, Cambridge CB2 1ER, UK)

16-19 September
Hydraulic Effects at the Glacier Bed and Related Phenomena. Interlaken, Switzerland. (Dr A. Iken, Versuchsanstalt für Wasserbau, Hydrologie und Glaziologie, ETH-Zentrum, CH-8092 Zürich, Switzerland)

30 September - 6 October
International Symposium on Glacier Mass Balance, Fluctuations and Runoff. Alma Ata, U.S.S.R. (Prof. V.M. Kotlyakov, Institute of Geography, USSR Academy of Sciences, Staromonetny Street 29, Moscow 109017, U.S.S.R.)

6-8 November
Arctic Land-Sea Interaction, 14th Arctic Workshop. Dartmouth, Nova Scotia, Canada. (ALSI 85, Bedford Institute of Oceanography, PO Box 1006, Dartmouth, Nova Scotia, B2Y 4A2, Canada)

1986

1-7 February
IHP 6th Northern Research Basins Workshop:River Ice Measurement Techniques. Houghton, Michigan, USA. (Dr H. Santeford, Department of Civil Engineering, Michigan Technological University, Houghton, Michigan 49931, U.S.A.)

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

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 East, Montréal, Québec,H2L 4M8, Canada)

1-10 July
I.A.H.S. 2nd Scientific General Assembly, Symposium on Modelling Snowmelt Induced Processes. Budapest, Hungary. (Dr A. Szöllösi-Nagy, VITUKI, H-1453 Budapest, Pf 27, Hungary)

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, U.S.A.)

18-22 August
8th Symposium of the IAHR Section on Ice Problems. Iowa City, U.S.A. (Dr R. Ettema, Inst. of Hydraulic Research, University of Iowa, Iowa City, Iowa 52242, U.S.A.)

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)

1987

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)

9-22 August
I.U.G.G. General Assembly. Vancouver, British Columbia, Canada. (Dr G. Needler, Fisheries & Oceans, Bedford Inst. of Oceanography, P.O. Box 1006, Dartmouth, Nova Scotia, B2Y 4A2, Canada

7-12 September
Fourth SCAR International Symposium on Antarctic Glaciology. Bremerhaven, Federal Republic of Germany. (Dr H. Kohnen, Alfred-Wegener-Institute for Polar Research, Columbus-Center, D-2850 Bremerhaven, F.R.G.)

NEW MEMBERS

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INTERNATIONAL GLACIOLOGICAL SOCIETY

Lensfield Road, Cambridge CB2 1ER, England

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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.

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ICE

Editor: Simon Ommanney

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All enquiries about the International Glaciological Society should be addressed to Mrs H. Richardson, Secretary General of the International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, England.

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