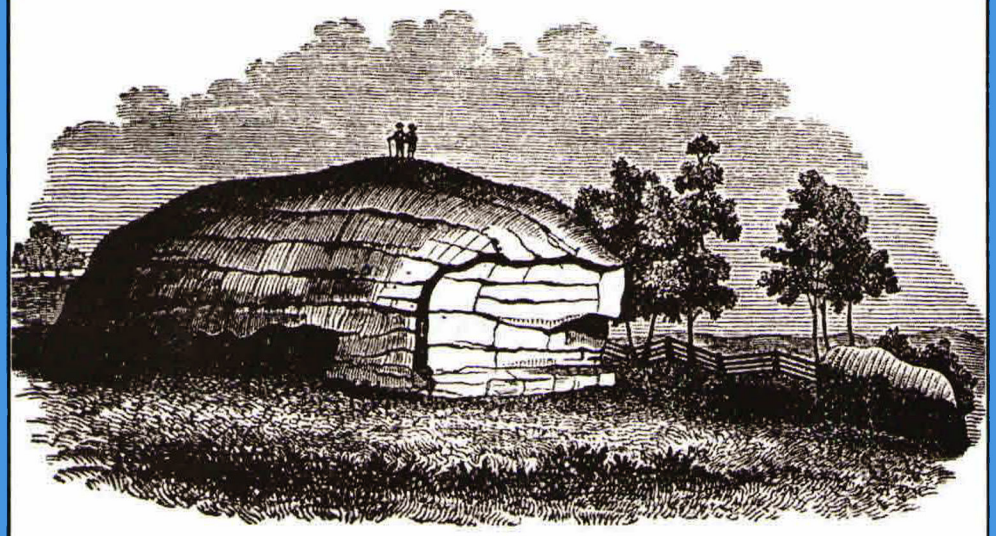
Number 94 *3rd Issue 1990*

ICE



NEWS BULLETIN OF THE INTERNATIONAL GLACIOLOGICAL SOCIETY

INTERNATIONAL GLACIOLOGICAL SOCIETY

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ICE

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Contents

COVER PICTURE: Sketch by Sir Charles Lyell in 1871 of a block 16 m long forming part of one of the boulder trains in the Richmond, Massachusetts area. (See article in *Journal of Glaciology*, 1966, Vol. 6, No. 45, p.431-37, for arguments about the origin of these trains.)

DENMARK

GLACIOTECTONICS

(S.A.S. Pedersen, DGU)

Glaciotectonic studies are being carried out in order to understand the 3-dimensional framework of the uppermost deposits in Denmark. The basis for these studies is the description of the well-exposed coastal cliff sections displaying cross sections through glaciotectonic thrust fault complexes, glaciotectonic duplexes and foreland fold and fault structures situated in various stratigraphic and dynamic settings. In these studies two main deformational regimes are distinguished:

(1) the structures due to gravity spreading deformation, and
(2) the structures formed by shear along the sole of the glacier.

The project is related to the glaciotectonic subgroup under the INQUA commission on genesis and lithology of Quaternary deposits. The project has reference to the working group preparing a glaciotectonic map of North Europe and North America.

MAPPING OF GLACIOGENE DEPOSITS

(K.S. Petersen, S.A.S. Pedersen, L.A. Rasmussen, DGU)

The dynamic features observed during the geological mapping procedure have formed the basis of the pleistocene stratigraphy following the kineto-stratigraphic concept.

A kinet-stratigraphic drift unit can be defined as comprising the sediments deposited by a single ice sheet or ice advance that processes a characteristic pattern and direction of movement.

Geological mapping of areas in central parts of Jutland supports the evidence of a continuous upper kineto-stratigraphic unit related to the Late Middle Weichselian ice advance.

DENMARK–NORWAY

OKSTINDAN GLACIER PROJECT

(N.T. Knudsen, J.T. Møller, GI/AU and W.H. Theakstone, MU)

During 1987–89 the accumulation and ablation measurements on Austre Okstindbreen have been developed into a mass-balance programme. The results are presented in an annual report. Measurements of meteorological variables, meltwater flow and ice velocity continue. The chemical and oxygen isotopic composition of glacial river water, snow and ice on the glacier and liquid precipitation are investigated to gain information on the temporal and spatial variability of water storage within and beneath the glacier. A radio-echo sounder has been constructed, and was brought into use during 1989 with positive result. This provides information on ice thickness, which so far has been unknown.

DENMARK–GREENLAND

WEATHER AND CLIMATE IN GREENLAND

(P. Frich, DMI)

A relational database has been operated at the Danish Meteorological Institute since 1986. Data from more than 40 stations in Greenland are added to the database every three hours. Nearly half of the stations are equipped with automatic sensors for air pressure, wind speed, wind direction, air temperature and relative humidity. Data from the automatic stations are transferred to the database via ARGOS telecommunication satellites. Most of these unmanned stations were started during the period 1980 to 1984.

Observations from about 15 stations have been recorded in the database since 1958 (1961). The quality of the data is quite good during the '60s, rather poor during the '70s and quite good during the '80s. Unfortunately the precipitation data are very difficult to correct. This task is a continuous process which will require both manpower and economic support in the future. Data can be delivered on all magnetic media, and the basic cost is DDK 1.16 per observation plus expenses for computing, programming, etc.

Several inquiries from glaciologists about monthly values of temperature and precipitation are awaiting external financing.

NORTH ATLANTIC CLIMATE DATA SET

(J. Cappelen, P. Frich, DMI; B. Aune, DNMI; R. Heino, FMI; T. Kvich, B. Dahlström, SMHI; T. Jonsson, VI; M.G. Roy, UKMO)

Preliminary steps have been taken to collect information from the Nordic countries concerning the set-up of a North Atlantic database with 18 climatological elements included.

More than 60 stations from 6 different countries have been selected. Most of these have observational records which started in the latter half of the 19th century. It is the intention to perform spatial homogeneity testing of all monthly values.

Analysis of the data set will emphasize:

(a) studies of trends and variability,
(b) interpretation of tendencies observed,
(c) comparisons with existing global data sets,
(d) development of baseline data to be used in extensive climate modelling of the North Atlantic region.

The data set could be used in glaciological studies as well.

The final homogenized data set will be available on a magnetic medium. The project is awaiting financial support from the EEC (EPOCH).

SATELLITE ALTIMETRY ON THE GREENLAND ICE SHEET

(S. Ekholm, KMS)

Surface heights derived from satellite-borne radar altimeters are primarily used for modelling of the geoid at sea, but due to the extreme flatness and smoothness of the ice sheet this datatype can be applied to model the ice topography as well.

Three satellites carrying radar altimeters have been launched up to now: GEOS-3 (1975), SEASAT(1978) and GEOSAT (1985–89). The last two are of greater interest because of their improved performance and better coverage (up to 72°N). After some corrections, the accuracy of the heights obtained from SEASAT and GEOSAT are (in the smooth, ice-covered part) estimated to be in the order of 2 m.

The data span a period over almost 15 years, and statistically comparing surface models from different epochs allows a possibility of investigating whether the average height of the ice sheet has changed significantly during this period. A number of groups are involved in this research.

The European satellite, ERS-1, when launched, will remove one of the main disadvantages of the data described, that of geographical limitations in coverage. ERS-1 will cover latitudes between 82°S and 82°N, including all of the Greenland ice sheet.

EUROCORE–GRIP

(W. Dansgaard, GI/GRIP)

Two European ice core drilling projects, EUROCORE and GRIP, were initiated during 1989 on the Greenland ice sheet at Summit. The field station is 3200 m a.s.l.; the mean annual temperature –32°C, the mean accumulation rate 23 cm of ice equivalent, and the ice thickness is 3000 m. 230 tons of building materials, vehicles, scientific equipment, fuel, food, and other supples were flown in from Søndre Strømfjord.

EUROCORE is a Danish–French–Swiss joint effort, funded by the EEC's Environmental Program and the Swiss National Science Foundation. The objective is to drill and analyze an ice core for a long series of environmental parameters, in order to learn more about climate changes through the last 1000 years.

A 300 m ice core was recovered by a Swiss drill. Logging and a number of on site analyses (acidity, hydrogen peroxide etc.) were carried out in a subsurface laboratory, and in a heated laboratory on the surface. 12 000 samples were cut in a continuous sequence and packed individually for subsequent stable isotope analysis. The core appears to date back to AD 704.

GRIP (Greenland Icecore Project) is an international European project under the auspices of the European Science Foundation (ESF) funded by member organizations in eight European countries. The main objective is to drill an ice core to bedrock at Summit in three field seasons during 1990–92. The GRIP Operation Center (GOC) is located at the Geophysical Institute, University of Copenhagen.

During the 1989 field season the GRIP activities at Summit were concentrated on preparation for deep drilling: (1) a 3 km long and 60 m wide runway for Hercules airplanes was established. (2) Two 7 m high dome-shaped buildings were erected; one of them is a two floor building that will house a 65 kW generator, kitchen, mess hall, radio room etc. The other one is erected on top of a 3.5 × 5 × 22 m excavated trench, and this will serve as a drill hall and storage room. (3) Connected with the drill trench by a 12 m long tunnel, a 23 m long science trench was excavated; it will be further extended 17 m for science and ice-core storage. (4) A number of weatherports were erected and used as garage, sleeping quarters etc. (5) A number of 100 m holes were drilled, one of them in the drill dome which will serve as a starting point for the deep drilling.

THE JAKOBSHAVN ISFJORD REGION — NEOGLACIAL CHANGE OF THE INLAND ICE MARGIN

(Anker Weidick, GGU)

Investigations of long-term fluctuations of the inland ice margin in Jakobshavn Isfjord region are based on the extensive radar mapping of the subsurface. This includes the subglacial extensions of the coastal fjords and ^{14}C-datings of marine subfossils brought to the present inland ice margin from the ice-covered fjords by the ice.

It is concluded that the inland ice margin at the end of the Holocene climatic optimum had a position at least 15 km behind the present one and that the subsequent re-advances culminated in AD 1850–90.

GREENLAND ICE SHEET, MASS-BALANCE MEASUREMENTS

(H.H. Thomsen, GGU)

Mass-balance measurements on the inland ice at Paakitsoq northeast of Jakobshavn are continued. Stakes were set up in 1982, starting on a outlet glacier (69°28′N, 50°12′W). During the seven years of measurements the stake net has been expanded. The net consists of 15 stakes covering the elevation range from 200 to 1070 m a.s.l. It is visited by helicopter twice a year during May and August. The annual equilibrium line for the measuring period lies close to 1100 m a.s.l. The data are presently being analyzed for publication.

HOT-WATER DRILLING ON THE INLAND ICE MARGIN NORTH-EAST OF JAKOBSHAVN

(O B. Olesen, E. Hansen and H.H. Thomsen, GGU)

The first GGU hot-water drill (see *Ice*, No. 86) was unfortunately destroyed during a helicopter operations in late August 1988 after a number of successful drillings: total drilled 5657 m; deepest hole 388 m.

The drill was rebuilt in 1989 with a slightly larger pump, increasing water output from 18 to 22.3 l min^{-1} which decreased water temperature from 85 to 63°C. A new guiding system, consisting of a topside commercial load cell and a down-hole inclinometer,

has been added. The inclinometer has been developed by GGU from a totally new concept utilising mercury as the moving part of a variable capacitor

The new system was successfully tested in August 1989 when a total of 1874 m was drilled, and maximum depth of 520 m was reached.

HOT-WATER DRILLING AND BOREHOLE LOGGING

(H.H. Thomsen, O.B. Olesen, GGU)

Hot-water drilling to investigate the glacier hydraulic conditions on inland ice were carried out. The location was the ablation zone at Paakitsoq northeast of Jakobshavn, West Greenland. During 1988, 11 holes were drilled with a total length of 3220 m, 4.2 km upstream from the ice margin. Explosives were used for blasting at the bottom of the boreholes to force a possible connection to the hydraulic system at the bed. At one drill site the water level was standing at the ice surface when the drill reached the bottom but dropped suddenly at the moment of blasting in the hole. However, continuous recording of water levels failed due to problems with rapid closing of holes, and with pressure sensors.

During 1989 nine holes, with a total length of 1872 m, were drilled about 1 km from the ice margin. In four of the holes continuous reading of water-level fluctuations were obtained. The continuous recordings showed a marked diurnal oscillation with higher water levels around 1600–1900 h and minima at 0700–0900 h local time. From the nature of the water level fluctuations there are good reasons to believe that the drill holes connected to the subglacial drainage system. The measurements show a subglacial water pressure close to the ice-overburden pressure.

DYE-TRACER EXPERIMENTS ON THE INLAND ICE

(H.H. Thomsen, O.B. Olesen, GGU; C. Leibundgut, IPG/ALU; A. Gees, GI/UB)

Artificial tracers were used on the inland ice at Paakitsoq northeast of Jakobshavn, for checking the results of glacier hydraulic modelling. The experiments were concentrated in an area of the ablation zone where the interpretation of model results are ambiguous. Three different fluorescent dyes were injected in selected moulins. The natural setting of the basin makes dye-tracer experiments difficult. Meltwater drains to the ice-free land through deep silty lakes and the exact points of exit from the lakes are not known. The experiment suggests a main subglaical drainage as predicted by modelling but with smaller deviations. The data are still being interpreted.

MEASUREMENTS OF ICE TEMPERATURES AT PAAKITSOQ NORTHEAST OF JAKOBSHAVN, WEST GREENLAND

(O.B. Olesen, H.H. Thomsen, GGU)

Measurements of englacial temperatures continue in the ablation zone of the inland ice. A thermistor string was drilled to a depth of 350 m during 1987. The hole, which extends to the bottom of the ice, is situated 9.5 km upstream from the ice margin with an ice surface elevation of 615 m a.s.l. Temperature readings reveal slightly negative temperatures from –0.1°C to –0.3°C through the ice body, decreasing to a minimum value of –2.1°C at a depth of 20 m. The relatively high ice temperatures are in agreement with similar measurements closer to the ice margin. Drilling of further thermistor strings is planned.

CONTINUED RADIO-ECHO SOUNDING OF THE INLAND ICE MARGIN

(L. Thorning, GGU)

At Paakitsoq near Jakobshavn, mapping of the ice margin subsurface by airborne 300 MHz radar was completed during 1988. Supplementary measurements were made during 1988 and 1989 by a 40–10 MHz monopulse radar at locations unsuited to airborne sounding. This device, built by GGU in 1987, was also applied to determine the ice thickness at the southern flank of Jakobshavn Isbræ during the autumn of 1989. The outlet (but not the ice stream proper) here fills an embayment ("the Ice Bay area") where the thickness of the ice was measured to a little over 200 m.

An attempt during 1989 at airborne sounding of the inland ice margin southeast of Godthåb/Nuuk (Isortuarssuup Sermia) followed the same procedure and was performed with the same equipment as at Paakitsoq but with far fewer reflections recorded.

MASS-BALANCE MEASUREMENTS AT THE TASERSIAQ AND QAPIARFIUP SERMIA BASINS DURING 1988–89

(O.B. Olesen, GGU)

At both basins mass balance studies have been carried out since 1981 with 1989 being the last year of measurements in the Qapiarfiup Sermia basin.

Measurements cover altitude ranges between 550–1050 m a.s.l. at Qapiarfiup, and 875–1400 m a.s.l. at Taseriaq. Stakes are visited during May and August/September, when winter and summer balances are measured.

During 1989 three automatic climate stations have been successfully tested at Tasersiaq, two on land and one on ice. Two of the stations measured temperature and humidity while the third included wind speed.

Since 1983 firn temperatures have been measured at intervals to 10 and 20 m below surface near various stakes in both basins.

MODELLING OF REFREEEZING IN SNOW AND FIRN ON A SMALL ICE CAP SOUTH OF SØNDRE STRØMFJORD

(C.E. Bøggild, GGU and GCI/UCPH)

In connection with mass-balance investigations at the Amitsulooq Ice Cap in West Greenland, studies have been conducted on the problem of refreezing meltwater. A transient thermodynamic model has been created to simulate freezing and cooling of the snow and firn in the winter, followed up by

successive warming by refreezing meltwater in the spring.

Recent calculations indicate that the results are in fair agreement with refreezing measured elsewhere. The model has proved that water content and thermal conductivity of mature firn is very different from snow. The problem needs further research.

QAMANARSSUP SERMIA, WEST GREENLAND 1988–89

(R.J. Braithwaite, GGU)

The field station (64°28′N, 49°30′W) is at the head of Godthåbsfjord. The last full year of operations was 1986 and the programme for 1988–89 only involved brief visits during May and August to measure transient balances on a few stakes. The automatic climate station continued year-round measurements at the old base camp. There was extremely high ablation during the 1987 summer, about equal to the previous record in 1985, followed by lower ablation in the 1988 and 1989 summers. In summer 1989 it was decided to discontinue operations from 1990. All remaining fixtures will be removed on a suitable occasion. Analysis of the data collected in the period 1980–89 continues.

HYDROPOWER FOR NUUK/GODTHÅB

(R.J. Braithwaite, GGU)

In connection with planning hydropower for Nuuk/Godthåb, glacier studies were made during 1983–89 in two basins south of Nuuk: Kangerluarsunnguaq (KNNQ) and Isortuarsuup Tasia (ISTA). This included simple mass-balance measurements on glacier 1CG14033 at 64°01′N, 50°40′W in the KNNQ basin and on the Greenland ice sheet at 63°53′N, 49°33′W in the ISTA basin. Runoff from the ISTA basin is strongly influenced by glaciers while the runoff from the KNNQ basin is little influenced by glaciers (GGU Open File Ser. 89/2). However, a strong correlation has been found between the summer runoff from the KNNQ basin and snow accumulation on glacier 1CG14033 (GGU Open File Ser. 90/3). This will be followed up as a possible method for seasonal runoff forecasting.

GLACIER HYDROLOGY, WEST GREENLAND

(R.J. Braithwaite, O.B. Olesen, H.H. Thomsen, GGU)

The simulation of runoff from the Greenland ice sheet near Jakboshavn using a spatially distributed model with mothly resolution was completed. This work is now in temporary abeyance as there is presently no need for it in connection with hydropower planning. However, more work has been done on a spatially lumped model with annual resolution which can be used at an early stage of hydropower planning. The critical part of this model is a negative correlation between snow accumulation and ice ablation which was found on Nordbogletscher but can now be confirmed for other sites, i.e. Qamanârssûp Sermia and glacier 1CG14033.

ENERGY BALANCE MODELLING

(R.J. Braithwaite, O.B. Olesen, GGU)

Earlier analyses of glacier–climate relations on Greenland glaciers used an ablation–temperature model but this has now been expanded to a full energy balance model using measured data for air temperature, humidity, wind speed, sunshine duration and shortwave radiation. The turbulent heat fluxes are calculated with equations from W. Ambach while the longwave radiation is calculated with an equation from A. Ohmura. The model has been tested with data from Nordbogletscher (6 summers) and from Qamanârssûp Sermia (7 summers). The model has also been used to study possible climate warming due to the greenhouse effect. For example, ablation at the margin of the Greenland ice sheet will nearly double for a 5°C temperature rise with a smaller ablation increase at greater elevations.

SURGING GLACIERS IN WEST GREENLAND

(A. Weidick, GGU)

A number of surging glaciers have been located on Disko Island and Nuugssuaq peninsula. The quiescent phase of the glaciers seems to be around 30 to 50 years while the surge event lasts only a few years or less according to the documentation (aerial photographs and historical records). The magnitude of the frontal variations due to the surges vary between one and a little more than two kilometres.

The observations indicate a decreasing surge activity through this century presumably connected to the pronounced decay of glaciers.

THE WORLD'S NORTHERNMOST SURGING GLACIER?

(A.K. Higgins, GGU)

The world's northernmost pulsing or surging glacier has been located in north Greenland at the head of Victoria Fjord (81°55′N, 45°W).

The development of the surging is documented by aerial photographs from 1947, 1953, 1963, 1971 and 1978, which provide information on frontal variations as well as of changes in the surface of the glacier. The surge-like character and the velocity changes are caused by a kinematic wave, which moved down the glacier at a rate of well over 1 km a^{-1}.

GLACIER VELOCITIES FROM AERIAL PHOTOGRAPHS IN NORTH AND NORTHEAST GREENLAND

(A.K. Higgins, GGU)

Studies of aerial photographs of north Greenland permit determination of the rate of surface movement of all major outlets of the inland ice between Petermann Gletscher in the west and Zachariae Isstrøm in the east. Average velocities vary between 900 m a^{-1} (Petermann Gletscher) and 300 m a^{-1} (outlet to Nioghalvfjerdsfjorden).

Velocities of a number of local glaciers were also measured. At Hans Tavsen Iskappe three small outlet glaciers draining into the fjord to the west have

measured velocities of 40–70 m a^{-1}, and a large outlet draining northwards 100 m a^{-1}, whereas outlets from Flade Isblink have movement rates of up to 360 m a^{-1}.

NORTH GREENLAND ICE ISLANDS

(A.K. Higgins, GGU)

Systematic examination of aerial photographs of north Greenland has revealed that the floating portions of many of the major outlets from the inland ice periodically calve large tabular icebergs resembling ice islands.

Possible sources of ice islands are Petermann, Ryder and C.H. Ostenfeld glaciers and Hagen Bræ in north Greenland, and outlets to Nioghalvfjerdsfjorden and Jøkelbugt in northeast Greenland. Other possible sources for ice islands are the local glaciers and small ice shelves on the north coast of Peary Land and a floating lobe of Flade Isblink.

Submitted by H.H. Thomsen

Abbreviations used in the text:

DGU	Geological Survey of Greenland
DMI	Danish Meteorological Institute
DNMI	Norwegian Meteorological Institute
FMI	Finnish Meteorological Institute
GCI/UCPH	Geographical Central Institute, University of Copenhagen
GGU	Geological Survey of Greenland
GI/AU	Geological Institute, University of Aarhus
GI/UB	Geographical Institute, University of Bern
GI/UCPH	Department of Glaciology, Geophysical Institute, University of Copenhagen
IPG/ALU	Institute of Physical Geography, Albert Ludwig University
KMS	National Survey and Land Register, Denmark
MU	Department of Geography, Manchester University
SMHI	Swedish Meteorological and Hydrological Institute
UKMO	Meteorological Office, Edinburgh
VI	Icelandic Meteorological Office

SWITZERLAND

GENERAL GLACIOLOGY

WORLD GLACIER MONITORING SERVICE

(W. Haeberli, H. Bösch, E. Herren and M. Hölzle, VAW)

The World Glacier Monitoring Service (WGMS) of the International Commission on Snow and Ice (ICSI/IAHS) continued its activity within the framework of the Global Environment Monitoring Systems (GEMS/UNEP) as a permanent service of the Federation of Astronomical and Geophysical Data Analysis Services (FAGS/ICSU). The year 1988 saw the publication of the *Fluctuations of Glaciers 1980–1985, Vol. V*, containing information on 655 glaciers from 22 countries (including the continent of Antarctica). For the first time, "special events" such as glacier surges, outbursts of ice-dammed lakes, ice avalanches, drastic retreat of calving glaciers on eruptions of ice-clad volcanoes were reported. The *World Glacier Inventory – Status 1988* was published in 1989. Detailed glacier inventories include information on surface area, width, length, orientation, elevation, morphology, tongue activity, moraine characteristics and snow-line position. In many parts of the world, however, only preliminary inventories based on satellite imagery with limited resolution are available at present. The printed volume gives an overview on what statistical information about glaciers is available in which region. Fluctuation and inventory data are being entered in a newly installed database management system. A new biennial Mass Balance Bulletin is now being prepared. Printing of the first issue (1988 and 1989) is planned for the winter of 1990/91. It will contain extensive information from about 10 glaciers and summary results from nearly 50 glaciers. Computer processing of glacier fluctation data from earlier years — especially concerning Scandinavia and the Alps and going back to 1894 — is underway. The main goal of this work is to build up standard curves for various glacier-length categories as a basis for worldwide intercomparison of glacier length and mass balance changes. Cooperation with specialized institutes with regard to satellite monitoring of remote glaciers to reach global coverage is being initiated.

ANNUAL SURVEY OF SWISS GLACIERS

(M. Aellen, VAW and GK/SANW; H. Bösch, M. Funk and W. Schmid, VAW)

The results of the 108th to 110th annual surveys (1987–89) of glacier snouts in the Swiss Alps are summarized by the following figures:

Number of glaciers	1987	1988	1989
advancing	35	27	19
stationary	13	6	3
receding	58	74	83
Total	106	107	105

The number of advancing glaciers has decreased at an almost regular annual rate since 1984, whereas the number of retreating ones has increased in all regions. Comparable conditions had last been observed in the years of great mass loss (1971, 1973, 1976) before the recent period of glacier advance (1977–85) which definitely belongs to the past, as is obvious also from the following facts. Some glaciers have started to recede after 20 to 30 years of continuous and steady advance (e.g. Fee and Trient Glaciers have advanced over a distance of 0.6 and 0.4 km since 1956 and 1958, respectively). On the other hand, long valley glaciers — except the 2 largest ones (Great Aletsch and Gorner) — have advanced temporarily in recent years (e.g. Fiescher and Lower Grindelwald, ranked 3rd and 6th by surface area).

Mass balances established for the glaciers of four high alpine river basins are summarized by the following figures (specific net values in g/cm^{-2}):

Glacier	1986/87	1987/88	1988/89
Gries	–88	–95	–102
Aletsch	+17	–24	–8
Limmern and Plattalva	+21	–24	–42
Silvretta	+65	–21	–40

In all years from 1983 to 1990, periods of mild and dry weather were typical features of the autumn and winter seasons. Heavy snowfalls in spring seasons or periods of cold and rainy weather in summer seasons were effectively preventing severe glacier mass losses in most years in the northern parts of the Swiss Alps, but less so in the southern parts. Therefore, mass balance is more negative for Gries than for the rest of the above-mentioned glaciers.

MASS BALANCE OF ALETSCH GLACIER

(M. Aellen and M. Funk, VAW)

Mass balance of the largest glacier (87 km^2) in the Alps is computed for the glacierized part (128 km^2) of the Massa river basin, using a simple hydrological model based on monthly values for hydrological years since 1922 and calibrated by geodetically determined volume changes from topographical surveys in 1926/27 and 1957. For the years from 1931 to 1987, the model was also applied with respect to shorter time intervals in order to gain insight into the variability of seasonal water storage in a glacierized high mountain basin of the Swiss Alps. Yearly glaciological measurements at a stake network have been carried out in the firn area since 1942 and in the ablation area since 1950, mainly at sites on the medial axis of Great Aletsch Glacier. Annual mass balance is computed from the data for the whole glaciarized area within the river basin assuming a simplified linear model for the mass balance gradient. Results are found to be in good agreement with the hydrologically determined mass balances.

RECONSTRUCTION OF RHONE GLACIER MASS BALANCE HISTORY

(J. Chen, GGEZ and M. Funk, VAW)

Records of annual mass balance established by the glaciological method (based on direct measurements) normally exist for the last 30–40 years only. On Rhone Glacier, accumulation and ablation measurements were made on stakes from 1884 to 1909 and again from 1979 to 1982. A continuous record of annual mass balances from 1883 to 1987 was computed by means of a model which correlates observed mass balances with precipitation and air temperature data measured at nearby weather stations (Reckingen, Andermatt). The volume change determined by the geodetic method and based on the topographical surveys in 1874/82 and 1959/69 was used to check the mean specific mass balance thus calculated for the investigated period.

LONG-TERM SNOW AND FIRN ACCUMULATION ON CLARIDEN-FIRN

(M. Aellen, VAW; G. Kappenberger, SMA; and H. Müller, Sargans)

Annual accumulation (or ablation) rates have been measured at stakes and in pits at 2 sites on Claridenfirn (Glaronese Alps) since 1915. Winter balance has been measured at the same site since 1957. The results, published every year in special reports until 1977, have been compiled by H. Müller and G. Kappenberger in a summarizing report for the 70-year period of 1915–84. The records from both sites (at the altitudes of 2700 and 2900 m) are fairly well correlated to the specific mass balance values determined by the hydrological method for the Aletsch Glaciers since 1922.

THE ROLE OF BED SEPARATION AND FRICTION IN SLIDING OVER A UNDEFORMABLE BED

(J. Schweizer and A. Iken, VAW)

The influence of debris concentration on the sliding process is investigated. The actual conditions where certain types of friction apply are defined, the effect for the case of bed separation due to a subglacial water pressure is studied and the consequences for the sliding law are formulated. The numerical modelling of the sliding of an ice mass over an undulating bed, including the effect of both the subglacial water pressure and the friction, is done by using the finite element method. Friction, seen as a reduction of the driving shear stress due to gravity, can be included in existing sliding laws which should contain the critical pressure as an important variable. An approximate functional relationship between the sliding velocity, the effective basal shear stress and the subglacial water pressure is given. Considering the seasonal velocity variations, Alpine valley glaciers may be classified according to the glacier bed characteristics, and probably vice versa.

PERIODIC FAST SLIDES OF ALTELS GLACIER

(A. Iken and W. Schmid, VAW)

A small hanging glacier on the 35° slope of Altels slides at a fast pace approximately every 5 years. A slide was expected in 1990 but took place in autumn of 1989. The sliding part, the upper half of the glacier, speeded up during August from 5 cm d^{-1} to 25 cm d^{-1} and in the first half of September to 80 cm d^{-1}. In October and November the velocity decreased gradually. The motion was recorded by an automatic camera. In addition, theodolite measurements were carried out from a nearby mountain. These measurements show the jerky structure of the motion in more detail and in particular indicate the zone where the speed-up started. Thickness changes of the glacier will be evaluated from aerial photographs.

FINITE-ELEMENT MODELLING OF ICE FLOW AT ALPINE DRILLING SITES

(S. Wagner and A. Iken, VAW)

Finite element modelling is being applied to data measured at Altels Glacier, which exhibits periodical events of fast sliding. Borehole deformation within the permafrost of the rock glacier Murtèl, Corvatsch, is being analyzed using a 2D model in order to investigate the flow behaviour and age of Alpine permafrost. To gain a better understanding about the flow pattern and age of the lower parts of ice cores at the Colle Gnifetti drill site, the 3D configuration of this saddle will be modelled.

HOT-WATER DRILLING ON JAKOBSHAVN GLACIER, GREENLAND

(A. Iken, VAW and K. Echelmeyer, University of Alaska)

In preparation for deep drilling, various tests were carried out on an Alpine Swiss glacier. In particular, the drill performance at high discharge was investigated. Subsequently, in a joint program with the University of Alaska, several holes were drilled on a transverse profile across Jakobshavns Glacier, 45 km inland from the calving front. The holes were drilled with a water discharge of 60 to 80 l min^{-1} at 60-80°C. The deepest hole reached the bed near the northern margin at a depth of 1630 m. Thermistors, tilt sensors and pressure gauges were installed in the holes; some data are still being recorded. The coldest ice with temperatures around –22.5°C was encountered between 1000 and 1300 m depth. The results of the drilling operation form the basis for an analysis of the dynamics of this fast-flowing ice stream.

COMPUTATION OF TEMPERATURE AND MOISTURE CONTENT IN POLYTHERMAL GLACIERS

(H. Blatter, GGEZ; M. Funk, VAW; and K. Hutter, TH Darmstadt and VAW)

A mathematical model for calculating temperature and moisture content in the cold temperate portion of a polythermal glacier is under development. The model is able to determine the position of the cold-temperate transition surface in a 2-dimensional longitudinal section of a glacier. Test runs with a stationary situation showed how far real glaciers depart from steady state. A time-dependent model calculation handling the evolution of the geometry, flow field and the polythermal condition of glaciers, and considering the temperature evolution to some depth below the ice, is currently being developed.

ELECTROMAGNETIC PROBING OF GLACIERS AND PERMAFROST

(G. Meyer, ICT; S. Wagner, D. VonderMühll, M. Funk and W. Haeberli, VAW)

Continuous high-frequency radio-echo soundings were done on Colle Gnifetti to investigate internal firn layers (isochrones) and to generate a 3D Finite Element Grid of the glacier in this saddle. Similar soundings were carried out around the permafrost borehole on the rock glacier Murtèl/Corvatsch as a test for potential applications of the method to the study of Alpine permafrost. The USGS monopulse ice radar was used to complete thickness measurements on Gries Glacier.

CALVING RATE IN DEEP FRESH WATER, NORDBO GLACIER, GREENLAND

(M. Funk, VAW)

In order to improve their hydro-electric power production in the Grimsel area Kraftwerke Oberhaslo (KWO power plants) plan to construct a new reservoir with a storage level about 100 m higher than the existing Lake Grimsel. This prospective lake will flood the tongue of Unteraar Glacier, which is expected to float and drift away, with calving continuing at a frontal ice cliff. The calving law to predict the rate of retreat of the glacier is an empirical linear relationship with water depth. This relationship is based on observations at glaciers ending in rather shallow lakes. Calving rates are now determined at Nordbo Glacier in Johan Dahl Land (Greenland), where mean water depth at the calving front is about 100 m. Terrestrial photogrammetry is used to record changes in the front position and stakes drilled into the glacier to measure ice flow. Water temperature and ice thickness are also measured.

PROPAGATION OF CALVING WAVES IN A LAKE

(A. Huber, D. Müller and M. Funk, VAW)

For the Lake Grimsel project mentioned above, the greatest expected calving waves reaching the dam must be determined in order to leave sufficient free height at the dam to avoid overflow. The expected calving events were determined with a numerical analysis of the retreat of the glacier tongue and of the stability of the calving front. The theoretically determined calving events are reproduced in an hydraulic model, in which the entire Lake Grimsel with its topography has been constructed at a scale of 1:250 for studying the propagation of the waves produced by calving.

GLACIER HAZARDS

(W. Haeberli, M. Funk, J. Alean and P. Müller, VAW)

The basis for assessing risks from potential glacier hazards in relation to safety considerations for settlements and other fixed installations in the Alps was further developed. General characteristics of unmeasured glaciers must be estimated using a rough parametrization scheme. Variations in glacier length, ice avalanches and glacier floods then have to be considered for time periods ranging from years to decades. As a result, maps of potentially endangered zones can be prepared. Such systematic assessments are becoming more and more important, because man continues to infiltrate previously avoided high-risk zones.

GLACIER PHOTOGRAMMETRY

(H. Bösch, W. Schmid, M. Aellen, M. Funk, W. Haeberli and A. Iken, VAW)

An analytical stereoplotter KERN DSR 15-18 together with a VAX station 3500 was installed at the VAW. Large format stage plates allow direct comparison of stereo-models from different times. Cooperation between the photogrammetrist and the glaciologist as well as instruction of operators is facilitated by a double inspection system. Image superposition enables fast determination of changes between two models. Analyses will focus on extended mass balance measurements, investigation of the 1970/80 glacier advance from numerous high-quality images, studies related to glacier hazards (mainly ice avalanches and lake outburst), and long-term monitoring of debris-covered glaciers and rock glaciers.

SNOW AND AVALANCHES

MEASURING AND MODELLING THE DEVELOPMENT OF SEASONAL SNOW COVER

(H.P. Bader, H. Gubler and P. Weilenmann, SLF)

Measurements and analyses of energy and mass exchange between snow cover and atmosphere have been refined and are used to model the temperature profile and settling of a layered snow pack numerically. Surface and internal melting as well as water percolation are being included in the model. The fine structure of snow surface temperature variations at a time resolution of 0.5 h has been modelled successfully. The goal of this project is to model snow metamorphism and mechanical stability of the snow cover in potential avalanche release zones.

REMOTE INSTRUMENTATION

(H. Gubler, P. Weilenmann and M. Hiller, SLF)

An automatic snow cover monitoring system with six remote stations connected by wire, phone or radio to the base station at the institute has been set in operation. Sensors include gauges for snow height, microwave snow profiles, temperature profiles and snow acoustic emission measurements. The experimental network is used to compare the development of the snow cover in different environments including release zones and forests at timberline.

SNOW DISTRIBUTION ON SLOPES AND IN DIFFERENT FOREST TYPES

(J. Rychetnik, SLF)

The influence of the forest canopy on distribution and stability of the snow cover is being measured in different forest stands to evaluate areas affected by single trees, tree groups, openings, etc. Additional measurements of climatic data in openings and under the canopy of a spruce and larch forest stand are being used to explain the differences of the snow cover development. The aim of these investigations is to define the diameter of openings in the forest canopy as a condition for avalanche release.

REGIONAL DISTRIBUTION OF SEASONAL SNOW COVER

(J. Martinec, SLF)

Snow cover monitoring by Landsat, NOAA, and SPOT satellites is used to evaluate areal average water equivalents of snow in different elevation zones and regions. The satellite data are processed at the Swiss Federal Institute of Technology in Zurich. The project is supported by the Swiss National Science Foundation and by private companies.

SNOW DEPOSITION AND SNOW MELTING IN FOREST OPENINGS ON A NORTH-FACING STEEP SLOPE

(R. Sommerhalder, SLF)

Snow deposits are measured in ten slot-shaped regeneration openings in a sub-Alpine spruce forest near Davos (Switzerland). Snow cover and melting process will be observed during some winters. The study aims at investigating the snow deposition in relation to the size of the openings and their orientation depending on the main wind direction.

STRAINS AND STRESSES IN SNOW

(H.P. Bader, M. Hiller and H. Gubler, SLF)

Shear strains as well as normal and shear stresses at the interface between old and new snow layers within the snow pack on a steep slope in an Alpine larch stand at timberline are recorded using special gauges. So far measured shear strain rates did not exceed $10^{-5}\,s^{-1}$ even at shear deformation of up to 0.1 m within a 0.05 m slab. For high winter snow cover no significant deviations of normal and shear stresses from neutral conditions have been found. The pinning range of larch trees is limited to a diamater of approximately 1.5–2 times the snow height for trunk diameters not larger than snow height and no gliding at snow–ground interface. To check the design criteria for avalanche defence barricades, snow loads on different types of snow fences are measured continuously.

Measured strain and stresses are compared with results of finite element calculations.

STABILITY OF SNOWPACK

(P. Föhn, SLF)

The areal variability of snowpack stability indices has been analyzed by "Rutschblock" tests and parallel shear frame measurements. On potential avalanche slopes these indices yielded a coefficient of variation of 15–30%. This is the same order of magnitude as other snow parameter (snow height, density, ram hardness, etc.) variations on these types of slope. The question of small or large weak zones or "deficit areas" will be pursued in future studies.

FRACTURE PROPAGATION CAUSING SLAB AVALANCHES

(H.P. Bader and B. Salm, SLF)

The mechanics of snow slab release is considered from the viewpoint of mechanics of continua. It is found that fracture can only occur if a thin weak layer exists, which is already partly fractured and where shear stresses from the overburden snow cannot be transmitted to the ground. This leads to the necessary stress and strain-rate concentrations. An important consequence is that the thinner a weak layer and the smaller its viscosity, the higher the probability of propagation of fracture.

AVALANCHE DYNAMICS

(H. Gubler and B. Salm, SLF)

The project to measure flow speeds, flow heights and slope perpendicular flow-speed profiles of large artificially released dense flow avalanches using microwave doppler radar is continued. Improved guidelines to estimate run-out distance, flow speed and flow height based on the Voellmy–Salm model are distributed to practitioners.

SETTLING PROCESSES IN POWDER SNOW AVALANCHES

(F. Herman, VAW and SLF, K. Hutter, Damstadt and VAW and B. Salm, SLF)

An experimental set-up for the laboratory-scale simulation of powder snow avalanches (with kink and run-out zone) allows measurements of particle speed and concentration by an ultrasonic Doppler method. Measurements have been carried out in both the avalanche head and the avalanche body which allow the estimation of dynamic pressures within the avalanche.

CHARACTERISTICS OF AVALANCHES WITH STARTING ZONES IN FOREST

(M. Meyer-Grass and R. Sommerhalder, SLF)

Avalanches are released not only outside forests or in forest openings, they may also start within forest stands. Such avalanches in the Swiss Alps are defined and described. The starting zones of more than 110 avalanches that have occurred over the past few years and around 90 surfaces selected in the neighbouring forest stands have been investigated. More than 50 parameters related to snow properties, weather conditions, general site, forest type and silvicultural treatment are being evaluated statistically to study the conditions allowing such avalanches to form. The investigation aims at discovering which parameters or combinations thereof are able to cause the formation of an avalanche in a forest. Approximately ten parameters concerning mainly forest type and stand structure have been elaborated so far. Site parameters have been found to be of secondary importance.

AVALANCHE HAZARD ASSESSMENTS BY NXD

(O. Buser, SLF)

In order to help predict avalanche hazards in a restricted area, the data analysing programme NXD was developed. This method compares observed conditions with the past 20 years' avalanche records, weather and snow data. The Parsenndienst, the local rescue service, ran the programme successfully for three winters. A demonstration for potential users was extremely well attended and resulted in a number of resorts and public services confirming their intention to use it.

TEMPORARY MEASURES AND AFFORESTATION IN A GLIDING SNOW AREA

(W. Frey and F. Leuenberger, SLF)

Gliding of the snow cover occurs frequently on sun-exposed slopes in the forest zone of temperate climatic regions. Successful afforestation of such areas is possible only if the planted trees are protected by temporary measures such as tripods, posts, small terraces or similar structures. Interrelations of snow cover, measures and planted trees are investigated to elaborate guidelines for practical use.

AFFORESTATION TECHNIQUES IN AVALANCHE STARTING ZONES OF THE SWISS ALPS

(W. Frey, SLF)

Research projects generally provide information concerning only the initial decades of afforestation. Investigations on critical periods of older afforestation activities therefore are quite rare. On the basis of up to 100 year old project papers, some afforestation areas in the eastern Swiss Alps are examined to obtain information on favorable planting and tending techniques.

SNOW COVER AND AVALANCHES IN A CHANGING CLIMATE

(P. Föhn, SLF)

Time-series of snow cover data (50–90 years) have been analysed to detect extraordinary trends in the past or present behaviour. Despite large fluctuations between individual winter seasons, earlier anomalies could be found which are similar to the present ones. An obvious change since the '80s concerns the trend towards a later beginning of snow cover formation. Recently observed fluctuations in avalanche activity are similar to those of earlier periods and remain well within the noise-band.

SNOW AND ICE CLIMATOLOGY/HYDROLOGY

GLOBAL ENERGY BALANCE ARCHIVE

(A. Ohmura and H. Gilgen, GGEZ)

Within the framework of the World Climate Program-Water Project A7, a computerized, worldwide data archive of all 14 energy balance components is being installed. Instrumentally measured energy balance components only are accepted in this archive. Information concerning glaciers and sea ice especially includes measurements of albedo, heat of fusion and evaporation. The archive will be made accessible to the scientific community via satellite by the end of 1990.

CLIMATE AT GLACIER EQUILIBRIUM LINES

(A. Ohmura, GGEZ)

The climate which prevails at the equilibrium lines of about 70 glaciers has been investigated and parameterized with annual precipitation, free atmosphere temperature and radiation. This parameterization made it possible to calculate the vertical shift of the equilibrium line and the change of mass balance as a result of climatic change.

INFORMATION SYSTEM ON GREENLAND

(A. Ohmura and K. Steffen, GGEZ)

Basic information on Greenland is systematically stored in the institute's VAX 3600. The information consists of coastal lines, glacier boundaries, surface and bottom topography of the ice sheet, distribution of air and ice temperature, precipitation and accumulation.

RELATION BETWEEN AIR AND FIRN/ICE TEMPERATURE

(W. Greuell, GGEZ)

The difference between the mean annual air temperature and the firn or ice temperature at a depth of 10–20 m is caused by processes such as refreezing of percolating melt water, isolation by the winter snow cover and the fact that the ice temperature cannot exceed the melting point. In order to quantify these effects, sensitive experiments will be performed with a numerical energy balance model that includes calculation of the temperature in the uppermost 25 m of the ice. This model has been developed at the Institute of Meteorology and Physical Oceanography in Utrecht. The model will be tuned with existing and future data from the EGIG profile (West Greenland).

SIMULATION OF SNOW ACCUMULATION AND ABLATION

(H. Lang, H. Jensen, M. Rohrer and L. Braun, GGEZ)

Successful physically based simulation of snow accumulation and ablation based on operationally available meteorological data is now possible at selected automatic weather stations of the Swiss Meteorological Service (ANETZ). These simulations allow the assessment of water-equivalent snow storage at individual points and prediction of seasonal discharge. In a further step, the simulation of basin snow-water equivalent is attempted.

SIMULATION OF GLACIER MASS BALANCE AND DISCHARGE IN GLACIERIZED BASINS

(H. Lang and L. Braun, GGEZ)

Different parameterizations of snow and glacier melt as suggested by various existing snowmelt/runoff models have been investigated with a view to their performance for modelling both daily discharge and annual specific glacier mass balance at different elevations in the basin of the Great Aletsch Glacier. Mass balance data in this heavily glacierized area have been found to be essential for calibrating models of snow and glacier melt. Most models are capable of furnishing either good discharge or glacier mass balance calculations, but great care needs to be taken in the choice of parameterizations of radiation and of interpolation schemes in order to obtain acceptable results simultaneously for both. Experience from the Aletsch Glacier will be applied to other glacierized basins.

CLIMATIC CHANGE AND GLACIER RUNOFF IN THE ALPS

(Chen Jiyang and A. Ohmura, GGEZ)

Based on maps and data covering the period since the 1870s, the Alpine ice-covered area is estimated at about 4400 km^2 around 1870, 3540 km^2 around 1930 and at 2900 km^2 around 1970 (glacier inventories). The present volume of the Alpine glaciers is estimated to be about 140 km^3. Mean specific mass balance during the investigated period as geodetically/photogrammetrically measured on several glaciers and reconstructed from temperature and precipitation data is estimated to be about $-300\ mm\ a^{-1}$, giving a volume loss of about 40%. The most intense mass loss occurred in the very dry and warm 1940s when the summer half-year temperature was about 1C above the mean. The decrease in annual runoff due to effects connected with the decrease in ice-cover is estimated to be about 12% for the period 1922/79 for the Massa at Blatten by Naters.

HYDROLOGICAL ATLAS OF SWITZERLAND

(J. Martinec, SLF and M. Aellen, VAW)

The Atlas will contain 20 maps illustrating hydrometric and precipitation networks, water balance components and water quality. Among these will be maps of snow gauging stations and of glacier observations as well as charts indicating extreme snow depths and water equivalents.

ICE CORE STUDIES

COLLE GNIFETTI CORE DRILLING SITE (MONTE ROSA, SWISS ALPS)

(W. Haeberli, S. Wagner, W. Schmid, M. Funk, VAW, D. Wagenbach, N. Beck, O. Münnich, Institute of Environmental Physics, University of Heidelberg, FRG; H. Gäggeler, U. Blatensperger, D. Zimmermann, PSI; H. Oeschger and collaborators, KUP)

Resurveying of the saddle surface in 1989 showed a general decrease in ice thickness since the beginning of the '80s. 2D flowline calculations for approximate dating of the ice cores was completed and 3D calculations are now being prepared. Analysis of borehole temperatures gave no sign of pronounced firn warming during the 20th century. A tunnel dug into the steep slope below Punta Gnifetti/Capanna Margherita — the assumed origin of the flowline leading to the boreholes — penetrated modern firn only and reached bedrock after a few meters. As a consequence, old ice in the deeper parts of the cores must have been deposited on the saddle itself and the influence of the steep slope can be disregarded in flow models. Continuous aerosol monitoring was started at the drill site using a new device, a so-called epiphaniometer. Local snow accumulation and main meteorological parameters are being recorded at the drill site in conjuction with chemical and isotopic analyses of surface snow (major ions, mineral dust, microparticles, radioisotopes, $\delta^{18}O$ and δD) in order to evaluate the existing environmental conditions at the drill site. Chemical stratigraphy (pH, conductivity) as well as $\delta^{18}O$ and δD records have been established from a 66 m core drilled to bedrock. The main results include (a) a significant change in background pH and conductivity during the present century due to anthropogenic inputs, (b) the appearance of acid spikes — probably of volcanic origin — in the preindustrial core section, and (c) a dramatic change towards a more negative level in the isotopic record near the ice base.

ICE CORE DRILLING AT THE FIESCHERHORN PLATEAU

(H. Oeschger and collaborators, KUP)

The fieldwork at the Fiescherhornplateau in the Jungfrau area (3920 m a.s.l.) was finished — after several interrruptions due to bad weather — in summer 1989. The core quality was good. According to the dating of core samples by the Tritium method, the core represents a time span from 1953 to 1988. The high annual accumulation (1.5 m w.e. a^{-1}) allows a detailed analysis of the evolution of air pollutants. Measurements of the sulfate, nitrate and ammonium concentrations are in progress. Initial measurements show seasonal variations which could be due to blocking inversion conditions during winter.

ICE CORE DRILLING IN GREENLAND

(H. Oeschger and collaborators, KUP)

After a test drilling in summer 1988 at Dye 3, core drilling was performed to 304 m depth at Summit (72°37'N, 37°37'W) as part of the international EUROCORE programme. The core quality was excellent down to 204 m beneath the surface. Below this depth difficulties were encountered in obtaining unbroken cores. However, with a few modifications of the drill and the drilling procedure it was possible — with a few exceptions — to obtain an acceptable core quality down to 304 m depth. The age of the ice at this depth is about 1200 years.

AIR MIXING IN THE FIRN OF DRY SNOW ZONES

(H. Oeschger and collaborators, KUP)

A firn ventilation experiment was performed as part of the EUROCORE drilling project at Summit, Greenland, in summer 1989 in collaboration with the Laboratoire de Glaciologie et Géophysique de l'Environnement, Grenoble, France. Air samples were collected in a freshly drill hole at different depth levels of the 70 m deep firn layer. The measured concentrations of CH_4 and CO_2 are in good agreement with diffusion model calculations concerning the penetration of the atmospheric CH_4 and CO_2 concentrations. The experiment confirms that the mixing of the air in firn is essentially controlled by molecular diffusion.

HISTORY OF ATMOSPHERIC COMPOSITION

(H. Oeschger and collaborators, KUP)

Measurements of the CO_2 and CH_4 concentration on air extracted from ice core samples have been continued. The results conform earlier results, especially the increase of the atmospheric concentrations of both components since the beginning of industrialization and the drastic changes during the transition from the last glaciation to the Holocene. There are indications of large and fast variations also of the atmospheric CH_4 concentration during this transition period. The required sample size has to be lowered by a factor of ten in order to reconstruct these variations in detail. Modifications of the measuring procedure are in progress.

MEASUREMENTS OF H_2CO, NH_4^+ AND LIQUID CONDUCTIVITY ON SNOW AND ICE CORES

(H. Oeschger and collaborators, KUP)

Measurements of the H_2CO concentration have been performed on snow and ice samples from Antarctica and Greenland. The measurements show concentrations of a few ppb with no seasonal variations. A drop of the concentration below 1 ppb has been observed during the last glaciation in the deep ice cores from Byrd, Antarctica, and Dye 3, Greenland. Measurements on a 300 m long ice core drilled within the frameowrk of EUROCORE show indications of an H_2CO increase during the period of industrialization. Comparison of NH_4^+ measurements with H_2O_2 results in a pit at Summit show that NH_4 varies seasonally with high values occurring during the summer months. Continuous measurements of NH_4^+ and the liquid conductivity have been performed in the field on selected intervals of the 300 m long-EUROCORE with a new melt technique. Ice strips with a cross section of about 3 cm are melted on a

heated aluminium block. The inner part of the strip, about 1 cm, is used for the measurements and the outer part flows to waste. The measurements show a normally low NH_4 value (1–2 ppb) with spikes up to 150 ppb during the summer months. There are intervals in the ice core where NH_4 neutralizes all the acids. Comparison with the liquid conductivity shows that NH_4 was deposited most probably as $(NH_4)_2SO_4$ or NH_4NH_3.

SNOW, ICE AND GAS PHASE MEASUREMENTS OF HYDROGEN PEROXIDE IN GREENLAND

(H. Oeschger and collaborators, KUP)
Hydrogen peroxide was measured continuously in the field on two Greenland ice cores (Dye 3, Summit). A special subcore melting device was constructed for continuous high resolution H_2O_2 analysis. The main results are as follows: (1) the strong seasonality of the H_2O_2 concentration in polar precipitation is smoothed due to recrystallization in the firn. In regions with annual accumulation rates below 0.3 m a^{-1}, like Summit in central Greenland, the seasonal signal does not survive firnification, whereas at Dye 3 (south Greenland) the annual cycle is preserved in the ice. (2) The H_2O_2 record of the last 200 years in the Summit core shows an increase of 10–20% of the mean H_2O_2 concentration during the last 15 years. A global increase of the atmospheric CH_4, CO_2 and NO_x emissions is also predicted by tropospheric chemistry models. This increase can also be seen in the Dye 3 record, but the influence of melt layers and the distrubed stratigraphy in the upper firn due to earlier activities near the Dye 3 drilling site prevented an unambiguous interpretation. (3) Low H_2O_2 concentrations were found in layers corresponding to large Icelandic volvanic eruptions. This can be explained by high SO_2 emissions reducing the atmospheric H_2O_2 content. H_2O_2 is known to be a very important oxidant for SO_2 in cloud droplets.

MEASUREMENTS OF ^{10}Be AND ^{36}Cl ON POLAR ICE

(J. Beer, UP EAWAG-ETHZ; H. Oeschger and collaborators, KUP; W. Wölfli and collaborators, IMP ETHZ-PSI)
Measurements of ^{10}Be and ^{36}Cl on ice samples from Greenland revealed several important results. Short-term (50–300 y) ^{10}Be concentration-variations during the Holocene agree surprisingly well with the known ^{14}C variations measured on tree rings. This strongly indicates that the main cause is solar modulation of galactic cosmic ray flux. This hypothesis is supported by the detection of a clear 11-year solar cycle in a ^{10}Be profile which is analyzed with a time resolution of one year. Measurements on the same ice core show an increase in ^{36}Cl concentration by a factor of almost 1000 at the end of the '50s caused by nuclear bomb tests near the sea.

SEA ICE

REMOTE SENSING, NORTHERN BAFFIN BAY

(Konrad Steffen, GGEZ)
The remote sensing studies of the North Water region (northern Baffin Bay) have been completed. Fractures and deformation processes in Arctic pack ice, and the ice conditions of an Arctic polynia have been studied based on infrared thermometry and visual information.

SEA ICE VALIDATION FOR THE DMSP SSM/I

(Konrad Steffen, GGEZ)
For the Defense Meteorological Satellite Program (DMSP), a Special Sensor Microwave Imager (SSM/I) sea ice validation effort was carried out to demonstrate a quantitative relationship between the SSM/I-derived sea ice parameters and those same parameters derived from other data sets including visible and infrared satellite imagery, aerial photographic and high-resolution passive and active microwave imagery from aircraft. The general question to be addressed is with what accuracy (relative to these other observations) can the following sea ice parameters be determined: (1) position of the sea ice boundary, (2) total sea ice concentration, (3) multi-year sea ice concentration. Specific tasks include (a) a study of the interrelationship of surface information content and sensor spatial and spectral resolution in order to establish relationships between ice surface features and the manner in which they are expressed in the satellite observations; and (b) to apply these relationships to map the sea ice features which can be used to evaluate NASA's proposed SSM/I sea ice algorithms. The analysis showed that ice concentration derived from passive microwave data has mean accuracy of 4% and 2% for global and local tie points, respectively, relative to high resolution Landsat imagery.

PERMAFROST AND PERIGLACIAL PROCESES

ANALYSIS OF PERMAFROST CORES FROM MURTEL ROCK GLACIER

(W. Haeberli, S. Wagner, VAW; H. Gäggeler, U. Baltensperger, E. Höhn, PSI; B. Stauffer, KUP and D. Wagenbach, Institute of Environmental Physics, University of Heidelberg, FRG)
Pilot analyses were performed on samples from the Murtèl/Corvatsch rock glacier experimental core (M I, uppermost 21m of the 50 m thick permafrost) which consists mainly of massive ice. Dimater of ice crystals is up to about 10 mm and *c*-axes are roughly parallel to the rock glacier surface. Stable isotopes show considerable scatter and indicate that fractionation during the ice formation was insignificant. Pollen concentration is extremely low and chemical

composition of the ice samples reflects diluted groundwater rather than atmospheric precipitation. Tritium and ^{210}Pb exclude recent ages (20th century). The investigated permafrost may, in fact, represent frozen groundwater from the earlier part of the Holocene. A programme for systematic investigation of the main core down to the bedrock is now being initiated.

MONITORING OF ROCK GLACIER PERMAFROST

(W. Haeberli, F. Keller, W. Schmid, D. Vonder Mühll and S. Wagner, VAW)

Long-term photogrammetry continues on the rock glaciers Gruben, Réchy, Gufer/Aletsch (Valais) and Murtèl/Corvatsch, Muragl, Ursina (Grisons). Vertical and horizontal borehole deformation as well as borehole temperature is continuously measured at Murtèl/Corvatsch. Installation and instrumentation of 2 new boreholes (no cores) has been prepared by geophysical soundings (BTS, seismic refraction, D.C. resistivity, radar) on rock glacier Ursina/Pontresina. First results from the borehole Murtèl/Corvatsch-show surface parallel steady-state creep in supersaturated permafrost overriding non-deforming structured frozen blocks. No dramatic increase in permafrost temperature has taken place since 1987.

ROCK GLACIER GEOPHSYICS

(D. Vonder Mühll and W. Haeberli, VAW)

In order to determine geophysical parameters of permafrost within Alpine rock glaciers (heat flow, thermal conductivity, electrical resistivity, characteristics of elastic and electromagnetic wave propagation) and to improve the interpretation of surface soundings (seismic refraction, electrical resistivity, radar), tests were performed at drill sites (Murtèl/ Corvatsch, Ursina/Pontresina) and comparison is made with borehole information (core stratigraphy, borehole geophysics). Analyses of borehole temperatures at Murtèl/Corvatsch show an average surface temperature of around –3°C, increased heat flow in the uppermost 50 m — perhaps due to cooling since about 1950 — and a heat flow inversion at the hole bottom, possibly reflecting warming during earlier decades of the 20th century.

HYDROLOGY OF DISCONTINUOUS MOUNTAIN PERMAFROST

(G. Tenthorey and E. Gerber, GGUF)

In order to develop a hydrological model for the periglacial belt of the Alps, water input, transit and runoff in rock glacier areas are being investigated using tracer experiments supplemented with geophysical soundings (electrical resistivity, seismic refraction). Continuous measurements of air and ground temperature as well as of precipitation and runoff are also carried out. The main test site is Val de Réchy, Valais, Pennine Alps.

PERMAFROST, SNOW AND AVALANCHES

(F. Keller, W. Haeberli, VAW, B. Salm and H. Gubler, SLF)

Activities for avalanche protection alter snow conditions and, hence, the energy balance of the ice-containing ground. On the other hand, permafrost in the ground markedly reduces the heat flow through the winter snow cover and thereby influences snow metamorphosis and snow cover stability. A study is being carried out in the Upper Engadin, Grisons (mainly Murtèl/Corvatsch and Ursina/ Pontresina) to investigate and describe these interactions as a basis for developing adequate strategies for avalanche protection in Alpine permafrost areas. Snow profiles from the winter 1989/90 exhibit large differences in snow characteristics over seasonally and perennially frozen ground, respectively.

PERMAFROST AND GLACIERS IN THE UPPER ENGADIN: 1850–1970–2050

(M. Hölzle and W. Haeberli, VAW)

Using a great number of BTS-soundings in winter snow for rapid permafrost mapping, a key is sought for predicting the distribution of Alpine permarost as a function of mean annual air temperature, direct solar radiation and roughly defined snow characteristics (windblown crest, foot of slope with avalanche cones, etc.). In addition, simple algorithms are developed to parameterize glaciers (thickness, thermal characteristics, flow, reaction and response times, past balances and length changes, bed characteristics, etc.) on the basis of glacier inventory data. The aim of the study is to model the effects on Alpine permafrost and glaciers with various scenarios of potential future warming, the time horizon being the year 2050.

PILOT PERMAFROST/GLACIER MAP OF THE UPPER ENGADIN

(W. Haeberli, M. Hölzle, F. Keller, D. Vonder Mühll, VAW, and M. Maisch, GGUZ)

The sheet No. 1257 St. Moritz of the 1 : 25 000 topographical map has been selected for a pilot study with a view of systematic permafrost mapping. A detailed inventory of rock glaciers and push moraines was compiled with specially flown infrared aerial photography; and a computer programme for mapping permafrost on the basis of a digital terrain model was developed within the Geographic Information System KRYO on ARC/INFO. Field checking, improvement of computer programmes and completion of the map with geophysical/borehole data as well as glacier information (historical, Holocene and late-glacial moraines) is now underway.

PERIGLACIAL DEBRIS FLOWS

(M. Zimmerman, D. Rickenmann, W. Haeberli, VAW and U. Rösli, INGEOL)

An extended analysis of the numerous — and in places catastrophic —1987 debris flows was carried out using qualitative and quantitative airphoto interpretation, geophysical soundings, glaciological, hydrological, geomorphological and geological assessments, dynamic flow considerations and historical reconstructions. The periglacial belt was most severely affected and a considerable percentage of debris flows originated in areas exposed by the glacier retreat of the 20th century. Many large events had started in thick and non-frozen, extremely loose

and highly permeable but hydraulically non-homogeneous scree and morainic material. The potential for many more debris flows exists in most catchments and the hazard potential could increase in future with continued or even accelerated glacier shrinkage and permafrost degradation.

GLACIAL GEOLOGY/ PALEOGLACIOLOGY

TILL FORMATION BY ALPINE GLACIERS

(Ch. Schlüchter and K. Dick, INGEOL)
Geological processes taking place at present-day glacier margins (Findelen, Tsijiore Nouve, Stein, Val Malenco) are documented in order to obtain a sedimentological reference for the verification of moraine complexes formed by glaciers in Antarctica and to improve the classification of primary and secondary tills.

GLACIER EXTENT IN 1850

(M.Maisch, GGUZ)
Reconstruction of glaciers at the maximum extent of the Little Ice Age (1850) is nearing completion for the Grisons. Losses in area and volume as well as changes in equilibrium line positon are being analyzed with respect to present-day conditions. Detailed investigations at individual glaciers reveal additional climatic and geographic aspects of the observed changes. It is planned to expand the historic inventory to include the entire Swiss Alps.

HOLOCENE GLACIER FLUCTUATIONS IN THE ALPS

(H. Holzhauser, GGUZ and H.J. Zumbühl, GGUB)
Fluctuations of Great Aletsch, Rhone, Rosenlaui, Lower Grindelwald and Interaar glaciers during the youngest part of the Holocene time period as reconstructed using a variety of historical and field methods was published for the 125-year jubilee of the Swiss Alpine Club (1988). With the exception of Unteraar, the investigated glaciers show a comparable behaviour. Research is now being extended to Belvedere, Gorner, Ried and Morteratsch glaciers. Reconstructions in these cases are mainly based on ^{14}C-dates of fossil soils and wood in moraines in combination with dendrochronology. Analyses of tree ring width are used to investigate the local climatic influence of advancing and retreating glaciers.

LATE GLACIAL EXTENT OF ALPINE GLACIERS

(M. Maisch, GGUZ)
Glacier extent during late glacial times is being reconstructed and attempts are being made to obtain relative age dating. Paleogeography of glaciers during the Younger Dryas time (ca 11 000–10 000 years BP, the so-called Egesen stage) will soon be completed in the Grisons (Eastern Alps).

ALPINE DEGLACIATION AND CLIMATIC CHANGES

(B. Wohlfarth, IGB; B. Amman, BUB; U. Eicher, KUP; W. Haeberli, VAW; A. Lotter, EAWAG; M. Maisch, GGUZ; F. Niessen, GEOLEZ; and Ch. Schlüchter, INGEOL)
Within IGCP 253 "Termination of the Pleistocene", a regional working group was set up to study the Alpine deglaciation history and the climatic changes at the transition from the Late Glacial to the Holocene time period. Special emphasis is placed on climatic changes having occurred during the Allerõd, Younger Dryas and Preboreal time periods in the Alps and in the Alpine foreland.

RETREAT STAGES OF THE RHONE/AARE GLACIER SYSTEM

(E. Krayss, GGUZ)
Various levels of the Rhone/Aare Glacier system can be discriminated by mapping marginal drainage patterns. The uppermost level corresponding to the maximum glacier exten is followed by a stage terminating near Grauholz/Solothurn and another stage which probably corresponds to the Bern readvance of Aare Glacier and the Stein am Rhein stage of Rhine Glacier.

THE LAST GLACIAL MAXIMUM IN THE ALPINE FORELAND

(C. Schindler, Ch. Schlüchter, K. Hildbrand, R. Lang, INGEOL)
The area of maximum extent of the Rhone Glacier within the Alpine foreland has been mapped in detail as part of the "Quaternary Mapping Project". Current work focuses on the Reuss/Aare Glacier bordering the ice-free area of the Napf region and on trimlines in the mountains of the Lower Engadin, Grisons. Facies analyses of sediments deposited during the considered time interval are being carried out and another set of pedostratigraphic data has been obtained from the Rhone Glacier area.

ALPINE PALEOGLACIOLOGY

(W. Haeberli and H. Gudmundsson, VAW)
Glacier retreat and the 50% loss in ice mass since the Little Ice Age was compared with ice shrinkage at the end of the last Ice Age (about 20 000–10 000 years BP). Temperature rise is faster and average mass balance considerably more negative in the 20th century. Modern length changes are also faster by roughly one order of magnitude if the influence of total glacier length and of the mass balance gradient are taken into account. A finite element model is being tuned to measured data of Aletsch Glacier in order to compare the modern glacier with the one at the Little Ice Age maximum, during the Younger Dryas time and at the 20 000 years BP situation.

ICE BUILD-UP AND MAXIMUM EXTENT OF RHEIN/LINTH GLACIER

(O. Keller and E. Krayss, GGUZ)
Assuming 7000 years from 25 to 18 Ka BP for the ice build-up of the Rhine/Linth Glacier system from a stage near Chur, mean mass balances of about

$+0.2\,m\,a^{-1}$ decreasing in time to $+0.05\,m\,a^{-1}$ were calculated. Corresponding advance velocities are estimated at about $80\,m\,a^{-1}$ at the beginning of the considered time interval (ice advancing in the Alpine troughs) and at less than $10\,m\,a^{-1}$ during the final phase at the margins of large piedmont lobes.

PLEISTOCENE GLACIAL SEDIMENTS

(Ch. Schlüchter, K. Dick, H.-R. Graf, S. Wegmüller, F. Zuber, INGEOL)

Facies associations of sediments produced by the Pleistocene glacier advances to the Alpine foreland are being investigated in order to obtain field data for paleoglaciological modelling. Emphasis is placed on the analysis of important glacigenic accumulations in inner-alpine valleys (Val d'Hérens, Schanfigg) as well as to a verification of a glacigenic influence on the formation of the Swiss "Deckenschotter" which probably represents accumulations of the Older Pleistocene.

GEOTECHNICAL PROPERTIES OF PERIGLACIAL SEDIMENTS

(Ch. Kapp and C. Schindler, INGEOL)

The influence of former as well as present-day permafrost conditions on geotechnical parameters of periglacial sediments is being investigated. The study is based on a number of cases, where special problems have been encountered in construction work. Main emphasis is on possible effects of Ice Age permafrost with respect to slope stability, cohesion, state of consolidation, strength, porewater pressure, water content and compressibility of today's soils.

OVERDEEPENED VALLEYS OF THE ALPINE FORELAND

(C. Schindler, Ch. Schüchter, K. Hildbrand and B. Müller, INGEOL)

Information on overdeepened valleys at the margins between the Alps and the foreland is being collected and the morphology of these deep erosional features described. A drilling programme on Quaternary sediments in the Seeztal — one of the major deeply incised vallyes cutting across the northern Alpine border — has been set up.

GLACIAL HISTORY IN THE ROCKY MOUNTAINS

(M. Maisch, GGUZ)

Studies and analyses on the geomorphology and glacial history in the region of the Colorado Front Range are being continued. The investigation mainly concerns glacier retreat during Late Wisconsin time and the activity of periglacial surface phenomena.

PLEISTOCENE GLACIATION IN JAPAN

(Ch. Schlüchter, INGEOL; S. Horie, University of Kyoto)

The mapping project continued in the Japanese Alps as well as in the Hidaka Mountains and was supplemented by stratigraphic reference sections documenting multiglaciations. Snowline depressions are being calculated for Hokkaido during the Last Glaciation. Summary publications are now being edited.

Submitted by Wilfried Haeberli

Abbreviations used in the text:

BUB	Botanical Institute, University of Berne
EAWAG	Swiss Federal Institute for Water Research and Water Pollution Control
ETH	Federal Institute of Technology, Zürich
GEOLEZ	Geological Institute, ETH Zürich
GGEZ	Geographical Institute, ETH Zürich
GGUB	Geographical Institute, University of Berne
GGUF	Geographical Institute, University of Fribourg
GGUZ	Geographical Institute, University of Zürich
GK/SANW	Glacier Commission/Swiss Academy of Sciences
ICT	Institute for Communication Technology, ETH Zürich
IGB	Institute of Foundation Engineering and Soil Mechanics, ETH Zürich
IMP	Institute for Intermediate Energy Physics, ETH Zürich
INGEOL	Engineering Geology, ETH Zürich
KUP	Climate and Environment Project, Physics Institute, University of Berne
PSI	Paul Scherrer Institute, Würenlingen
SLF	Swiss Federal Institute for Snow and Avalanche Research, Weissfluhjoch-Davos
SMA	Swiss Meteorological Institute, Zürich
VAW	Laboratory of Hydraulics, Hydrology and Glaciology, ETH Zürich

SOVIET GLACIOLOGICAL RESEARCH IN 1989

In 1989 glaciological investigations were conducted in the Caucasus, Middle Asia, in the Khibini mountains, in Siberia, Far East and Kamchatcka, in the Arctic and Antarctica.

The investigations were carried out by the following organisations, which are identified in the text by their abbreviation:

Institute of Geography of the USSR Academy of Sciences	IGAS
Institute of Solid-State Physics of the USSR Academy of Sciences	ISSP
Institutes of Geography of the:	
Siberian Department of the USSR Academy of Sciences	IGSD
Pacific Far Eastern Department of the USSR Academy of Sciences	PIG
Academy of Sciences of Kazakh SSR	IG ASKazSSR
Academy of Sciences of Georgian SSR	IG AS GSSR
Institute of Water–Ecological Problems of the FED of the USSR Academy of Sciences	IWEP
Institute of Geology of the Academy of Sciences of Estonian SSR	IG AS ESSR
Institute of Geology and Geophysics of the UzSSR	IGG AS UzSSR
Geocryology Institute of the Siberian Department of the USSR Academy of Sciences	IG SD AS USSR
Institute of Volcanology of the FED of the USSR Academy of Sciences	IV FED
Institutes of the State Committee for Hydrometeorology of the USSR:	
West-Siberian	WSRI
Middle-Asian	MARI
Trans-Caucasian	TRI
Arctic and Antarctic	AARI
Boards of the State Committee for Hydrometeorology of the USSR:	
Azerbaijyn	AzBHSC
Georgian	GBHSC
Kamchatka	KBHSC
Kazakh	KazBHSC
North-Caucasian	NCBHSC
Tadjik	TadBHSC
Novosibirsk Institute of Railway Transport	NIRI
Industrial Research Institute of Engineering Constructions of Gosstroy of the USSR	IRIEC
Kirghiz Aero-Geodetic Enterprise SBCC	KirgAGE
Moscow State University:	
Department of Cryology and Glaciology	DGG MSU
Institute of Mechanics	IM MSU
Airspace Methods Laboratory	ASML MSU
Problem Laboratory of Snow Avalanches and Mudflows	PLAM MSU
Tomsk University	TSU
Kazan University	KSU
Leningrad Mining Institute	LMI
Tien Shan Physics-Geographical Station of the Academy of Sciences of Kirghiz SSR	TSPGS.

The information is based on reports sent by the above organizations to the Glaciology Section of the Soviet Geophysical Committee.

MATHEMATICAL MODELLING IN GLACIOLOGY

AUTOMATIC MAPPING

(KirgAGE)

Investigations were conducted, methods and software developed for isoline mapping of areal properties of glaciers, such as mean elevations and their changes, etc.

ICE-SHEET MODEL INCORPORATING COMPRESSIBILITY

(KSU, AARI)

A mathematical ice-sheet dynamics model was developed incorporating compressibility (compaction) of snow–firn and ice with trapped gas bubbles, for theoretical assessment of glacial ice age and distribution of its density with depth. A mathematical model was likewise developed for computations of thermohydrodynamic parameters of air used as a

circulation agent in mechanical drilling of glaciers. The model accounts for a possible condensation of moisture caused by the cooling of an air flux. It was shown that two condensation regimes are possible: condensation on channel walls only and bulk condensation. This second type of condensation could cause the quality of face cleaning to deteriorate.

SNOW COVER AND AVALANCHE MODELS

(PLAM MSU)

A two-dimensional mathematical model was developed for computations of a stressed state of snow on mountain slopes to assess the effect of snow catchment transverse curvature on snow stability and avalanche formation. A probabilistic model was put forward to assess the pressure exerted by avalanches on obstacles in the avalanche deceleration zone. The pressure was assessed for different laws governing the distribution of avalanche density and velocity.

(WSRI)

WSRI developed and sent for commercial testing: a draft of methodological instructions, a testing programme and software "Estimation of snow pack stability with account of its viscous flow" which was added to the WSRI information pool, while the software algorithm is valid for all geographical regions.

AN ALPINE REGION DEVELOPMENT MODEL

(PLAM MSU)

Data were collected in the Khibini Mountains to cover the Kirov–Apatity region for the "Khibini-I" mathematical model for assessing ecological implications of industrial development. Data were selected for the "Natural resources" and "Population" blocks, files and computer programmes were developed for personal computers and the "natural resources" block was incorporated into the model.

GLACIAL LIGHT EXPOSURE MODEL

(KirgAGE)

Potential light exposure of the Abramov and Golubin glaciers' surface was assessed using digital topographic landscape models.

GLACIAL SYSTEMS INSTABILITY

(IGAS)

Theoretical investigations were conducted of different mechanisms of glacial systems instability produced by the interaction of glaciation with the atmosphere, ocean and lithosphere.

ICE PHYSICS

ICE CRYSTAL GROWTH

(PLAM MSU)

Processes of ice crystal generation and growth in vapour and liquid phases and in disperse mountain rocks were examined in the course of analytical and experimental studies.

OHMIC ELECTRODES FOR THE ICE–METAL CONTACT

(ISSP)

When a direct current or an alternating current having a frequency much below the Debary frequency is applied, a bulk charge is formed in the near-electrode area which inhibits the flow of current. There is no exchange of carriers between ice and metal because of the great electron difference: 4 ev. A technique was suggested to overcome this barrier which, in its turn, increases the current by two orders of magnitude at the same voltage, while the flow of current becomes temporarily stable (without formation of a bulk charge). The observed effect is achieved due to the formation of ice with a high OH ion concentration in the near-electrode area. Later these metal electrodes with a thin covering layer are frozen on to the sample examined.

THE NATURE OF CHARGE CARRIERS IN ICE

(ISSP)

The development of an Ohmic metal electrode with ice made it possible to address again the problem of proton conductivity. Experiments conducted in the temperature range from +20°C to –40°C measured the amounts of hydrogen and oxygen released during the passage of direct current through a sample. The amount of released gases coincided with predictions.

ICE–ELECTRON CONDUCTOR INTERFACE

(ISSP)

The interface between ice and electron conductors (metals, semi-conductors) is of particular interest since it separates substances with different types of conductivity. Conditions were found which make an exchange of charges possible at this interface, and a system of electron levels in ice, ensuring such a charge exchange, was described.

RECOMBINATIONAL INJECTION OF CHARGE CARRIERS INTO ICE

(ISSP)

Ice sample conductivity was found to go up when direct current flows through it. Experiments established an increased concentration of carriers inherent to ice, and determined their lifetime and mobility of their ions. Failing to describe such an increase with the help of familiar types of injection, a recombinational injection model was suggested wherein non-equilibrium carriers appearing as atomic H and O are recombined into H_2 and O_2 molecules.

ICE AND SNOW CHEMISTRY

ICE CHEMISTRY OF THE AMUR

(IWEP)

Experiments examined the chemical composition of the Amur river ice cover and established a relationship between vertical and areal distribution of chemical composition components and the structure and textural features of genetic horizons.

MELTWATER CHEMISTRY

(IWEP)

The temporal variability of meltwater chemical composition in the Amur basin on the territory of the Bolshe-Khekhtsir reserve is characterized by concentration maxima caused by 1) a washout of substances from the snow column, 2) arrival of water from remote parts of the watershed, 3) slower melting or cessation thereof in the evening, 4) ion exchange. Lower horizons of melting snow accumulate potassium and ammonium ions.

WATER–ICE–ROCK

(IWEP)

Processes of oxidation, ion exchange, degradation of organic compounds, sedimentation of mineral and organic compounds are exceedingly active at negative temperatures. Weathering of rocks in the cryolithozone results in the formation of hydrocarbonate-sodium, -magnesium, -sodium-magnesium, -sodium-calcium, -calcium-sodium and ferrous ice and water. Ice interacting with organic rocks yields low-mineralized ice and water with a high content of fulvic acids.

SNOW CONTAMINATION

(IWEP)

The snow cover of the Komsomolsk reserve (the Amur basin) was examined for the content of trace elements which come from gas and dust emissions of industrial activities located in Komsomolsk, Amursk, and Khabarovsk. The contamination was assessed through the values of fractionation coefficients, by correlation and comparison. Despite their distinctly anthropogenic source, none of the elements exhibits concentrations above their MPC.

GLACIERS

MASS-BALANCE MEASUREMENTS

(IVAS)

Basic characteristics of surface mass exchange were measured at Koselsky glacier (the Avachinsk volcanic group). The 1988/89 winter balance was 357 g cm^{-2} (including the 17 g cm^{-2} internal infiltrational accumulation), which is close to normal. The summer balance was less than normal by 10% and amounted to 431 g cm^{-2}. Thus, the 1988/89 annual balance of the glacier amounted to 74 g cm^{-2}. Despite the fact that the conditions of the ablation period in 1989 were similar to those of the preceeding year (as regards the air temperature values), the value of ablation decreased by 10%, because surface melting was controlled by a melting moraine.

(TSU)

Weather conditions on the Altai in 1989 were characterized by higher amounts of annual and winter precipitation and positive air temperature anomalies which were +0.7 and +4.5°C. Numerous summertime snowfalls kept the glacier covered with a 10–15 cm layer of snow (the highest was 50–60 cm), thus diminishing their melting by 20–30%. The year is characterized by substantial accumulation exceeding the mean long-term record value by 10–15 g cm^{-2}. The value of ablation was close to normal, so that the mass balance of glaciers was positive:

Maly Aktru 22
Levy Aktru 3
Vodopadny 10
Pravy Aktru 19 g cm^{-2}

Thus, the period of positive mass balance of the Altai glaciers has been distinctly observed since 1982/83. Surface velocities considerably increased in the middle part of terminuses, while the retreat of their fronts substantially slowed down. Thus, the tip of the Maly Aktru terminus retreated by only 3.2 m.

The total runoff from the Aktru glacial basin, from 1 May to 12 September 1989, was 21.45×10^6 m^3, or 615 mm, which is 20% below normal over the same period. The glacial constituent is 13.21×10^6 m^3, or 380 mm, i.e. 62%.

JOINT SOVIET–CHINESE WORK IN TWO GLACIAL BASINS ON THE TIEN SHAN

(IGAS, Institute of Glaciology and Geocryology, Lanzhou)

Joint stationary studies were initiated in two glacial basins of the Tien Shan: on the Akshiyrak ridge in the USSR and in the Urumqi river basin in eastern Tien Shan, China. It was discovered that the role of the summer balance in the annual glacial mass variations grows with the growth of continentality from west to east and with the shift of the annual precipitation maxima to the middle of the summer (up to 80% in June–August). In eastern Tien Shan, in disperse glaciation conditions, the altitudinal precipitation gradient is virtually non-existent in the glaciation zone, while in the area of compact glaciation, on the Akshiyrak and Bogdo massives, the altitudinal precipitation gradient is rather high.

CALCULATIONS OF ABLATION FOR THE EQUATORIAL AND TROPICAL ZONES

(IGAS)

A technique was developed for calculating glacial ablation in the equatorial and tropical zones where no relationships exist between ablation and temperatures of the calendar summer. The melting of such glaciers is assessed through the annual dynamics of heat balance components with a +20% error.

THE ROLE OF LANDSCAPE AND CLIMATE IN MOUNTAIN GLACIATION AT 30°–65°N

(IGAS)

Special methods were used to compare mountain elevation fields and equilibrium line altitude fields of glaciers in the Karakorum, Pamirs, Caucasus, Alps, Coastal and Rocky mountains, and mountains in south-eastern Alaska. The analyses showed that topography is more important for glaciation than climatic conditions. It was also shown that accumulation prevails over ablation, and that the role of accumulation increases with the increase of continentality.

LIQUID PRECIPITATIONS ON GLACIERS

(IGAS)

Global regular features were discovered in the distribution of liquid precipitations and their share in total atmospheric precipitation amount in the largest alpine glaciation systems of the Northern Hemisphere. It was shown that at the equilibrium line altitude, liquid precipitations affect the heat balance of maritime glaciers.

(IGAS GSSR)

Ice melting was studied on the Buba glacier in the Bubistskali river basin, and at the height of 2900–3100 m its value averaged up to 7.9 g cm^2 d. Control gauges were installed to measure water balance components of the river over the ablation period. From 15 July to 20 August glacier runoff was 3.28×10^6 m^3. Actinometric and meteorological observations were also conducted.

(DCG MSU)

Continuous long-record mass-balance observations were continued on the Dzhankuat glacier, on the northern slope of Central Caucasus. The 1988/89 season was characterized by increased accumulation, especially in the glacier's upper zones. The accumulation field structure was statistically studied to assess its temporal similarity. The Dzhankuat local-level geo-information system is being set up.

(IGAS KazSSR)

Surface and dynamic mass- and energy-exchange was observed between the Tuyuksu glacier in Zailiysky Alatau and the Shumskiy glacier in Dzhungar Alatau. Observational materials were processed on internal variability of mass balance and on the dynamic regime of the Tuyuksu glacier over 1987/88. Analysis was performed of long-record data on the glacier's mass balance, its spatial and temporal variability, variations of balance components and its dependence on climatic factors. Quantitative characteristics of changes in Zailiysky Alatau glaciers were assessed over 20–30 years in terms of length, area and volume of the ice they contain.

(MARI)

Regular detailed microscale snow surveys were conducted on the galcial and non-glacial surfacers of the Abramov glacier in conditions of intensive wind-caused redistribution of snow.

RECONSTRUCTION OF SPECIFIC BALANCE

(KSU, IGAS)

A method was developed for the reconstruction of specific mass balance of a mountain-valley glacier for given profiles of its free surface and bed. The efficiency of the method largely depends on the availability of additional information on the shape of mass-balance curves.

GLACIAL RUNOFF PREDICTION

(TSPGS)

Ice resources were estimated for glaciers of the Issyk-Kul area and the Sary-Dzhaz basin. The volume of ice in the first region is 25.97 km^3, and in the second 209.62 km^3. A forecast of possible runoff changes was made for the Issyk-Kul area, for a 1° and 2° climate warming. If the predicted climate warming actually takes place, it is glaciers lying on the southern slope of the Kunghey Ala-Too ridge which will be in a most disadvantageous position. By 2025, their area will shrink by 76.6% compared with the contemporary area, and the amount of glacial runoff will decline from 102.4 to 26.4×10^6 m^3. As for the northern slope of the Terskey Ala-Too ridge, though the area of the glacier will shrink by 31.9%, its glacial runoff will, nevertheless, be 23.4% higher than now.

(MARI)

Methods were developed for the prediction of the glacier and snow runoff components of the Sokh river for the summer months (June–August). For 24 river basins of the Ghissaro-Alay region and 16 river basins of the Pamirs, the volumes and variation coefficients of total glacial melting and glacial runoff were estimated on the basis of data about the extent of glaciation in 1957 and 1980; changes in glaciation water resources in the same basins were likewise assessed over the period of 1957-80.

(IGG AS UzSSR)

The instrumental and literature-derived data point to the recession of Severtsov glacier on the Ghissar ridge, in the upper reaches of the Kashkadarya river. Over the period 1850–1900, the glacier retreated every year by 2.2 m on average and lost 10.5×10^3 m^2 every year, while during 1900–89 the figures were 5.8 m and 4.8×10^3 m^2, respectively. During the second interval the glacier lost 72.8×10^6 m^3 of ice.

(IGAS GSSR)

The rates of retreat of glacial terminuses on the southern slope of the Greater Caucasus are different; that of Adishi, Chalaati, Buba, Tbilisa is 5–10 m a^{-1}. Lekhziri, a composite valley glacier, retreated by 43 m during the year.

(NCBHSC)

In the northern Caucasus observations were conducted over 29 glaciers, 21 of which were retreating, 4 were stationary and 4 were advancing. The values of retreat were 0.6–42.8 m, and the values of advance 0.8–12.6 m. Out of large valley glaciers, the Mizhirghi glacier continues to advance and moved 12.6 m during 1988–89. The Bezenghi glacier retreated by 0.8 m during 1988–89. Glaciological observations

were conducted on the glaciers Shaurtu, Nizhny and Verkhny Kulak in the Cheghem river basin.

(ASML MSU)
A photosurvey of the Elbrus glaciers was performed from a helicopter. A map of spatial alterations of the Garabashi glacier was constructed for the period of 1959–87: its linear retreat amounted to 70 m, and the height of the surface in the lower part of the terminus became 30 m less on the average. A surface photo-theodolite survey of the Shkheld glacier was made simultaneously with plane and perspective surveys from a helicopter. The terminus of the Jankuat glacier, which was virtually stable in recent years, was surveyed once more.

(TRI, GBHSC, AzBHSC)
Observations were conducted on the Yuzhny, Yugo-Vostochny, Tykhitsar, Merkar glaciers in the eastern Caucasus; the Devdoraki, Ghergheti, Abano, Mna glaciers and on the Suatisi-Kazbek glaciation. The observations included: surveying the fronts of their terminuses, glacier surface altitude measuring, measurements of ice speed and ablation at fixed transverse profiles. Water discharge was measured at the sources of the Chkheri, Kila and Seldy which have their sources at the Yuzhny and Yugo-Vostochny glaciers, and the Tykhitsar and Murkar glaciers, respectively. The observations showed that the glaciers continue to retreat, but no more than 8–10 m a^{-1}; the Yuzhny glacier still has a tendency to grow, and ice thickness at the tip of its terminus increased by 3–5 m.

(TSPGS)
Glaciers of the Issyk-Kul region were examined in the basins of the Chon-Kyzyl-Su rivers, the Karabatkak glacier, the Barskaun river-glaciers N 129, 131, and the Zapadny Suyek glacier in the upper reaches of the Bolshoy Naryn. The observations point to the on-going shrinkage of the glaciers and their negative balance. The extent of glaciers lying on ridges with maximum elevations reaching 4400–4600 m diminishes not only in the terminal parts, but also in the areas of greatest accumulation.

(IVAS)
Observations were initiated to study the movement of the Cheremoshny glacier on the southern flank of Tolbachik volcano, in Kamchatka. In 1984–88 its front moved with the speed of 30–40 m a^{-1}, in September 1989 it advanced by 2 m d^{-1}, and over the year the length of its terminus increased by 200 m.

GLACIER FLUCTUATIONS IN THE ALPS

(IGAS)
Maps of annual shift of fronts of 124 glaciers in the Alps were constructed for the period of 1981–85. A high degree of similarity was found between annual shifts of glacier fronts, with a 0.8–0.9 correlation coefficient.

SURGING GLACIERS

(TSPGS)
A catalogue of surging glaciers in Kirghizia was prepared on the basis of aerial photosurveys, large-scale maps and flight-derived data. 84 surging glaciers were discovered. Nearly all of them are far from development regions, so there is no immediate danger.

(IGAS, KazAGE)
A simplified operational stereo-photogrammetric processing was performed using the data obtained during six flights made in 1989 to survey the Medvezhiy terminus (25.03, 20.04, 12.05, 22.06, 9.07 and 3.10). For the first time they obtained and analysed a detailed kynematics pattern of the glacier in a stage of advance since its beginning in the winter of 1988/89.

PULSATION OR SURGE

(IGAS)
A concept is being developed about the existence of two essentially different types of glacier-caused disasters: pulsating and surging glaciers are associated with different natural mechanisms.

VOLCANISM AND GLACIATION

(IVAS, KSU)
The processing of core and thermometric data obtained in a drill hole on Schmidt Pass in the area of Klyuchevskoy volcano has been completed. Theoretical simulations of heat and mass transfer in the Pass' saddle based on the in situ measurements have yielded estimates of the geothermal heat flow on the glacier bed near the base of the glacier, which was 8 W m^{-1}, and of the ice melting rate: 0.75 m a^{-1}, with the surface ice mass balance being 0.18 m a^{-1}.

RADIO-ECHO SOUNDING OF GLACIERS

(TSU)
A topographic survey was conducted to examine the bed of one of the largest glaciers on the South-Chuysk ridge — the Sofia glacier, 17.6 km^2. Radio-echo sounding was performed on 30 glaciers in the course of work in the north Chuysk, south Chuysk and Katun ridges. The maximum thickness, 328 m, was observed on the Tronov Brothers glacier, 10.4 km^2, which begins on the slopes of Mt Belukha. Ground-based radio-echo sounding became possible on many glaciers through the use of a portable radar designed in TSU.

(KirgAGE)
A ground-based topographic survey of the Golubin glacier bed topography was performed at a 1 : 10 000 scale. It was a radio-echo sounding survey based on the use of a portable TSU-designed radar. 1 : 5000 maps of surface topography, bed and thickness of ice were made for three hanging glaciers (NN 129–131 in the Catalogue) on the northern slope of the Terskey-Ala-Too ridge.

(IGAS KazSSR)
Ice reserves in the Dzhungar Alatau glaciers and ice volume in the glaciers of the Lake Balkhash basin were assessed on the basis of geophysical work.

SNOW COVER AND AVALANCHES

GENERALIZATION OF SNOW COVER DATA

(MARI)

A reference book on mountain snow cover in the USSR is being compiled. Climatological generalization of ground-based and aerial snow survey data has been performed for alpine regions of Middle Asia, the Caucasus, the Carpathians and the Crimea. Materials have been prepared on the intra-annual distribution of year-to-year variability of snow reserves, depth of snow cover and its density.

ADIABATIC EVAPORATION OF SNOW

(PLAM MSU)

Adiabatic evaporation of snow in isothermal conditions was studied in the laboratory. Data were obtained on oversaturation of water vapour in snow pores. A group of laboratory and field investigations of mass transfer in a snow column under the effect of a superimposed temperature gradient was conducted in the Elbrus area.

DYNAMIC PROPERTIES OF SNOW

(MARI)

A draft of methodological instructions has been prepared for in situ studies of dynamic characteristics of snow with the help of a hard indentor complete with a piezoelectric accelerometer.

SIMILARITY BETWEEN SNOW RESERVE FIELDS

(IGAS)

The hypothesis about a high degree of similarity between snow reserve fields during the maximum accumulation period in different years and in different scales has been corroborated for Spitsbergen and the Caucasus.

LOSS OF HEAT FOR SNOW COVER MELTING

(IGAS)

The effect of snow melting on the formation of the spring temperature field has been quantitatively assessed for the USSR. It was established that heat losses for seasonal snow melting retarded the heating of the atmosphere by about three times, i.e. the snow cover itself regulates snow melting.

SNOW SURVEYING

(NCBHSC)

Snow surveying was conducted on the northern and southern slopes of the Greater Caucasus (within the Russian Federation) along 15 ground and air profiles. Most snow surveys were performed in March. On some profiles snow surveys were conducted every month from December to April. Most snow accumulation was observed in western Caucasus in the Belaya, Shakhe and Mzymta basins; in the upper reaches of the Belaya, in March 1989, at the height of 1580 m the depth of snow cover was 380 cm, and at the height of 2540 m it was 740 cm. In Central Caucasus, at 1600–2600 m heights, the depth of snow cover was 150–200 cm, while above 3000 m an intensive wind drift of snow was recorded.

AVALANCHE CONDITIONS IN THE USSR MOUNTAINS

(PLAM MSU)

Avalanche conditions were assessed for the USSR mountain regions: methods were developed for assessing the recurrence of genetically heterogeneous avalanche-prone situations, maps of distribution and occurrence frequency of avalanche-prone periods were constructed, and avalanche-prone territories were divided into zones with respect to types of avalanche conditions.

AVALANCHES IN GEORGIA

(TRI)

70 avalanche-prone sites were identified along the Dzhvari–Mestia road. For 42 of them morphometric characteristics were calculated, dynamic indices were determined and a chart of propagation was constructed. In the Krestovy pass area, spacio-temporal variability of snow-cover properties was investigated.

AVALANCHES OF SOUTHERN ADJARIA

(PLAM MSU)

The dynamics of snow accumulation and avalanche activity in southern Adjaria were assessed on the basis of research conducted during 1972–88. Periods of increased snow accumulation have been identified, which occur every 3–4 years, while winters with extreme snow accumulation occur every 10–11 years.

AVALANCHES OF CENTRAL CAUCASUS

(PLAM MSU)

Aerial photo-surveys and ground-based field observations were used to examine avalanche catchments of Central Caucasus (Dombai, the Elbrus area — valleys of the Teberda, Aksaut, Baksan rivers), zones of potential destruction by an avalanche air wave were identified. A quick-response wave-type sensor was designed to measure the velocity of snow-and-air flow, and of moving snow in an avalanche.

AVALANCHES OF THE TIEN SHAN

(IGAS KazSSR)

In situ investigations were carried out, including avalanche mapping and measurements of avalanche activity elements in control basins of Zailiysky Alatau. The variability of maximum snow reserves was assessed for Kazakhstan mountains, the following maps were drawn: a map of maximum snow reserves for the Jungar Alatau, a map of snow accumulation indices distribution in control basins, a

map of avalanche hazard in typical parts of central and northern Tien Shan.

AVALANCHES OF THE UDOKAN RIDGE

(IG SD)

In the central part of the Udokan ridge (northern Trans-Baikal region), most dangerous avalanche-prone areas were examined with the aim of selecting optimal avalanche-control measures and siting of protective constructions.

AVALANCHES IN THE ELBRUS REGION

(PLAM MSU)

Data were generalized on spacio-temporal variability of snow cover in the Elbrus region. Large-scale avalanche-hazard maps were drawn for representative basins, a testing site was selected for conducting long-term observations of snow avalanches and their impact on the structure and dynamics of periglacial landscapes.

PREDICTION OF AVALANCHES ON SAKHALIN

(MARI)

Methods were developed for predicting avalanches with a 0, 12 and 24 h lead time for the Chamgin pass on Sakhalin. A background avalanche prediction method is being developed for the territory of Sakhalin, using aerial synoptic information.

PREDICTION OF AVALANCHES IN THE TRANSCAUCASIA

(TRI)

A method of background prediction of fresh-snow avalanches was developed for Transcaucasia, taking into acount snowfall and air temperature forecasts and actually observed parameters, such as snow cover accretion and humidity. The lead times of the avalanche forecasts are 12, 24, and 36 h, with 12 h validity. Computer programmes were developed for the entire technological cycle.

RELATIONSHIP BETWEEN SNOW COVER PROPERTIES AND UNDERLYING TOPOGRAPHY

(PLAM MSU)

The analysis and in situ experiments have revealed the deterministic nature of variability of the texture and properties of snow cover lying on mountain slopes, which depends on specific features of the underlying surface.

MOVEMENT OF AN AVALANCHE

(ASML MSU)

A stereophotogrammetric survey of a moving avalanche was performed in the Elbrus region, and speeds of its movement were measured. Surveying instruments are being modified and perfected; data obtained in the course of surveys are being processed.

EXPERTISE OF AVALANCHE CONTROL AND PROTECTION

(PLAM MSU)

Methods were tested of strengthening the avalanche-control structures of the Salang tunnel along the USSR–Afghanistan highway and of erecting such structures at a section of the Baikal–Amur railway track.

REMOTE RECORDING OF AVALANCHES

(PLAM MSU)

A system developed for measuring avalanche parameters by remote sensors is being tested in the Khibini mountains; as soon as the system is installed and adjusted and good data begin to come in, it will be given over to the PO "Apatity". Geophysical methods were generalized and analysed in terms of their application to the study of snow avalanches and glaciers.

ACOUSTIC EMISSION OF AVALANCHES

(MARI)

On the basis of 30-year-long experiments aimed at studying a possible use of waveguides for recording acoustic emissions in the avalanche tear-away zone, a method was developed for siting sensors in snow catchments.

ULTRASONIC SNOW-DEPTH SENSOR

(MARI)

A breadboard model of an ultrasonic snow-depth sensor "Ulyss" and a snow-reserve sensor "BDPN-3" were tested in situ. Specifications were developed for a snow-cover electromagnetic emission sensor, and breadboard models were made for its HF assemblies and processing units.

METHODS AND TECHNOLOGY OF GLACIER DRILLING

ICE CUTTING

(LMI)

Theoretical substantiations of ice-cutting processes were developed for estimating energy lost in the destruction of ice, depending on mechanical drilling velocity and on geometrical characteristics of the drill bit; a methodology of bench experiments was developed. Shop drawings were made and a rock-drilling tool with diameters of 61.78 and 114 mm was manufactured for drilling through ice and its underlying rock.

ACOUSTIC LOGGING

(LMI)

A methodology is being tested and experimental acoustic logging is conducted in deep holes bored in the ice column.

SAMPLING

(LMI)

A method is being developed for taking samples from an ice core for micro-mineralogical analysis; an assessment was made of the possibility of determining ice fabrics and precise backdating of ice by the cosmogenic ^{53}Mn isotope. Attachments were designed and manufactured for testing a down-hole sampler for sterile sampling of ice, a component assembly of the ice sampler was performed and production forms and records were reviewed.

GLACIAL GEOLOGY AND PALEOGLACIOLOGY

LICHENOMETRY OF MORAINES ON SPITSBERGEN

(IGAS ESSR)

Work continues to prove the possibility of backdating young moraines with the help of lichen indicator species, depending on the lithology of the substrate in Arctic conditions. Measurements were performed on terminal moraines in Bockfjord (glaciers Adolfbreen, Niygertbreen, Karlsbreen) and in Kongsfjord (glaciers Midre-Lovenbreen, Nongswegenbreen and Morebreen). It was established that Late Holocene lateral moraines are more favourable for the growth of indicator species of lichens than terminal moraines of the same age. This might result from the fact that terminal moraines are more dissected because of the melting of stagnant, buried glacier ice.

LICHENOMETRY ON KAMCHATKA

(IVAS)

A reconnaissance survey of moraine deposits and lava flows was conducted on the flanks of the Klyuchevskoy and Tolbachin volcanoes to assess the utility of lichenometry for the solving glacio-volcanologic problems.

A SET OF DATING METHODS USED ON THE ALTAI AND SAYANY

(TSU)

In the mountains of the Altai-Sayany region, Little Ice Age moraines were separated and backdated (jointly with IGAS) using the lichenometric method. The lithological method was also applied there. More ancient formations, older than 3000 y, were dated using the thermoluminescent method. The study succeded in identifying and dating a glacial advance in Late Holocene, and the age of moraines during the maximum advance of ice flows was identified as Late Pleistocene. Similar results were obtained from the nanocyclite analysis which proved the possibility of absolute dating of sediments in dammed lakes in the entire Pleistocene period.

SNOW COVER RECONSTRUCTIONS

(TSU)

On the basis of lithological and bio-indicational information, the sequence of glacial fluctuations in central Tien Shan was reconstructed over the last 3000 y. A prediction was made about a probable glacial advance in the decades to come.

DIAGNOSTICS OF MORAINE AND MUDFLOW DEPOSITS

(IGAS)

Work has been conducted on genetic diagnostics of moraines and glacial mud-flow deposits. The latter have an increased content of sand, which is caused by the entrainment of fluvioglacial deposits by a mud-flow and loss of clay–silt particles during the mud-flow dehydration stage.

WEST-SIBERIAN ICE SHEET

(IGAS)

A statement was put forward about the existence of the West-Siberian ice sheet in the Pleistocene which changes the present ideas about Eurasian paleoglaciology.

GLACIAL MUD FLOWS

MUD-FLOW HAZARD IN THE NORTHERN CAUCASUS

(PLAM MSU)

The following were prepared: an inventory of mud-flow basins and a map of mud-flow hazards (1 : 200 000) with an explanatory note for the territory of the Checheno-Ingush ASSR and Krasnodar region; an inventory of mud-flow basins and a map of mud-flow hazards (1 : 200 000), and a map of vegetation as a factor and indicator of mud-flow formation for the territory of the Daghestan ASSR; a map of mud-flow basins with morphometric indices for the entire territory of the northern Caucasus (1 : 200 000).

REGIONAL STUDIES OF MUD-FLOWS

(PLAM MSU)

Spring-melt mud flows and water–snow flows were studied in the Khibini mountains, in the Carpathians and on Sakhalin, records of actual data were compiled, and recommendations for protection issued. In the Khibini, Caucasus, Tien Shan and Pamirs, data were collected on the state of mud-flow-control constructions for the inventory of mud-flow-control measures, while the existing data on catastrophic mud flows and sustained damage were generalized.

(IGAS KazSSR)

Catastropic mud flows which occurred in Kazakhstan were analysed and optimal control measures put forward. Tests continued of the artificial intellect "Poisk", designed for estimating the mud-flow

hazard of moraine lakes and other mud-flow-prone bodies. An analysis was conducted of the structure and evolution dynamics of moraine formation in Zailiysky Alatau. Recommendations are being developed to computerize calculations of glacial outburst floods.

DAMAGE FROM MUD FLOWS AND AVALANCHES

(PLAM MSU)

A new methodology was developed and a new edition of *Methodological instructions for assessing immediate damage from mud flows and snow avalanches* prepared; the lay-out of a catalogue of avalanche-protection structures used in Soviet construction engineering was issued.

ASSESSMENT OF A COMPLEX OF NIVAL-GLACIAL AND CRYOGENIC PROCESSES

(IRIEC)

An assessment was made of the development of certain nival-glacial and cryogenic processes on USSR territory: avalanches, mud flows, ice-formation, cryogenic heaving, solifluxion, thermokarst, and thermal erosion. Lay-outs of small-scale maps (1 : 5 000 000, 1 : 7 500 000) were made for the Russian Federation and certain regions of the Republic, showing the degree to which those territories are affected by the above processes, their potential hazard and their intensification in the course of national economic development. The economic cost of nival-glacial and cryogenic processes reaches 1 billion roubles a year.

ENGINEERING GLACIOLOGY

"ARTIFICIAL FIRN" FOR WATER TREATMENT AND DESALTING

(IGAS)

Experiments proved the efficiency of the "artificial firn" for the desalting of saline water, water purification and removal of insoluble contaminants, and the solution of ecological problems: demineralization of drainage-waste water, mine water, lake, sea and underground water.

SUBSOIL ICE

PERMAFROST IN THE TIEN SHAN

(IG SD AS)

The thickness and temperature of the cryolithozone were determined for the Akshirak ridge, Inner Tien Shan. In the range of altitudes between 4000 and 4200 m, the thickness varies from 100 to 270 m, while the temperature varies from –1.5°C to –6.5°C. A temperature profile of the Davydov glacier and the underlying rocks to a depth of 600 m was obtained, from an altitude of 4050 m.

INVENTORY OF ROCK GLACIERS

(IG SD AS)

An inventory of rock glaciers was completed in Zailiysky Alatau and Kunghei Alatau, northern Tien Shan. The total number of discovered active rock glaciers is 851. For some of these, rates of movement over the last 20 years were determined. They range from a few centimetres to 14 m a year.

DEFORMATION OF FROZEN SOIL

(IGAS KazSSR)

A new method was developed for studying ice formation in frozen soil, wherein the basic indices were obtained from acoustic emission measurements.

RIVER AND LAKE ICE: ICING

THE SYSTEM OF ICING AND RIVER ICE IN THE SAYANY MOUNTAINS

(IG SD AS)

On the basis of long-term regime observations and surface expedition surveys conducted in representative watersheds of the eastern Sayany, various ideas were developed. These included treating icing and ice cover on river basins as one system formed as a result of specific processes of interaction between surface and ground water in the free water-exchange zone in the areas of continuous and interrupted distribution of permafrost, and in zones with deep seasonal freezing.

PHYTO-INDICATION OF ICING

(IG SD AS)

On the basis of regime observations and glaciological landscape profiling in representative basins of the eastern Sayany (the Elen, the Enega), phyto-indicators of icing were discovered, which allow one to restore morphological characteristics and the lifetime of large icings in ground water. Data were collected on the spacio-temporal variability and floristic composition of vegetation growing in icing-prone parts of river basins, and a correlation was established between types of vegetation cover near a river bed and the in-bed ice amount.

ANTARCTICA

DRILLING OF THE AMERY ICE SHELF

(IGAS)

A 252 m-deep borehole with core recovery was drilled through the entire depth of the Amery Ice Shelf not far from the ice front. The ice column lying below

180 m is of continental origin; the rate of melting near the bottom does not exceed 1 m a^{-1}. Thermometric measurements were carried out in the borehole, the stratigraphy of the snow–firn column and fabric and structure of the ice were studied for the entire borehole depth, and samples taken for isotope-geochemical analysis.

FLUCTUATIONS OF THE ANTARCTIC ICE-SHEET EDGE

(IGAS)

The analysis of the Antarctic ice sheet calving and its dependence on cyclonic activity over the last 100 years has shown that the calving of huge ice shelves and outlet glaciers can be regarded as an indicator of a change in the intensity of zonal and meridional circulation in the Southern Hemisphere.

DRILLING AT VOSTOK STATION

(LMI)

Experimental drilling of a deep borehole N 47-2 at Vostok continues. At present its depth is 2546 m. In borehole N 3G at Vostok a group of geophysical observations was carried out, including thermometric, inclinometric and cavernometric measurements, with a view of studying the dynamics and thermal conditions of the glacial cover in the region, and for perfecting the methodology of geophysical investigations in deep boreholes filled with liquid. The long-record regular observations of a borehole deformation aimed at studying rheological properties of ice were continued at N 1-2 bis borehole.

DRILLING ALONG THE MIRNY–VOSTOK ROUTE

(LMI)

Three 150 m-deep boreholes were drilled during an expedition along the Mirny–Vostok route at distances of 60, 140 and 200 km from Mirny. Down-hole inclinometric and cavernometric measurements were conducted. A complete cycle of geophysical investigations, down to the 740 m depth, was performed in a borehole 105 km away from Mirny.

CARBON DIOXIDE IN THE ICE CORE

(LMI)

Carbon dioxide content was measured in ice samples from the Antarctic ice sheet at Vostok. The samples were recovered from depths of 1621 to 2373 m at borehole N 4G-2 and from a depth 69 to 274 m at the borehole along the Mirny–Vostok route, 105 km from Mirny.

ISOTOPE ANALYSIS OF THE CORE FROM ICE DOME B

(IG AS ESSR)

A curve was constructed of oxygen isotope composition in an ice core from Ice Dome B which reflects glacio-climatic changes in central Antarctica over the last 30 000 years. The detailed analysis of the most interesting sections of the core continues, as well as the interpretation of ^{18}O and δD data jointly with scientists from the Grenoble glaciological laboratory (France).

ISOTOPE ANALYSIS OF THE ICE CORE FROM THE SHACKLETON ICE SHELF

(IG AS ESSR)

An isotope analysis was made of the ice core from the Shackleton Ice Shelf drilled by specialists from the AARI in 1978. The isotope analysis of samples from the ice core and from snow pits showed that the average accumulation rate in the drilling zone is about 84 g cm^{-2} a^{-1}. The isotope analysis of the entire ice core showed that the ice shelf was formed by local atmospheric precipitations and that the glacier does not contain continental ice, and that there is no bottom freezing of sea water in the Shackleton Ice Shelf.

ISOTOPE ANALYSIS OF ICE FROM DRONNING MAUD LAND

(IG AS ESSR)

An oxygen isotope analysis was performed on a number of sub-moraine ice samples collected by specialists from the Central Institute of Isotope and Radiation Research of the GDR Academy of Sciences in the northern part of the mountain ridge on Dronning Maud Land. It was established that in the Late Pleistocene the ice cover of the region was thicker than now, and that ice had a "lighter" isotope composition, i.e. the climate was more severe.

ISOTOPE INVESTIGATIONS IN ANTARCTIC OASES

(IGAS ESSR)

An isotope analysis was performed on samples of water, snow and ice from Molodezhny and Bunger oases collected by a specialist from the Tallinn Botanical Garden. It has been established that water-reservoirs of oases are mostly fed by local atmospheric precipitation, and in some cases by continental ice. There are a number of saline and hypersaline lakes. Their hydrochemical and thermal conditions are being studied with the help of isotope-geochemical, biochemical and other methods.

PALEOCLIMATIC RECONSTRUCTIONS USING DOWNHOLE THERMOMETRIC DATA

(KazSU. AARI)

A modified mathematical model was developed and numerical experiments were conducted on paleoclimatic reconstructions on the basis of thermometric data obtained in a deep borehole at Vostok. The best fit between the estimated temperature changes in the past and the data yielded by the ice-core isotope analysis is achieved if the age of ice at the 2000 m depth is taken to be 20–30% less than the now-accepted 160–170 000 years.

SNOW–FIRN COLUMN ALONG THE MIRNY–VOSTOK TRAVERSE

(PLAM MSU)

A study was conducted of the texture, thermal conditions and compaction of the snow–firn column in Antarctica at the 240th kilometre of the Mirny–Vostok traverse. Regular features were established in

short- and long-range changes in snow surface temperature, as well as changes in the structure of the snow–firn column in the active layer.

ICE CHROMATOGRAPHY

(LSU)

A method of statistical vapour-phase chromatographic analysis was tested on Antarctic ice samples. This was done at the Laboratory of Chromatography, Leningrad University, together with the Pacific Oceanographic Institute, USSR AS.

ARCTIC

HYDROTHERMAL CONDITIONS OF SPITSBERGEN GLACIERS

(IGAS)

On the basis of aerial radio-echo sounding with a 620 MHz frequency, a scheme of distribution of glaciers with different thermal conditions was made for Spitsbergen: cold, warm, two-layer glaciers and glaciers with many water inclusions. Experiments with inclined surface radio echo-sounding showed that the obtained speeds of electromagnetic wave propagation can be also used as an indicator of the hydrothermal state of glaciers. Model-based calculations, conducted jointly with the IM MSU, showed that two-layer glaciers could be formed due to the cooling of initially warm glaciers and the warming-up of cold glaciers during the Little Ice Age, and the subsequent warming of the climate. The depth of the melt isotherm in such glaciers is determined as a function of time, glacier surface temperature and water content in "warm" ice.

ANALYSIS OF THE CORE FROM THE EASTERN ICE FIELD ON SPITSBERGEN AND FROM THE AKADEMII NAUK ICE DOME, SEVERNAYA ZEMLYA

(IGAS)

Paleoglaciological conditions and dome formation history were reconstructed over the last 1500–2500 years. It was established that the acidity of solid sediments deposited in the 20th century had increased, which points to a substantial man-induced pollution in those Arctic areas.

HANS TIDEWATER GLACIER, SPITSBERGEN

(IGAS)

A detailed surface radio-echo sounding and a geodetic survey of Hans tidewater were conducted together with the University of Silesia, Poland. In southern Spitsbergen about 75% of the glacier bed is below sea level, and its maximum thickness is 400 m. The glacier lost 1.25 km^3 of ice in comparison with 1936. The 1988/89 annual mass balance was negative, with iceberg runoff accounting for more than 60% of the balance.

Submitted by A.F. Glazovsky

International Glaciological Society

JOURNAL OF GLACIOLOGY

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

E M SHOEMAKER
A subglacial boundary-layer regelation mechanism.

J CUNNINGHAM, E D WADDINGTON
Boudinage: a source of stratigraphic disturbance in glacial ice in central Greenland.

H RENTSCH, W WELSCH, C HEIPKE, M M MILLER
Digital terrain models as a tool for glacier studies.

S J FITZSIMONS
Ice-marginal depositional processes in a polar maritime environment, Vestfold Hills, Antarctica.

P MARTINERIE, V LIPENKOV, D RAYNAUD
Correction of the air-content measurements in polar ice for the effect of cut bubbles at the surface of the sample.

M A LANGE, P SCHLOSSER, S F ACKLEY, P WADHAMS, G S DIECKMANN
^{18}O concentrations in sea ice of the Weddell Sea, Antarctica.

C J VAN DER VEEN, I M WHILLANS
Flow laws for glacier ice: comparison of numerical predictions and field measurements.

J C BOURGEOIS
A modern pollen spectrum from Dye 3, south Greenland ice sheet.

S C COLBECK
Vapor-pressure dependence on temperature in models of snow metamorphism.

E KARLSEN
Variations in grain-size distribution of suspended sediment in a glacial melt-water stream, Austre Okstindbreen, Norway.

M Q EDENS, R L BROWN
Changes in microstructure of snow under large deformations.

M FILY, J-P BENOIST
Large-scale statistical study of Scanning Multichannel Microwave Radiometer (SMMR) data over Antarctica.

F REMY, J F MINSTER
A comparison between active and passive microwave measurements of the Antarctic ice sheet and their association with the surface katabatic winds.

G K C CLARKE, E D WADDINGTON
A three-dimensional theory of wind pumping.

INTERNATIONAL SYMPOSIUM ON MOUNTAIN GLACIOLOGY RELATING TO HUMAN ACTIVITIES

Lanzhou, China 26 – 30 August 1991

CO-SPONSORED BY
Institute of Glaciology and Geocryology, Lanzhou: Chinese Academy of Sciences

SECOND CIRCULAR
July 1990

SYMPOSIUM ORGANIZATION: H. Richardson

LOCAL ARRANGMENTS COMMITTEE:

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CHIEF EDITOR: R.L. Hooke
ASSOCIATE EDITORS: (to be appointed)

INFORMATION ABOUT THE SYMPOSIUM MAY BE OBTAINED FROM:
Secretary General, International Glaciological Society, Lensfield Road,
Tel: Cambridge (code from outside U.K. = (223) 355974 Fax: (223) 336543

Registration for the symposium will take place on Sunday 25 August and sessions will be from Monday 26 to Friday 30 August.

A mid-symposium tour is planned.

1. PARTICIPATION

This circular includes forms for registration and booking of accommodation. The form and accompanying payments should be submitted in accordance with the instructions given on the forms before 1 May 1991. There will be a £20.00 surcharge for later registrations. *Participants'* registration fees cover organization costs, distribution of preprints of summaries, reception, day tour, banquet and a copy of the Proceedings Volume. *Accompanying Persons'* registration fees include organization costs, reception, day tour and banquet. *There is an administration surcharge for participants who are not members of IGS or the Chinese Academy of Sciences (CAS).

REGISTRATION FEES:

Participant (IGS or CAS member)	£170
*Participant (not a member of IGS or CAS)	£200
Accompanying person aged 18 or over	£70
Surcharge for late registration (after 1 May)	£20

Refunds on registration fees can be made on a sliding scale, according to date of receipt of notification, up to 1 August 1991. After this date it may be impossible to make any refund. See booking form for methods of making payment.

2. TOPICS

The Symposium will be concerned with the effects on human activities of the following aspects of mountain glaciology:

1. Glacier-related floods and other ice, snow and avalanche hazards in mountain areas.
2. Permafrost and ground ice in high mountains.
3. Ice and snow water resources in mountain areas.
4. Fluctuations of mountain glaciers and climate.
5. Micrometeorology of glacierized valleys.

3. PROGRAMME

A detailed programme will be given in the Third Circular. Both plenary and poster sessions are planned. Various local tours and visit will be available for accoompanying persons, and may be booked when registering on Sunday 25 August.

4. PAPERS

(i) SUBMISSION OF PAPERS

Those participants who would like to contribute to the Symposium should first submit a summary of their proposed paper in English; this summary should contain sufficient detail to enable us to form a judgement on the likely merit of the proposed paper, but should not exceed two pages of typescript, on the international size paper A4 (210 × 297 mm). **References and illustrations are not required at this stage.** Place the title and authors' names and addresses at the top of the first page of your summary and not on a separate sheet.

Summaries should be sent to: Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, England, and should arrive there by 1 February 1991 at the latest. This is a firm deadline.

LAST DATE FOR RECEIPT OF SUMMARIES: 1 February 1991

(ii) SELECTION OF PAPERS

Each summary will be assessed, taking into account scientific quality and relevance to the topics of the Symposium. Authors whose summaries are acceptable will be invited to present their contribution at the Symposium. We hope to write to authors of papers in early April 1991 about acceptance (or otherwise). The letter will be sent to the first author listed in multi-authored papers and not to all of those authors. Acceptance of a summary implies that the paper based on that summary should be submitted to the proceedings volume and not to another publication. Summaries alone will not be published in the proceedings volume.

(iii) DISTRIBUTION OF SUMMARIES

The summaries of the accepted papers will be distributed to all registered participants before the Symposium.

(iv) SUBMISSION OF FINAL PAPERS AND PUBLICATION

Papers presented at the Symposium will be considered for publication in the procedings volume (*Annals of Glaciology*, Vol. 16). Final typescripts of these papers should be submitted to the Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, England, by 1 June 1991. They should be written in English and prepared in accordance with the instructions that will be sent to authors when they are notified about acceptance of papers for the Symposium. Authors will be told the maximum length for their papers when they receive notice of acceptance of their summaries. The papers will be refereed according to the usual standards of the Society before being accepted for publication. Speedy publication of the proceedings will depend upon strict adherence to deadlines.

LAST DATE FOR SUBMISSION OF FINAL PAPERS: 1 June 1991

5. ACCOMMODATION

A block booking has been made in Beijing and Lanzhou by the Chinese Academy of Sciences for the nights of Thursday 22 and Friday 23 August in Beijing and Saturday 24 August through Friday 30 August (with departures on Saturday 31 August) in Lanzhou. These arrangements in Beijing and Lanzhou may only be booked through the International Glaciological Society, as indicated on the bookings form in this circular, and are available only to participants and accompanying person registered for the symposium. Participation in the symposium is only

available through this block booking.

The cost is £358 per person in a twin-bedded room, £482 per person for single occupancy. It includes hotels in Beijing and Lanzhou, ground transportation, flight to Lanzhou, food, and some sightseeing and service charges.

6. SOCIAL EVENTS

There will be a reception on Monday 26 August, when participants will meet dignatories from Gansu Province and the Chinese Academy of Sciences. On Wednesday 28 August there will be a day tour and on Friday eveing there will be a banquet.

7. POST-SYMPOSIUM TOURS

Two tours have been arranged, one to Tibet and one to east and south China. The cost of these is indicated below and includes ground transportation, accommodation, food, flights and service charges.

The tours are open only to participants and accompanying persons registered for the symposium in Lanzhou.

Payment is to be made to the International Glaciological Society at its HQ office: see booking form in this circular. A deposit should be paid when paying your registration fee for the symposium. We will bill you for the balance in June.

Alternative tours will be arranged if necessary.

It is important for us to know your blood group – see booking form.

(i) TIBET TOUR – approximate cost £1300 per person, depending on prices current in mid-1991. The tour begins in Lanzhou and finishes in Kathmandu, and lasts 13 days. It will include visits to high level lakes and glaciers, and show the dangers to villages, livestock and roads of ice and snow avalanches, drifting snow, permafrost and rapid glacier advances.

The proposed itinerary is as follows:

August 31 (Saturday)	–	overnight train to Chengdu
September 1 and 2	–	Chengdu
September 3	–	flight to Lhasa
September 3, 4, 5	–	Lhasa (hotel) – acclimatisation
September 6	–	by road to Shigatse and overnight (hotel)
September 7	–	by road to Dinggye and overnight (hotel)
September 8 (Sunday)	–	by road to Rongbuk
*September 8 and 9	–	Rongbuk (base camp of Mt Everest – tents)
September 10	–	by road to Dinggye and overnight (hotel)
September 11	–	by road to Zhangmue and overnight (hotel)
September 12 (Thursday)	–	by road to Kathmandu (Nepal) and overnight (hotel)
September 13 (Friday)	–	tours ends. Group or individual travel arrangements.

*An alternative programme will be arranged for these two days for participants who do not wish to walk at such heights.

We shall be accompanied by a doctor throughout the tour. It is advisable that people with heart or respiratory problems do not join this tour. For participants who encounter problems en route we will be able to get them down to Chengdu quickly. Please be sure to complete all sections on the booking form, including blood groups.

Note: The itinerary may be subject to change, according to local conditions.

The tour will be cancelled if fewer than 15 persons book places.

(ii) EAST & SOUTH CHINA TOUR – cost £900 per person, depending on prices current in mid-1991. The tour begins in Lanzhou and finishes in Guilin, and lasts 10 days. This tour will include visits to several academic institutes, and show features such as the effects of loess and climate change on agriculture, the response of lakes to climatic change, karst phenomena and caves.

The itinerary is as follows:

August 31 (Saturday)	–	flight to Xian
August 31 and Sept. 1	–	Xian (hotel). Visit Institutes studying loess and quaternary geology
September 2	–	overnight train to Nanjing

September 3	–	Nanjing (hotel). Visit Institute of Geography and Limnology, CAS
September 4	–	bus to Hangchow
September 4 and 5	–	Hangchow (hotel). Visit Second Institute of Oceanography, Bureau of Oceanography
September 6	–	train to Shanghai
September 6 and 7	–	Shanghai (hotel). Visit Antarctic Institute, Chinese Antarctic Committee
September 8 (Sunday)	–	fly to Guilin
September 8 and 9	–	Guilin (hotel). Visit Institute of Karst Research, Ministry of Geology
September 10 (Tuesday)	–	tour ends. Group or individual travel arrangements.

Note: The itinerary may be subject to change, according to local conditions.

The tour will be cancelled if fewer than 5 persons book places.

8. GROUP FLIGHTS FROM EUROPE & N. AMERICA

In order to reduce the costs of travel from Europe and North America, we have authorized Traveller's World to negotiate with the airlines. Their brochure will not be available until November 1990, because airlines will not commit themselves to prices more than 11 months ahead of the travel dates. Members of IGS will receive a copy. There are 3 arrangements for Europe and 3 for North America. One from each area is for those participants who wish to attend the symposium only, and the others are for those who wish to join one of the post-symposium tours. **These tours are available only for people who register for the Symposium in Lanzhou.**

It will be greatly to the advantage of participants to book these group flights. We must travel together to China on the stated dates, but individual return travel may be arranged if so desired.

Please not that payments for the group flights must be made to Traveller's World, as will be indicated in their brochures. Payments for the symposium and the post-symposium tours must be paid to the International Glaciological Society in Cambridge, in £ sterling.

METHODS OF MAKING PAYMENT

Payments should be made in £ sterling, making sure that IGS gets the correct amount (the international banking charges should be paid by you):

- by sterling cheque payable to International Glaciological Society and sent to the Secretary General at the Society's address (Lensfield Road, Cambridge CB2 1ER, U.K.);
- or by sterling bank transfer to International Glaciological Society account no. 08102112* and sent to the National Westminster Bank plc, 56 St Andrew's Street, Cambridge CB2 3DA, U.K.

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

Please note: Owing to the complex currency arrangements involved in the symposium we need to deal in £ sterling only at our Cambridge account.
Thus –
(a) We cannot accept payments in any other currency than £ sterling
(b) Payments should be sent direct to our Cambridge address (listed above) and not to our U.S. or Canadian accounts.
(c) Bank charges should be paid by you.

(Chinese participants resident in China may pay the Chinese Academy of Sciences in local currency. They will be informed about these arrangements by CAS.)

INTERNATIONAL GLACIOLOGICAL SOCIETY

Booking form for Registration, Accommodation, Post-Symposium Tours

SYMPOSIUM ON MOUNTAIN GLACIOLOGY RELATING TO HUMAN ACTIVITIES

25 – 31 August 1991, Lanzhou, China

Mail to: Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, U.K. BEFORE 1 MAY 1991.

A. REGISTRATION AND ACCOMMODATION (please type or print in black ink)

Name of participant

. . . . . ./ . . . . . / Male/Female

(family name) (initials)

Address . . . . . .

. . . . . .

. . . . . .

Accompanied by (indicate age if under 18)

Name . . . . . Male/Female

Name . . . . . Male/Female

I send registration fee/s as follows:

Participant (IGS, CAS) £170 each	£	
Participant (not IGS, CAS) £200 each	£	
Accompanying person/s £70 each	£	
Surcharge for late registration £20	£	
TOTAL REGISTRATION FEE/S		£ . . . . .

B. ACCOMMODATION

I send payment for the CAS block booking (9 nights)

£358 per person in twin room	£	
£482 in single room	£	
Number of people [ ]	£	
TOTAL ACCOMMODATION PAYMENT		£ . . . . .

Note:- Accommodation and travel Beijing/Lanzhou is only available through this group arrangement made especially by the Chinese Academy of Sciences for participants and accompanying persons.

C. POST-SYMPOSIUM TOURS

*I enclose [ ] deposit/s for Tour 1 (Tibet) £100 per person	£	
*I enclose [ ] deposit/s for Tour 2 (E & S) £100 per person	£	
TOTAL TOUR DEPOSITS		£ . . . . .
TOTAL PAYMENTS		£ . . . . .

Blood groups for all people included on this form

. . . . . / . . . . . / . . . . . .

D. GROUP TRAVEL EUROPE & N. AMERICA

*I wish to participate in these arrangements and have sent the group travel booking form and deposit to Traveller's World.

* Delete as appropriate.

JOINT ROYAL METEOROLOGICAL SOCIETY AND

INTERNATIONAL GLACIOLOGICAL SOCIETY MEETING

Imperial College, London
17 April 1991, 1400–1800 h

ICE AND CLIMATE
Final Programme

H. Cattle (Meteorological Office) – The role of ice in the general circulation of the atmosphere.
D. Peel (British Antarctic Survey) – Paleoclimate from ice cores.
J. Paren (British Antarctic Survey) – Antarctic warming and ice sheet stability.
P. Wadhams (Scott Polar Research Institute) –Sea ice variability.
D. Roberts (Meteorological Office) – Modelling of ice in general circulation models.
G. Boulton (Edinburgh University) – Mapping and modelling former glaciations.
L.W. Morland (School of Mathematics, University of East Anglia) – Sea ice modelling.

Further information may be obtained from Tom Lachlan-Cope, British Antarctic Survey, High Cross, Madingley Road, Cambridge CB3 0ET.

Glaciological Diary

** IGS Symposia
* Co-sponsored by IGS

1991

3-5 February
6th International Symposium on Okhotsk Sea and Sea Ice, Mombetsu, Hokkaido (Masaaki Aota, Sea Ice Research Laboratory, Hokkaido University, Minamigaoka 6-4-10, Mombetsu, Hokkaido 094, Japan)

24-28 March
6th Biennial Meeting of the European Union of Geosciences, Strasbourg (Organizing Committee, E.U.G. VI Meeting, University of Trieste, Institute of Mineralogy, Piazza le Europa, 1–34100 Trieste, Italy)

3-6 June
* Symposium on the Tropospheric Chemistry of the Antarctic Region, Boulder, Colorado (Barry A. Bodhaine, NOAA-CMDL R/E/CG1, 325 Broadway, Boulder, CO 80303, U.S.A.)

23-28 June
OMAE 1991. 10th International Conference on Offshore Mechanics and Arctic Engineering: Arctic/Polar Symposium (including ice mechanics and properties of ice, and remote sensing), Stavanger Forum, Stavanger, Norway (Nirmal K. Sinha, Member, Executive Committee, Offshore Mechanics and Arctic Engineering Division (OMAE/ASME), Division of Mechanical Engineering, National Research Council of Canada, Ottawa, Ontario, Canada K1A 0R6)

2-9 August
XIII INQUA Congress, Beijing, China (Chinese Academy of Sciences, 52 Sanlike, Beijing 100864, China)

11-15 August
ISOPE-91. First (1991) International Offshore and Polar Engineering Conference, Heriot-Watt University, Edinburgh, U.K. (ISOPE-91 Edinburgh Secretariat, 4 Frederick Sanger Road, Surrey Research Park, Guildford, Surrey GU2 5YJ, U.K.)

11-24 August
20th General Assembly of the International Union of Geodesy and Geophysics, Vienna, Austria.

26-30 August
** IGS Symposium on Mountain Glaciology relating to Human Activities, Lanzhou, China (Secretary General, IGS, Lensfield Road, Cambridge CB2 1ER, U.K.)

September
6th International Symposium on Ground Freezing, Beijing, China (Hans Jessberger, Ruhr-University Bochum, P.O. Box 102148, D-4630 Bochum 1, Germany)

1-6 September
Symposium on the Physics and Chemistry of Ice, Sapporo, Japan (Norikazu Maeno, Institute of Low Temperature Science, Hokkaido University, Sapporo 060, Japan)

16-20 September
VAW/ETHZ International workshop on Permafrost and Periglacial Environments in Mountain Areas, Interlaken, Switzerland (W. Haeberli, Head, Section of Glaciology, Laboratory of Hydraulics, Hydrology and Glaciology, ETH-Zentrum, CH-8092 Zürich, Switzerland)

23-28 September
Antarctic and Global Systems – A Conference on Antarctic Science, Bremen, Germany (G. Hempel, SCAR Antarctic Science Conference, Alfred-Wegener-Institute for Polar and Marine Research, Columbusstrasse, Postfach 12 01 61, D-2850 Bremerhaven, Germany)

1992

17-22 May
** Symposium on Remote Sensing of Snow and Ice, Boulder, CO, U.S.A. (Secretary General, IGS, Lensfield Road, Cambridge CB2 1ER, U.K.)

29 June-3 July
Interpraevent 1992: Protection of Habitat against Floods, Debris Flows and Avalanches, Berne, Switzerland (Interpraevent 1992, c/o Bundesamt für Wasserwirtschaft, Postfach 2743, CH-3001 Bern, Switzerland)

14-18 September
** Symposium on Snow and Snow-related Problems (as part of an International Forum on snow Areas), Nagaoka, Japan. Co-sponsored by the Japanese Society of Snow and Ice and the City of Nagaoka (Secretary General, IGS, Lensfield Road, Cambridge CB2 1ER, U.K.)

News

ICE RESEARCH IN CANADA

Changes have been made at the National Research Council of Canada concerning ice research. From 1 April 1990, all the ice researchers from the old Division of Building Research (now Institute for Research in Construction) i.e. Nirmal Sinha, Mohamed Sayed, Lorne Gold and R.M. Frederking, have been transferred to the Low Temperature Laboratory of the Division of Mechanical Engineering. The two technicians, Ron Jerome and Bill Cooke, have also been transferred. Garry Timco, of the Hydraulics Laboratory in Mechanical Engineering, is now attached to this Lab. All of NRC's ice research in Ottawa has thus been consolidated in a Cold Regions Engineering project in the Division of Mechanical Engineering.

R.M. Frederking is responsible for coordinating all ice and ice-related research at NRC. This includes the Division of Mechanical Engineering in Ottawa and the Institute for Marine Dynamics in St. John's.

NEW POLAR WORKING GROUP

The Polar Region Caves and Ice–Karst Research Working Group was constituted in 1989. The President is Professor Adolfo Eraso (Universidad Politécnica de Madrid, Spain); Secretary, Professor Jaques Schroeder (Montreal University, Canada); and East Countries Coordinator, Professor Marian Pulina (Silesia University, Poland). The address for correspondence is: Prof. Dr Adolfo Eraso, Catedra de Hidrogeologia-Escuela de Minas, Universidad Politecnica de Madrid, c/ Rios Rosas, 21, 28003-Madrid, Spain.

NORSK BREMUSEUM

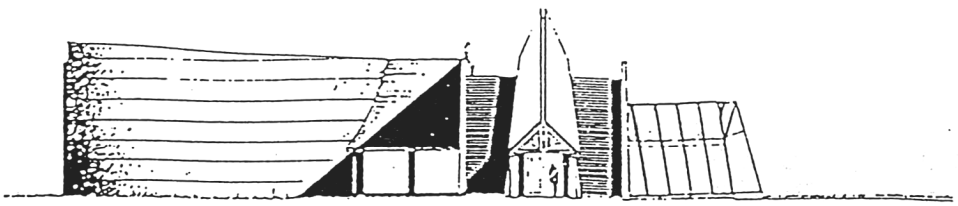
The Norwegian Glacier Centre is a $4 million-project now being realized in Fjaerland, between the Jostedals Glacier and the Sognefjord. Building started in August this year, and on 11 October HRH Crown Princess Sonja will lay the foundation stone. It will open to the public on 1 June 1991.

The project was established as a non-profit foundation by the Universities of Bergen and Oslo, Norsk Polarinstitutt, NVE and two other Norwegian institutions, and by IGS. It has received gifts from more than 50 companies and more than 200 individuals, and from the Norwegian Government. The project was briefly described in *ICE* 91 (3rd issue 1989), when former IGS President, Sam Colbeck, and many other colleagues were present at a ceremony to mark the site purchase.

The Centre will inform the general public about the how, where and why of our science: ice, glaciers, the ice ages, and the relationship between climate, glaciers and sea level. It will do so in an entertaining fashion, and the centre includes a 225° glacier adventure film, a walk under a simulated glacier to see how it erodes, and many opportunities to do experiments with real glacier ice.

The building itself is two-storey, narrow, 80 m long, built in white concrete, with a sunken-in central section. Walking on the roof (which is encouraged) should give the feel of going along a glacier crevasse. It makes use of running water, and has been designed by one of Norway's most internationally-acclaimed architects. The building is described in the June issue of the British magazine *Architectural Review*.

The Centre also contains a library and office facilities for visiting scientists and students. Many colleagues have already donated reprints and books to the library, and we would be very grateful for further such contributions. Please send such material to Norsk Bremuseum, The Norwegian Glacier Centre, 5855 Fjaerland, Norway.



Artist's impression of Sverre Fehn's Norwegian Glacier Centre

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Dear Colleagues and Friends,

I would welcome suggestions on how to solve three problems with ice simulation, at room temperatures, for the Norwegian Glacier Centre:

1) A material, or combination of material and internal lighting, that will look like ice from the outside and can be used to simulate a glacier front and tunnel into the glacier.
2) A material that will simulate the optical properties of snow and can be used to build an igloo.
3) A material that can be used to make a glacier that will flow in a fashion similar to real glaciers, and at speeds so that phenomena can be observed by a layman during a museum visit.

All suggestions, however wild, will be welcome! Please send to Professor Olav Orheim, Norsk Polarinstitutt, P.O. Box 158, 1330 Oslo Lufthavn, Norway.

****

New members

Edward M. Arons, Snow and Ice Branch, US Army CRREL, 72 Lyme Road, Hanover, NH 03755-1290, U.S.A.
Alex J. Biss, 8 Uphill Grove, Mill Hill, London NW7 4NJ, U.K.
Georg Delisle, BGR, Postfach 510153, D-3000 Hannover 51, Germany.
Pieter W. Donglemans, 4 London Street, Edinburgh EH3 6NA, U.K.
Jacques A. Druez, Département des Sciences Appliquées, Université du Québec à Chicoutimi, Chicoutimi, Québec G7H 2B1, Canada.
Adolfo Eraso, Catedra de Hidrologia, E.T.S. Ingenieros de Minas, c/o Rios Rosas 21, 28003 Madrid, Spain.
Mark A. Fahnestock, Geology 170-25, California Institute of Technology, Pasadena, CA 91125, U.S.A.
Douglas A. Fifolt, Thayer School of Engineering, Dartmouth College, Hanover, NH 03755, U.S.A.
Gary A Kuehn, 129 Lyme Road, Hanover, NH 03755, U.S.A.
Andreas Lueck, Institute of Geography, University of Bonn, Martinstrasse 7, D-5270 Gummersbach, Germany.
Gareth J. Marshall, Scott Polar Research Institute, University of Cambridge, Lensfield Road, Cambridge CB2 1ER, U.K.
Ayako Ouchi, Geographisches Institut ETH, Winterthurerstrasse 190, CH-8057 Zürich, Switzerland.
Victor F. Petrenko, Thayer School of Engineering, Dartmouth College, Hanover, NH 03755, U.S.A.
Clive P.R. Saunders, Physics Department, UMIST, Sackville Street, Manchester M60 1QD, U.K.
Erland M. Schulson, Thayer School of Engineering, Dartmouth College, Hanover, NH 03755, U.S.A.
Christopher Shone, 4A High Street, Gifford, East Lothian EH41 4QU, U.K.
Martin J. Siegert, Scott Polar Research Institute, University of Cambridge, Lensfield Road, Cambridge CB2 1ER, U.K.
Larry J. Weber, Civil and Environmental Engineering, The University of Iowa, Iowa City, IA 52242-1585, U.S.A.
Sandra J. Wilson, Department of Geography, RHB New College, University of London, Egham Hill, Egham TW20 0EX, U.K.
Zhang Junjie, Thayer School of Engineering, Dartmouth College, Hanover, NH 03755, U.S.A.

INTERNATIONAL GLACIOLOGICAL SOCIETY

Lensfield Road, Cambridge CB2 1ER, England

SECRETARY GENERAL H. Richardson

COUNCIL MEMBERS

			Date first elected to the Council (in present term of office)
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	G. Wakahama	1988-91	1988
	B. Wold	1990-93	1990
IMMEDIATE PAST PRESIDENT	S.C. Colbeck	1990-93	1984
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	*S. Jonsson	1988-91	1988
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	*F. Nishio	1989-92	1989
	*G. Weller	1989-92	1989
	*N. Young	1989-92	1989
	H. Björnsson	1990-93	1990
	*K.C. Jezek	1990-93	1990
	M.A. Lange	1990-93	1989
	*A. Ohmura	1990-93	1990
CO-OPTED	*R. LeB Hooke	1990-91	1990

*first term of service on the Council

CORRESPONDENTS

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SELIGMAN CRYSTAL AWARD RECIPIENTS

1963	G. Seligman	1983	W.O. Field
1967	H. Bader	1983	J. Weertman
1969	J.F. Nye	1985	M.F. Meier
1972	J.W. Glen	1986	G. de Q. Robin
1972	B.L. Hansen	1989	H. Oeschger
1974	S. Evans	1989	W.F. Weeks
1976	W. Dansgaard	1990	C.R. Bentley
1977	W.B. Kamb	1990	A. Higashi
1982	M. de Quervain		

HONORARY MEMBERS

W.O. Field	M. de Quervain
R.P. Goldthwait	U. Radok
P. Kasser	H. Richardson
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L. Lliboutry	A.L. Washburn
M.F. Meier	Z. Yosida

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

INTERNATIONAL GLACIOLOGICAL SOCIETY

Lensfield Road, Cambridge CB2 1ER, England

DETAILS OF MEMBERSHIP

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

ANNUAL PAYMENTS 1991

Private members	Sterling	£33.00	
Supporting members	Sterling	£133.00	
Contributing members	Sterling	£53.00	
Junior members	Sterling	£17.00	
Institutions, libraries	Sterling	£100.00	for Volume 36 (Nos. 112, 123, 124)

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

Note: Payments in currencies other than £ sterling should be calculated at the exchange rate in force at the time of payment. Then add sufficient money to cover the bank charges (currently £6.50). The Society needs the full payment, so that the extra £6.50 to cover bank charges should be paid by you. Thank you.

ICE

Editor: H. Richardson (Secretary General)
Assisted by D.M. Rootes and S. Stonehouse

This news bulletin is issued to members of the International Glaciological Society and is published three times a year. Contributions should be sent to the Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, England.

Annual cost for libraries, etc., and for individuals who are not members of the Society:

Sterling £15.00

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