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ICE

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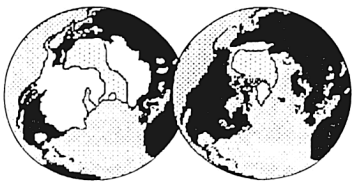

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CONTENTS

COVER PICTURE: Slab avalanche area. Photograph by E. Wengi, Institute for Snow and Avalanche Research, 7260 Weissfluhjoch, Davos, Switzerland.

***NEW AWARDS*: The Council has agreed that Honorary Membership shall be awarded to U. Radok, and Seligman Crystals to H. Oeschger and W.F. Weeks. The Crystals will be presented during the IGS symposium in Seattle, August 1989. Full details will be given in the next issue of *ICE*.**

RECENT WORK

ITALY

Glaciological research in Italy is mainly coordinated by the Comitato Glaciologico Italiano (C.G.I.), with the financial support of the Consiglio Nazionale per le Ricerche (CNR) and the Ente Nazionale per l'Energia Elettrica (ENEL). Principal studies dealing with snow and avalanches are currently carried out by a special inter-regional association (AINEVA), and have been published in *Neve e Valanche* since 1984.

One institutional activity of the C.G.I. since 1925 has been the systematic annual checking of the snout variations of about 100 glaciers, about 10% of all those in Italian territory. Results were published in the *Bollettino del Comitato Glaciologico Italiano* until 1977 and thereafter in *Geografia Fisica e Dinamica Quaternaria* published by the C.G.I. in Turin. In the field of glacial fluctuations, Italy contributed to the programmes of the P.S.F.G., now W.G.M.S. IUGG-FAGS/ICSU, with data on Italian glaciers published in Vols. I-V of *Fluctuations of Glaciers*, IAHS-UNESCO.

As regards glacier mass balance, research has been carried out on two glaciers of the Ortles-Cevedale Group (Central Alps) by G. Zanon (since 1988) and C. Smiraglia (since 1986). Studies on the use of satellite images in the interpretation of glacial dynamics are being continued by R. Serandrei Barbero.

The glaciers of the southern slope of the Alps were previously listed and described in the four volumes of the *Catasto dei Ghiacciai Italiani* (1959–62) as a contribution to the I.G.Y. 1957–58. This inventory included 838 existing glaciers, covering an area of 540 km^2 together with 190 glaciers which had become extinct over the preceding 50 years. During the 1980s, Italy concluded its collaboration on the IAHS-UNESCO World Glacier Inventory, which now contains the regional inventories of the Italian Alpine Regions and Autonomous Provinces, according to international regulations and with the coordination of the C.G.I..

The Italian glaciers in the W.G.I. cover a total surface area of 608 km^2, or 20% of the glacierized surface of the Alps. The Italian section of the W.G.I. also includes glacierets up to a minimum surface area of 0.05 km^2. Revision of the previous 1959–62 inventory is planned for the near future, using updated information from the W.G.I..

Glaciological research in Italy for the period 1960–1980 is listed in G. Zanon (1980), *Ghiacciai, Neve e Valenghe*, Convegno AGEI, La Ricerca Geografica in Italia, 1960–1980, ASK, Varese, pp. 693–702. Updating is supplied by G. Zanon (1985), Glaciology, *in* Gruppo Nazionale Geografia Fisica e Geomorfologia, CNR, *Italian Research on Physical Geography and Geomorphology: an overview*, Addendum, pp. 3–6, presented at the lst International Conference on Geomorphology, Manchester (1985).

Research on glacial and periglacial geomorphology is currently being carried out mainly by the Gruppo Nazionale *Geografia Fisica e Geomofologia of the Comsiglio Nazionale delle Richerche* (CNR). For a bibliographical review, see *Italian Research ...* (op. cit.); G. Orombelli, *Glacial Geomorphology*, pp. 27-30; F. Dramis, *Periglacial Geomorphology*, pp.31-35; and G.B. Pellegrini, *Geomorphological Mapping and Regional Geomorphology*, pp. 51-60. Some other recent research results come from the Gruppo Nazionale Geografia Fisica et Geomorfologia, CNR, (1986) in Geomorphological Researches in the high Val di Pejo (Cevedale Group), *Geogr. Fis. Dinam. Quat.* 9, 137-191; recent work on the Italian rock glaciers is reported in S. Belloni, M. Pelfini and C. Smiraglia (in press), Morphological features of the active rock glaciers in the Italian Alps and climatic correlations; and A. Carton, F. Dramis, C. Smiraglia (and collaborators) (in press), A first approach to the systematic study of the rock glaciers in the Italian Alps, both presented at the 5th International Permafrost Conference of Trondheim (1988).

In Antarctica, researches on glaciology and glacial and periglacial geomorphology (G. Orombelli and C. Baroni, in press) were carried out in the Terra Nova Bay area in 1986–87. In 1988, G. Zanon carried out preliminary studies on the mass balance of local glaciers and of the Campbell glacier, within the ambit of a 1985–91 research programme operating from a recently created permanent Italian base.

Submitted by G. Zanon

SWITZERLAND

GLACIERS

WORLD GLACIER MONITORING SERVICE

(W. Haeberli, P. Müller, P. Alean, H. Bösch, VAW)

The new World Glacier Monitoring Service (WGMS) of the International Commission on Snow and Ice (ICSI/IAHS) started its activities in 1986 within the framework of the Global Environment Monitoring System (GEMS/UNEP), the Division of Water Sciences of

UNESCO and the Federation of Astronomical and Geophysical Services (FAGS/ICSU). It combines the former Temporary Technical Secretariat for the World Glacier Inventory and the Permanent Service on the Fluctuations of Glaciers. The service has five main tasks, two "classical" ones: (1) the periodical publication of the Fluctuations of Glaciers, and (2) the completion and continuous upgrading of the World Glacier Inventory — and three new activities: (3) the publication of more frequent reports on mass balance data from selected reference glaciers, (4) the stimulation of regular analysis of satellite imagery from remote glacierized areas to reach global coverage, and (5) the introduction of periodical assessments with regard to ongoing changes. So far, the WGMS has been fully occupied with the preparation of the *Fluctuations of Glaciers 1980–85* and the *World Glacier Inventory – Status 1985*. First steps have also been undertaken to organize international cooperation for publishing a (probably biennial) *Glacier Mass Balance Bulletin* in the near future. Work for the tasks (4) and (5) is presently being planned. The goal is to build up (over the next few years) a modern service of global glacier monitoring, the planning horizon being the early 1990s when the official establishment of international cooperation and coordination in the field of long-term glacier monitoring approaches its centenary.

ANNUAL SURVEY OF SWISS GLACIERS

(M. Aellen, VAW and GK/SNG, M. Funk, VAW)

The results of the 106th to 108th annual surveys (1985–87) of glacier snouts in the Swiss Alps are summarized by the following figures:

Number of glaciers	1985	1986	1987
advancing	57	42	36
stationary	9	9	14
receding	51	63	56
classified	117	114	106

A high percentage of advancing glaciers was observed in the southern parts of the Alps (Tessin and Adda river basins) in 1985 (67%) and in 1986 (60%), and on the northern slopes of the western part (Reuss and Limmat river basins) in 1987 (50%), while a low percentage was found in the western parts of the internal Alpine regions (Rhine and Inn river basins) in all three years (39%, 18% and 12% respectively). The most recent period of glacier advance, having lasted in general from 1977 to 1985, seems already to belong to the past.

Mass balances established for the glaciers of four high Alpine river basins are summarized by the following specific net values (given in g/cm^3):

	Gries	Aletsch	Limmern & Plattalva	Silvretta
1984/85	−34	+17	+29	+51
1985/86	−71	−4	−46	−27
1986/87	−52	+16	+21	+65

Typical features of the climatic conditions in these years were periods of rather mild and dry weather in the autumn and winter seasons, with cold and wet periods delaying the beginning of the melting season; this was especially so in 1985 and — with the exception of the southern alpine regions — in 1987. Negative mass balance values are mainly due to high ablation rates as a result of intensive melting in the 1985 and 1986 summer seasons, to low winter accumulation and an early start of ice ablation in 1987. Heavy rainstorms, reaching up to unusually high altitudes and causing catastrophic flood waves in many Alpine valleys, were outstanding events in a rather wet 1987 summer season.

THE ROLE OF THE CRYOSPHERE IN CLIMATIC VARIATIONS

(A. Ohmura, GGEZ)

New maps of the monthly mean air temperatures on the Greenland ice sheet were plotted using the data of all permanent stations and most temporary expeditions. A new topographic map was drawn to remove inconsistencies between available maps and other data. The data of more than 70 glaciers were used to parameterize mass balance and equilibrium line altitude with climatological elements. It is planned to use the result in a model of global atmospheric circulation. The variations of the latent energy content of the cryosphere between the last glacial maximum and the present are being calculated and related to variations in the insolation.

EMPIRICAL GLACIER–CLIMATE RELATIONSHIPS

(P. Müller and W. Haeberli, VAW)

Data on glacier fluctuations in the Swiss Alps since 1950 have been analyzed. The investigated time interval contains — for the first time in history — pronounced advances of various glacier tongues as a reaction to a clearly developed and well documented double peak in cumulative mass balance. Robust statistics had to be applied to the measurement series in order to determine statistically satisfactory reaction times for about half the glaciers studied. These reaction times range from four years to several decades and are best explained by the total glacier length and the slope of the accumulation area. Average transmission velocities of "kinematic waves" inferred from the statistically deduced reaction times are generally slightly higher than expected (5 to 6 times the estimated surface flow velocity), but compare well with the kinematic wave theory regarding correlations with ice thickness (positive) and surface slope (negative).

THE ADVANCE OF FINDELENGLETSCHER
(A. Iken, H. Bösch, W. Schmid, H. Röthlisberger, VAW)
Unspectacular signs of the beginning of the advance were noticed in 1979. In the winter 1979/80, the glacier sheared off from its right (northern) margin. A network of survey stations and areal photo markers was established in 1979 and 1980. Surface velocity was measured at three sites by survey of poles at intervals of approximately 2 months from 1980 to 1987. In the vicinity of the survey markers, velocity gradients were determined in order to calculate the velocities at fixed coordinates. Photographs taken by the "Eidgenössische Vermessungsdirektion" in 1977 and annually since 1980 were evaluated, determining thickness changes in a 50 m grid.

Maximum velocities occurred in 1980 and 1981; after 1982 velocities decreased at first rapidly, then more gradually. Velocity variations are being compared to thickness variations (which were small except at the very snout) and to stress-gradient variations. Data on subglacial water pressure are included in the interpretation.

ICE AVALANCHES
(J. Alean and W. Schmid, VAW)
In 1984 two automatic single lens reflex cameras were installed near Fletschhorn-gletscher (Valais). This glacier is known to produce many ice avalanches within a short period of a few weeks once every two to four years. The next phase of intensive ice avalanche activity was expected to occur either in 1985 or 1986. Avalanching started in mid-September 1986, remained intensive until the end of October and finished in early December. Both starting zone and runout zone were successfully monitored by the cameras which took pictures daily; in the critical 3 month period, the occurrence of fog disturbed the photo in only three instances.

The cameras recorded dozens of ice avalanches with volumes between 200 m^3 and 200,000 m^3 (2 avalanches). One of the two largest events was directly observed (including the situation before break-off) by a mountain guide, who was then able to describe the event most precisely.

The final ice debris deposit had a volume of about 800,000 m^3. Therefore, the largest single avalanches contributed only a quarter to the total volume of this deposit. This might be a typical situation for a glacier which repeatedly releases ice avalanches. Ice debris cones produced in one dominant event such as at Mattmark in 1965 or Altels in 1885 could be relatively rare. Therefore, caution must be exercised when volume measurements of ice avalanche deposits are used to calibrate mass-dependent models of avalanche motion and runout distances.

ELECTROMAGNETIC PROBING OF INTERNAL GLACIER STRUCTURES
(G. Meyer, ICT)
A monopulse ice-radar with centre frequencies of several hundred MHz was developed in order to investigate the internal structure and shape of Alpine firn and ice bodies. The directional characteristics of various antennas were investigated as well as guided waves in layered media, such as snow. Testing was carried out on Vorab glacier, Grisons. In collaboration with members of VAW, marked time horizons such as Sahara dust layers in cold firn at the Colle Gnifetti core drilling site, the position of the 0 °C boundary in partially cold glaciers such as Gruben, and pronounced shear horizons in rock-glacier permafrost are now being investigated.

STRESS INVESTIGATION AT THE GLACIER BED
(A. Zryd, H. Röthlisberger, VAW)
To gain a better understanding of the mechanism at the ice-bed interface in an Alpine glacier, shear stress and normal pressure have been measured on an artificial obstacle at the base of Findelen glacier near Zermatt. Simultaneously, movement and strain rates were recorded. The rheological properties of the temperate basal layer (and hence sliding over an obstacle) are strongly influenced by the water content. A system is being designed to measure this parameter *in situ* by cold wave propagation. In a next step, the rheology of ice close to the melting point will be studied by low-frequency internal friction at the Swiss Federal Institute of Technology in Lausanne.

FRICTION AT THE BASE OF A GLACIER
(J. Schweizer and A. Iken, VAW)
The influence of friction due to debris in the basal ice layer on the sliding velocity of a glacier is being studied; the ice flow over a wavy impermeable rock bed has been simulated by the finite-element method. The friction results from rock particles embedded in the basal ice being forced against the glacier bed in zones of vertical strain, eg. on the crests of rock bumps (the so-called Hallet model). An increase in debris concentration reduces the sliding velocity linearly; in the case of a nonlinear flow law, the reduction is 3 to 4 times higher. Studies on the influence of the subglacial water pressure on the sliding velocity in the presence of friction show that even a very low areal concentration of rock fragments in contact with the bed leads to a remarkable reduction in the sliding velocity. It seems obvious that friction plays an important role in the sliding process. A functional relationship between sliding velocity, subglacial water pressure and debris concentration of the basal ice layer has been determined.

COMPUTATION OF WATER CONTENT IN POLYTHERMAL GLACIERS
(H. Blatter, GGEZ, M. Funk and K. Hutter, VAW)
A mathematical model for calculating one-dimensional profiles of temperature and water content in polythermal glaciers has been

developed in order to enable sensitivity studies to be done and to aid interpretation of field measurements. Because little information is available about conditions at the glacier bed, only those boundary conditions which can be determined in the field from the glacier surface were prescribed in the model. The model can now be used to estimate the water content of the temperate part in a measured englacial temperature profile. A more complex model is being developed in order to investigate the characteristics and dynamics of polythermal glaciers.

SNOW AND AVALANCHES

STABILITY OF SNOWPACK

(P. Föhn, SLF)

In order to gain more insight into the areal variability of snowpack stability, a measuring and evaluation programme of shear frame indices is underway. It will clarify the measuring method and the reproducibility of measurements.

WIND AND SNOW TRANSPORT

(R. Meister, SLF)

The transport rate of drifting snow depends on wind speed, surface conditions of the snow cover and precipitation rate. Boundary-layer winds over a ridge crest show a bulked shape with a maximum some 1–20 m above surface; this differs from the logarithmical shape. In addition, vertical density profiles show a concentration at a height of 0.5 to 1.0 m above terrain, depending on the turbulent structure of the wind speed. In dry conditions, the greatest portion of mass transport occurs by creeping and saltation, but strongly depends on the hardness and density of the uppermost snow layer.

STRAINS AND STRESSES IN NEW SNOW

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

The strains and stresses in layers of new snow in an Alpine forest are being investigated. Normal and shear stresses as well as shear deformation at the old/new snow interface are being measured experimentally, and numerical Boundary and Finite Element techniques used to solve the governing equations. The influence of external parameters like slope angle, ground roughness, arrangement of trees etc. and of internal parameters like viscosity, density and weak layers is being evaluated.

MEASURING AND MODELLING THE DEVELOPMENT OF SEASONAL SNOW COVER

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

Remote measurements of standard meteorological and snow specific parameters such as snow depth, snow temperature profiles, snow surface temperature, microwave radar stratigraphy profiles and acoustic emission are being performed in or close to natural avalanche release zones. The data are being used to develop and test models for the resulting snow layering and snow cover stability. To determine the temperature profile in a multi-layered snow cover as a function of time, Finite Difference methods are being applied to solve the one-dimensional heat diffusion equation for the various boundary conditions.

ACOUSTICAL PROPERTIES

(0. Buser, SLF)

The response of snow to an airborne acoustical wave may be regarded as being that of a porous medium within a rigid frame. Measurements of the impedance at different frequencies allow the determination of such snow parameters as porosity, pore size, tortuosity and to some extent grain shape. In cooperation with the Open University, Milton Keynes, UK, a field measuring device for snowcover investigation is being developed.

STRUCTURE OF SNOW

(W. Good, SLF)

Significant progress has been made in the understanding of snow structure by extending the two-dimensional analysis (2-D) to 3-D. The meaning of "snowbond" has had to be reinterpreted since the definition given for 2-D analysis greatly overestimates the number of bonds. Techniques have been developed to count the number of bonds automatically and to evaluate their cross sections.

SEASONAL SNOW COVER MONITORING USING FMCW RADAR

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

Stationary, ground-buried and mobile, sledge-mounted FMCW radars are being used to investigate snow stratigraphy. The systems have proved their feasibility for localized, nondestructive measurements of snow layering, water equivalence, initial percolation of meltwater etc. Data are automatically transmitted from radars buried in release zones and appended to bitmap presentations of the stratigraphy. The sledge-mounted systems are being used to determine areal distributions of snow layering, in order to investigate the effect of forests on snow stability.

MODELLING INITIAL FRACTURE AND FRACTURE PROPAGATION CAUSING SLAB AVALANCHE RELEASE

(B. Salm and H.U. Gubler, SLF)

Microstructural features of weak layers are being used to model initial ductile shear fracture within a slab as a function of snow load increase by precipitation, snow cover surface temperature, settling and variation of snow strength. Starting from this ductile weakened zone, shear fracture propagation within a thin weak layer has been modelled. Due to the nonlinear behaviour of snow, it has been shown that propagation of fracture is always faster upwards than down-slope. Transition time from ductile to brittle

fracturing strongly depends on the ratio of existing crack length to thickness of the low viscosity weak layer.

POWDER SNOW AVALANCHES
(F. Hermann and K. Hutter, VAW)
The runout zone of a powder snow avalanche is being investigated, using laboratory scale simulation in which particle speed and density are measured by means of an ultrasonic technique. A new setup which has 4 independent ultrasonic-channels enables transient phenomena such as avalanche heads on settling processes to be measured.

AVALANCHE DYNAMICS
(H.U. Gubler, SLF)
Avalanche flow speeds of large artificially released dense flow avalanches are being measured from start to stop using microwave Doppler radar. Slope perpendicular flow speed profiles and depth of dense flow are being determined from localized FMCW radar profiles. The data are being used to optimize a granular flow model and to calibrate existing standard models.

SNOW MOTION AND AVALANCHES IN FORESTS
(H. Imbeck and M. Meyer-Grass, SLF)
Avalanches with starting zones in the forests of the Swiss Alps are being investigated and evaluated statistically in order to find out the conditions which allow such avalanches to start (snow properties, forest types, ground and weather conditions).

ALTERNATIVE FOUNDATION TECHNIQUES FOR AVALANCHE DEFENCE STRUCTURES
(M. Heimgartner and U. Suter, SLF)
Since 1976, alternative foundation techniques for avalanche defence structures such as snow fences and snow bridges have been tested. The purpose is to reduce the effects of conventional foundations which use concrete pedestals/bases and bed plates on mountain slopes (increased erosion, loss of slope stability). We have developed a technique incorporating drilled anchors with diameters of 90–105 mm and lengths between 2 and 5 m. Present work includes field tests to establish the required anchor lengths, and applications of new materials, such as cements and envelope textiles, to improve the method.

AFFORESTATION AND TEMPORARY STRUCTURES
(W. Frey and F. Leuenberger, SLF)
Since a well developed forest is the best protective measure in avalanche starting zones and gliding snow areas, a good afforestation technique in treeless areas is most important to restore such a forest. In many cases, the young trees have to be protected from snow movements by temporary structures such as wooden rakes, tripods, posts and small terraces. Guidelines for silvicultural and technical measures are being elaborated.

SNOW DISTRIBUTION ON SLOPES AND 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. The aim of this investigation is to define the diameter of openings in the forest canopy as a condition for avalanche release.

AVALANCHE FORECAST NXD
(W. Good and 0. Buser, SLF)
After several years of exploring numerical avalanche forecasts, a practical version has been found, namely NXD — a computer assisted search of the most similar days in the past 20 years, producing the avalanche activity of those days. Tests with people who are responsible for avalanche control appear to be successful, and confidence in the method is growing. It is planned to introduce NXD in several different places, with the aim of finding out whether the results are useful for establishing the avalanche situation in regions not covered by some sort of interpolation.

SNOW AND ICE HYDROLOGY

CLIMATIC VARIATIONS AND GLACIER RUNOFF
(A. Ohmura and Chen Jiyang, GGEZ)
Variations of air temperature and precipitation during the last 100 years in the Alpine region are being related to glacier mass balance, surface area and runoff.

GLACIERIZED BASINS: SIMULATION OF GLACIER MASS BALANCE AND DISCHARGE
(H. Lang and L. Braun, GGEZ)
Different parameterizations of snow and glacier melt, as suggested by various well-known snowmelt runoff models, have been investigated with respect to their performance in modelling both daily discharge and annual specific glacier mass balance at different elevations in the basin of Grosser Aletschgletscher. Most models are capable of either good discharge or glacier mass balance calculations, but none of them yields acceptable results simultaneously for both. Further model developments are needed, such as parameterizations of radiation and interpolation schemes of precipitation, and our initial experience will be applied to other glacierized basins.

LIQUID WATER CONTENT IN SNOW MEASURED BY CALORIMETER AND MICROWAVE SENSORS
(J. Martinec, SLF)
An Ohmura-type calorimeter (ETHZ), two microwave sensors by Mätzler (University of Bern) and the Denoth capacity probe (University of Innsbruck) have been tested at Weissfluhjoch (2540 m a.s.l.). The snow cover

at the end of April 1987 was 2 m deep and the liquid water content in the different snow layers varied between 0 and 5 vol. %. Differences between the corresponding values as measured by the respective devices are mostly within 1 vol. %.

AREAL WATER EQUIVALENT OF SNOW FROM SATELLITE SNOW COVER MAPPING

(J. Martinec, SLF)

SLF is cooperating with the ETHZ and the Universities of Zürich and Bern to develop a method enabling the water equivalent of snow to be estimated from a sequence of satellite images. The project is supported by the Swiss National Science Foundation and aims at evaluating the distribution of snow in Alpine regions with regard to regional anomalies and the elevation above sea level.

SIMULATION OF SNOW ACCUMULATION AND ABLATION

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

Operationally available meteorological data enable successful, physically based simulation of snow accumulation and ablation to be carried out at selected automatic weather stations of the Swiss Meteorological Service (ANETZ). In a further step, simulations are being attempted for any given point in the Swiss Alps for the purpose of assessment of snow storage and prediction of seasonal discharge.

ICE CORE STUDIES

CHERNOBYL FALLOUT ON SWISS GLACIERS

(H. Gäggeler, U. Baltensperger, D. Jost, PSI, W. Haeberli, VAW, U. Schotterer, LLC)

Chernobyl fallout in the Swiss Alps was determined at 9 different sites with altitudes between 3010 and 4455 m a.s.l. Collection of firn samples, in the form of 2 m long core drillings, was performed on 1 and 4 July, i.e. about 2 months after deposition. At high altitude locations above about 3800 m a.s.l. sharp activity horizons were found whereas at lower altitudes percolating meltwater had already started migration of the deposited nuclides (mainly ^{134}, ^{137}Cs). The total activity at the time of collection ranged from 0.5 to 14 kBq.

ICE CORE DRILLING IN COLD ALPINE GLACIERS

(H. Oeschger and collaborators, LLC; W. Haeberli, W. Schmid, M. Funk, VAW; in collaboration with D. Wagenbach and 0. Münnich, Institute of Environmental Physics, Heidelberg, FRG)

The fieldwork on Colle Gnifetti concentrated on various shallow cores (depth about 14 m) to get more information about the deposition pattern between 4200 and 4550 m a.s.l. Meteo tower and stake readings were maintained by members of the Heidelberg group of environmental physics and the VAW which also collaborate in the continuous pit study programme. Trajectory calculations based on stake observations and radio-echo soundings were performed to investigate the age distribution within the Colle Gnifetti firn saddle. Borehole temperatures are now being studied with respect to effects of twentieth-century warming. In order to check the validity of records of pollutant concentrations (sulfate and nitrate) from Colle Gnifetti, another drilling place was found at the cold (about $-7\,^{\circ}$C) Fiescherhorn plateau in the Jungfrau region. First results indicate a much higher accumulation rate (1–2 m w.e.) than on Colle Gnifetti (0.3m w.e.) and little influence of melt layers. It is planned to obtain an ice core which covers at least the environmental record of the last 30 years.

AIR MIXING IN THE FIRN OF DRY SNOW ZONES

(H. Oeschger and collaborators, LLC)

The air trapped in the bubbles of ice is not of the same age as the surrounding ice. This is due to the fact that air is trapped in isolated bubbles only at the firn-ice transition depth. Within the overlying porous firn the air is able to mix and to exchange to a certain degree with the atmosphere. To investigate the mixing ratio of air in the firn layer, the diffusivities of CO_2 and O_2 (in N_2) in firn samples from Siple Station and Dye 3 have been measured. It could be shown that the dominant mixing process is molecular diffusion. The exchange time of air in the firn layer has been calculated with a one-dimensional diffusion model to be between 10 and 50 years.

ICE CORE DRILLING IN GREENLAND

(H. Oeschger and collaborators, LLC)

In summer 1985 first tests with a 4 inch electromechanical drill for intermediate depth bore holes were performed at Dye 3 (South Greenland). The modified drill was tested again at the same location in summer 1986, when an ice core to 300 m depth was recovered. The drill has been further modified since, with the goal of obtaining high quality ice cores in dry bore holes.

HISTORY OF ATMOSPHERIC COMPOSITION

(H. Oeschger and collaborators, LLC)

Analyses of air extracted from ice samples from Dye 3, Siple and Byrd stations (both West Antarctica) showed the following main results:

Reconstructions based on methane concentration measurements on air extracted from samples of an ice core from Siple Station have shown that over the last 200 years there has been an increase in atmospheric methane from 650 to 1650 ppbv $^{13}C/^{12}C$ measurements on CO_2 extracted from bubbles of the ice core samples indicated that the increase in the atmospheric CO_2

concentration runs parallel with a decrease in the $\delta^{13}C$ value. The decrease corresponds to the calculated one, assuming that the atmospheric CO_2 increase is caused by oxidation of biomass and fossil fuels.

Measurements of the methane concentration in ice core samples from Byrd Station and Dye 3 showed that the atmospheric methane concentration was only about 350 ppbv during the last glaciation, compared with a mean preindustrial level of about 650 and a present value of 1650 ppbv.

Detailed measurements of the CO_2 concentration have also been performed on ice core samples from Byrd Station, and from a core section covering the time period of about 50,000 to 5,000 years B.P.

^{10}Be AND ^{36}Cl CONCENTRATION MEASUREMENTS

(H. Oeschger and collaborators, LLC; Institut für Mittelenergiephysik ETHZ)

Analyses of the ^{10}Be and ^{36}Cl concentration in ice core samples from Camp Century (North Greenland) and Dye 3 showed the following main results:

An increase in ^{10}Be concentration is observed in both Greenlandic cores for the glacial period.

The main cause is most probably a lower precipitation rate during the glaciation. Short term ^{10}Be variations (period 200 years) are rather well correlated with short term ^{14}C variations observed in tree ring records. This indicates that both variations are mainly due to changes in the production rate.

Not only do ^{10}Be and ^{36}Cl concentrations show some local and temporal variations due to varying transport and deposition characteristics, but the $^{10}Be/^{36}Cl$ ratio also shows a surprisingly high variability.

H_2O_2 MEASUREMENTS ON SNOW AND ICE CORE SAMPLES

(H. Oeschger and collaborators, LLC)

Measurements of the H_2O_2 concentration have been performed on fresh snow samples from Weissfluhjoch and in the snow pack during and at the end of the winter season. There is a large variability in the H_2O_2 concentration between different precipitation events. Part of the H_2O_2 decays relatively quickly in the surface layer of the snow cover.

H_2O_2 is well preserved in polar ice samples. Records of the H_2O_2 concentration along ice cores from Siple Station and Dye 3 show a strong seasonality. The records, covering about the last hundred years, show no clear trend in the B_2O_2 concentration, giving therefore no evidence that the atmospheric B_2O_2 concentration has changed during the last 100 years.

SEA ICE

ANTARCTIC SEA ICE: KINEMATICS AND CLIMATOLOGY

(H. Enomoto, GGEZ)

The seasonal and interannual variations of the distribution and movement of the sea ice around Antarctica are analysed using satellite data. Synoptic atmospheric data are used to investigate the processes controlling the sea ice dynamics.

FROZEN GROUND AND PERIGLACIAL PROCESSES

CORE DRILLLING THROUGH ROCK GLACIER PERMAFROST

(W. Haeberli and H. Röthlisberger, VAW, J. Huder, IGB)

A core drilling project has been started on the active rock glacier Murtèl I, (2660 m a.s.l.) Piz Corvatsch/Engadin, Swiss Alps. Drilling operations took place in spring 1987. Borehole temperature is close to $-2\,^{\circ}C$ at 15 m depth and permafrost reaches down to severely fissured bedrock at about 50 m depth. The perennially frozen material contains pure and massive ice (top 12 m beneath the active layer), supersaturated frozen sands with ice lenses (17 m), and ice-bearing blocks (18 m). About 75% of the borehole deformation takes place at the base of the supersaturated finegrained sediments i.e. within the permafrost. Creep of the structured block-ridden layer appears to be negligible. Geothermal and mechanical analysis of borehole data is underway and the recovered cores — in a frozen state — are now being analysed.

AEROPHOTOGRAMMETRICAL MONITORING OF ROCK GLACIER PERMAFROST

(W. Haeberli and W. Schmid, VAW)

An observational network for aerophotogrammetrically monitoring the behaviour of mountain permafrost within five active rock glaciers (Gruben, Réchy, Gufer/Aletsch, Murtèl, Muragl) has been established in the Swiss Alps. First results from measurements at the Gruben rock glacier in the 1970-79 time period indicate that (1) the flow pattern of the creeping perennially frozen debris changes very slowly with time, (2) deformation can contribute as much as or even more than geothermal effects to changes in permafrost thickness, (3) growth and degradation of permafrost can take place simultaneously at different places within the same rock glacier, and (4) an overall tendency exists for the rock glacier permafrost to thin at a rate of a few centimetres per year, probably as a consequence of twentieth century warming. It is planned to continue photogrammetrical analysis at 5- to 10-yearly intervals for each rock glacier.

MICROCLIMATIC INFLUENCE ON SOLIFLUCTION ACTIVITY

(M. Gamper, GGUZ)

In the Swiss National Park, ground and air temperatures have been recorded since 1978 on solifluction lobes. Movements of slope debris have been measured within the same

area each year. Similar measurements of temperature and solifluction movements were started on solifluction lobes in the Grossglockner Region (East Tirol, Austria) in cooperation with H. Stingl (University of Bayreuth, Germany) in 1984. The goal of the study is to investigate the influence of parameters such as snow cover, wind conditions and permafrost on solifluction activity in the Alps.

PERIGLACIAL DEBRIS FLOWS
(M. Zimmmermann, D. Rickenmann and W. Haeberli, VAW)
Following the heavy damage caused by periglacial debris flows in summer 1987, especially at Poschiavo (Grisons) and Münster (Valais), a systematic investigation of possible causes and processes connected with the formation and dynamics of debris flows in glacier forefields and within high-mountain permafrost was started. The study involves analysis of specially flown aerial photographs, field mapping and geophysical soundings at selected sites. It is part of a general Federal Government programme concerning the catastrophic floods in the Swiss Alps during 1987.

GLACIAL GEOLOGY/PALAEOGLACIOLOGY

METHODS OF SNOWLINE RECONSTRUCTIONS
(S. Bader, GGUZ)
New methods for reconstructing late-glacial snowlines are being investigated in order to reduce the uncertainties involved with the commonly used approach of assuming constant AAR values for steady-state conditions. Based on recent and historical glacier data, a model is being developed which reflects the influence of various parameters such as avalanching, shadow-effects or debris cover, and which should be applicable to every glacier.

TILL FORMATION
(Ch. Schlüchter, INGEOL)
Investigations on actuogeological processes along glacier margins, especially with regard to gaining information on lateral till complexes (Findelengletscher, Tsijiore Nouve, Steingletscher), have been continued; they include the differentiation of primary (ortho) tills and secondary (allo) tills, and studies of the relationship between glacier bed configuration, ice-flow pattern and sedimentation.

MAXIMUM GLACIERIZATION DURING THE PAST CENTURY ("1850") IN THE ALPS
(M. Maisch, GGUZ)
Detailed analysis of conditions during the Little Ice Age maximum around 1850 and comparison with 1973 glacier inventory data has revealed pronounced scatter in geometrical and snowline changes of a large number of systematically reconstructed glaciers in the Grison Alps. The study is now being extended to the Swiss Alps as a whole, and it is hoped to document effects of twentieth century warming as well as to improve interpretation of late-glacial snowline information.

GLACIER BEHAVIOUR DURING THE LITTLE ICE AGE
(H.J. Zumbühl, GGUB, H.P. Holzhauser GGUZ)
The fluctuations of the Great Aletsch, Rhone, Rosenlaui and Unteraar glaciers have been reconstructed in detail using paintings, drawings, prints, photographs, written sources, and ^{14}C-dating of fossil soils and buried wood. The results concern the Little Ice Age, but also extend to the Middle Ages. Publication is planned within the framework of the 125-year jubilee of the Swiss Alpine Club in 1988.

HOLOCENE GLACIER VARIATIONS IN THE ALPS
(H. Holzhauser, GGUZ)
Reconstruction of Holocene glacier variations using mainly ^{14}C dating of fossil soils and wood in moraines, but also historical paintings and written sources, has been extended to glaciers in the Bernese Alps (Unteraar, Oberaar, Lower Grindelwald). Dendrochronological work includes investigation of annual tree-ring widths within pieces of larch found in glacier forefields, and the construction of tree-ring chronologies at the timberline as a basis for dating and climatically interpreting past glacier fluctuations.

ALPINE PALEOGLACIOLOGY
(W. Haeberli and J. Schweizer, VAW, Ch. Schlüchter, INGEOL)
Efforts to reconstruct, parameterize and model vanished glaciers are being continued. The Little Ice Age maximum of the especially well-documented Rhone glacier has been examined with respect to the large-scale distribution of basal shear stresses; a pronounced slope dependence of longitudinally averaged stresses has been found. Concerning the 18 ka BP maximum glaciation, encouraging agreement seems to exist between simple temperature models of the then existing piedmont glaciers and the present day-distribution of geothermal heat-flow values within the now ice-free Swiss Plateau. Investigation of 3-D effects, ice/bed-coupling and nonsteady-state conditions will be examined next. It remains of critical importance, however, to improve the geological input information, especially with respect to former accumulation areas and to the ice build-up period.

LATE-WUERM DEVELOPMENT OF THE RHEIN GLACIER SYSTEM
(0. Keller and U. Krayss, GGUZ)
The maximum extent and early retreat of the late-Würm Rhein glacier system have been investigated. Depression of the equilibrium line altitude for the maximum stage is

calculated to be around 1300–1400 m with respect to present-day conditions. A marked readvance must have taken place ("Weissbad" stage) when the equilibrium line was around 900–1000 m lower than that today. However, detailed mapping (at scales of 1:100,000 and 1:25,000) of ice conditions during this time reveals that mainly smaller glaciers (Alpstein region) — but not large ice streams — may have reacted to the corresponding climatic change.

QUATERNARY GLACIER FLUCTUATIONS AND CLIMATE VARIATIONS IN THE SWISS ALPS
(G. Furrer and collaborators, GGUZ)
Investigations of glacial and climatic history since the Eemperiod are being continued. The research programme includes geomorphological studies, tree-ring analysis on living as well as fossil trees, and interpretation of pollen spectra. Regionally, emphasis has been placed on the area of the former Rheingletscher.

THE LAST GLACIAL MAXIMUM IN THE ALPINE FORELAND
(C. Schindler, Ch. Schlüchter, B. Müller, K. Hiltbrand, INGEOL)
Two areas of maximum glacier extent are being mapped in detail in the northern Alpine Foreland (Reuss-/Aare-, Rhonegletscher). This study is supplemented by detailed facies analysis, paleogeographical reconstructions for the time of maximum glaciation and an evaluation of the climate-stratigraphic position of the so-called "Supermaximum".

PLEISTOCENE GLACIAL SEDIMENTS
(Ch. Schlüchter, St. Werthmüller, F. Zuber, INGEOL)
The facies associations of the sediments produced by the Pleistocene glacier advances to the Alpine Foreland are being studied. Comparison of glacigenic sediments in the Alpine Foreland with accumulations in inneralpine areas is being made. Glacier erosion and deposition as related to one single advance is being mapped.

PLEISTOCENE GLACIATIONS IN JAPAN
(S. Horie, Univ. Kyoto and Ch. Schlüchter, INGEOL-ETHZ)
Mapping the extent and investigating the stratigraphic relationship of glacial deposits in the Japanese Alps of Honshu and in the Hidaka Mountains of Hokkaido was undertaken. Multiglaciations have been recognized at lower elevations than known from the literature.

Submitted by Wilfried Haeberli

USSR

SOVIET GLACIOLOGICAL RESEARCH IN 1987

In 1987 glaciological research was undertaken in the Caucasus, Middle Asia, the Khibini Mountains, Siberia, and Far East and Kamchatka, in the Arctic and in Antarctica.

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

Institutes of Geography of the USSR Academy of Sciences (IG AS),
the Siberian Department of the USSR Academy of Sciences (IG SD AS),
the Pacific Far Eastern Department of the USSR Academy of Sciences (PIG),
the Academy of Sciences of the Kazakh SSR (IG AS KazSSR),
the Academy of Sciences of the Georgian SSR (IG AS GSSR);
the Institutes of:
Geology of the Academy of Sciences of the Estonian SSR (IG AS ESSR),
Geology and Geophysics of the UzSSR Academy of Sciences (IG andG AS UzSSR),
Geocryology of the Siberian Department of the USSR Academy of Sciences (IG SD AS USSR),
Physical-Technical Problems of the North of the Siberian Department of the USSR Academy of Sciences (I.P.T.P.N.),
Volcanology of the Far Eastern Department of the USSR Academy of Sciences (IV FED AS SSSR);
the Khabarovsk complex Scientific Research Institute of the Far Eastern Department of the USSR Academy of Sciences (KhabCSRI);
the Department of Protection and Efficient Use of Natural Resources of the TadzhSSR Academy of Sciences (D.P.E.U.N.R.);
the State Hydrological Research Institutes of the State Committee for Hydrometeorology of the USSR (SHRI):
Tien-shan Physical-Geographical station (TSPGS),
Middle Asia (MARI),
Transcaucasia (TRI),
Arctic and Antarctic (AARI),
West Siberia (WSRI),
High Mountain Geophysical (HMGRI);

the Boards of the State Committee for Hydrometeorology of the USSR:
Northern Caucasia (NCBHEC),
Kamchatka (KBHEC),
Azerbaijan (AzBHEC),
Sakhalin (SBHEC),
Georgia (GBHEC),
Tajik (TBHEC),
Kazakh (KazBHEC);
the Novosibirsk Institute of Railway Transport (NIRT);
the Industrial Research Institute of the Engineering Constructions of Gosstroy of the USSR (IRIEC);
the State Research and Production Centre "Nature" (StRPCN);
the Northern Baikal Department of the Baikal-Amur Railway, Enterprise No. 19 of SBGC;
the universities of:
Moscow (MSU),
including the Snow Avalanches and Mud Flows Problems Laboratory (SAMFPL)
and the Airspace Methods Laboratory (AML),
Kharkov (KSU),
Altai (ASU),
Tomsk (TSU) and
Kazan (Kaz SU);
and the Kazakh Pedagogic Institute (Abay) (KazPI).

The information was compiled on the basis of the reports of these organizations received by the Section of Glaciology of the Joint Geophysical Committee, and submitted by V.M. Kotlyakov and O.N. Solomina.

GLOBAL GLACIOLOGICAL PROCESSES AND THEIR MODELLING

SOURCES OF WATER VAPOUR AND DISTRIBUTION OF SNOW AND ICE ON THE EARTH

(IG AS)

On the basis of the analysis of the maps of the *World Atlas of Snow and Ice Resources*, the effect of the oceanic sources of water vapour on the global distribution of snow cover and glaciers was calculated; transfer of moisture reaching the snow cover through the continental watersheds was quantitatively estimated; energy losses for snowmelting were calculated, and the contribution to the formation of air temperature patterns over the continents estimated.

INTERACTION BETWEEN GLACIATION AND ATMOSPHERE, OCEAN AND LYTHO-SPHERE

(IG AS)

Working out the conceptual model of interaction of the basic elements of glaciosphere — glaciers, snow cover, sea ice with the atmosphere and the ocean — was finished; a preliminary qualitative model of interaction between glaciation and lythosphere was worked out. Work continues on the improvement of the hydrodynamics model of "sea" glacier covers, and numerical modelling of the form and external mass transfer of ancient ice sheets with account of the dynamic conditions on the subglacier floors. Models of the calculation of the stability and variability of fluctuations in mass exchange of glaciers were worked out. The model of a multidimensional ablation field for the Pamirs was developed and solved.

(TIG)

The one-dimensional model of thermodynamical processes and interaction within the block "atmosphere – snow – sea-ice – the upper quasi-homogeneous ocean layer" with the polynomial representation of the vertical temperature profile was developed and solved. The effect of the polynomial degree, parametrization of the seasonal change of insolation, hydrometeo-elements and albedo on the reproduction capacity of the climatic characteristics was investigated. The simplest variant of a dynamical-statistical model describing the processes of atmospheric moisture transfer to the regions of continental glaciations and precipitation on the climatic scale of averaging was studied. The first versions of the thermomechanical model of seasonal snow cover were suggested. The cycle of elaborations of parametrization of daily variability of radiation flows and characteristics of the interface layer of atmosphere was finished. A numerical scheme of through counting for modelling the dynamics of the global continental glaciations on the geographical coordinate grid was suggested. Algorithm of imitation of the dynamics of absolute and relative sea level was worked out.

(KazSU)

A two-dimensional model of the dynamics of a non-stationary surface glacier cover with spontaneous relief of the bed was numerically solved. The reasonableness of the chosen differential scheme was shown. Computer investigations were carried out on the similitude of the fields of maximum snow reserves on a mountain glacier as an input characteristic of an evolution model of mountain glaciation.

GLACIOCHEMISTRY

(KhabCSRI)

The results of investigations were summarized, and theoretical and methodological fundamentals of glaciochemistry worked out; its place in the system of the Earth sciences was determined, the objectives of investigations, methodological approaches, and basic concepts were described. The problems of the chemical composition of ice and melt waters were considered; data on the effect of ice formation on the chemical composition of natural waters were obtained, the reaction of the soluble substances during ice and snow melting, the role of ice formation in geochemical processes in the oceans and on the continents as well as in the ecologo-geochemical processes in water bodies and water courses, some matters of gas exchange between the hydrosphere and the atmosphere during sea and continental ice formation were studied.

GLACIERS

STABILITY AND VARIABILITY OF MOUNTAIN GLACIERS

(IG AS)
The main causes and mechanisms of the stability and variability of mountain glacier mass exchange, linked to the stipulated climate fluctuations, casual processes and the feedback links between mass input and discharge, were determined. The conditions of the formation of the anomalous great snow accumulation in the winter of 1986/87 in the glaciers of the Caucasus and Middle Asia were analyzed, as were the assumptions about slowing down and further possible stopping of the intensive retreat of the mountain glaciers.

The Caucasus glaciers

(IG AS)
The balance, hydrometeorological surveys and geodetic works were carried out on the Elbrus glaciers. A number of boreholes were drilled in the firn–ice sequence (including some 24 m deep), which made it possible to investigate the processes of ice formation. For the first time the ice thickness here was measured by means of drilling — it equals 77 m on the Garabashi firn plateau.

(NCBHEC)
On the Bezengi glacier integrated glacio-hydro-meteorological observations were carried out from 1 June to 30 September 1987.

(TRI, AzBHEC and GBHEC)
Observations on 10 Caucasian glaciers were continued. On the Gergeti, Yuzhny and Yugo-Vostochny glaciers estimates were made of ice movement, velocity and ablation, changes of surface levels on longitudinal and cross-cut profiles, fluctuations of the tongues, and melt waters discharge at the plots and at the outlet of glacier rivers. On the rest of the glaciers the routine observations during the ablation period took place. It was found that for the balance year under consideration the Eastern Caucasus glaciers continued to retreat, but with a smaller velocity of 1–9 m/year. On the Yuzhny glacier a kinematic wave was observed, causing the formation of deep cracks and an increase of ice thickness to 10–15 m at the end of the tongue.

(IG AS GSSR)
The components of water balance in the basins of the Adishura and Suatisi rivers were investigated. Meteorological and actinometric observations were carried on in the first basin. On the glacier tongue at the height of 2500 m, the runoff from the plot was simultaneously measured and hourly observations over meteorological components completed.

The Middle Asia glaciers

(MARI)
All-year-round works on the estimation of the water–ice balance, the study of the hydro-meteorological regime, and ecological conditions according to the programme of background monitoring were continued at field stations in the basin of the Abramov glacier on the Pamir-Alai. A method of forecasting the Vahsh river runoff for July–September was worked out, which provides higher reliability and a separate estimation of the snow and ice components.

(DPEUNR)
Integrated investigations in the mountain-glacial basin of the Gurumdy river (the Alitchur head river on the Eastern Pamir) were carried out; measurements of the mass balance, started in 1986, were continued on one of the glaciers of the basin.

(IG AS, IG AS KazSSR)
Study of the variability of the mass balance and the runoff from glaciers in the continental conditions of Tien Shan continued. An experiment was carried out on simultaneous measurement of glacioclimatic characteristics on the Central Tuyuksu glacier situated on the periphery of the mountain country, and on Akshijrak situated within it. Accumulation, ablation and annual mass balance of the Tuyuksu glacier were calculated, diagrammatic maps of the principal quasi-stationary characteristics of its dynamics made. Comparable values of average glacier runoff of the rivers of the Balkhash-Alakul'skaya depression basin for many years were received. The materials of geodetic measurements on the glaciers of Zaili'sky Alatau were processed. Heat balance observations on the glaciers situated on the Peter Pervy mountain ridge were completed.

(TSPGS)
It was determined that on the glaciers of the Issyk-Kul' lake basin the quantity of precipitation increases in conformity with height practically everywhere, for instance in the range of 3000–4000 m. The average value of the layer of the ice melting off for many years was determined; in the basin of the

Cary-Dzhaz river at a height of 3600 m it was 2.5 m, in the Issyk-Kul' lake basin it was 2.2 m. It was shown that on the glaciers with a southern orientation and of meridional extent the melting is 18% and 23% more than on the glaciers with a northern orientation. The glacial component of the annual runoff of the Issyk-Kul' lake basin rivers accounts for approximately 30% of the total, and of the summer runoff, 40–50%. Despite the stable reduction of the snouts of glaciers, a direct effect on the water content of rivers of glacial nourishment is not detected. Thus we can consider that even with the climate getting warmer by 1–2° river runoff will not decrease, but probably increase due to the involvement into the process of melting such ice areas, which are situated higher than the present-day firn line. For the first time on the Tien Shan, observations on the hanging glaciers were organized and carried out. The main cause of their unfavourable existence is a considerable (up to 30%) drifting of snow from the surface, while melting on them is comparable with the melting of the valley glaciers.

(IG and G AS UzSSR)
Material was collected for correlation of the velocity of glacier movement and the fluctuations of snouts with temperature and precipitation over the warm and cold halves of a year, with different periods of averaging. On the Dzholdzhiga glacier in the Kitchik-Alai mountain ridge balance-gradient observations, tacheometric surveys and sampling for petrographic analysis were carried out. In addition, water, snow and ice were sampled for hydrochemical analysis, and hydrometric observations were made. Reduction of glaciers in the basin of the Dzholdzhiga river was observed. Thus, during 1983–86, the Karazazyk-zapadny glacier retreated with a velocity of 24 m/year.

The Altai glaciers
(TSU)
Observations of the mass balance of the Aktru basin glaciers continued. On the Maly Aktru glacier the total accumulation in 1986/87 turned out to be lower than the norm by 5%, with melting and inner nourishment higher than the norm by 40% and 17% correspondingly. The year balance was negative. For the Levy Aktru and Vodopadny glaciers all the balance components exceeded the norm, and the total balance was close to zero. During the ablation period of 1987 up till the end of July an extremely low position of the seasonal snow line on the glaciers was noticed, lower than usual by 200–300 m, and later its sharp reduction up to the heights typical of the average position for many years. The distribution of large fields of glacial nourishment in the continental areas of the Altai (up to two-thirds of the glacial areas, the thickness of the superimposed ice being 10–15 cm), frequent snowfalls in June, at the end of July, the beginning and the end of August, and their non-syncronous falling in different parts of the Gorny Altai was registered. The runoff layer in the Aktru basin for the period of observation was a little less than the norm, while the share of the glacial component did not exceed 34% of the total summer runoff.

The Kamchatka glaciers
(KBHEC, MARI)
Measurement of the mass balance of two glaciers on the slopes of the Anachinsky volcano was begun.

MAP-MAKING AND CATALOGUING OF GLACIERS
("Priroda" AzSSR)
The recent glaciation of Uzbekistan and Kirghizia was mapped, and this map can be used to estimate changes, as a review map for glaciological investigations, and for compiling other thematic maps (for instance, recreational), as well as for the re-determination of glacial contours while bringing up to date topographic maps on corresponding scales. Map-making of the Kirghizian glaciers started on a scale 1:100 000 according to the space images, with a sterographic survey of the terrain and the glacier surface.

(MARI)
On the basis of space image survey and new cartographic materials a renewed Gissaro-Alai glaciers catalogue as from 1980 was prepared. New data on the extent of glaciation and other characteristics were set into the data bank of the automated information subsystem "Glaciers" of the State water cadastre.

SOUNDING OF GLACIERS
(TSU)
Radio echo-sounding of nine glaciers in the Severo- and Yuzhno-Chujsky mountain ridges was completed. It was found that all of them have a double-layer structure, the intermediate reflecting horizon (according to preliminary data) corresponding to the ice melting isotherm. The average glacier sequence is within the limits of 74–92 m, and the average depth of the reflecting horizon is 38–45 m.

(Enterprise No. 19 of SBGC)
Geodetic substantiation was created and a detailed radio echo survey of the bottom relief of four glaciers in the Akshijrak massif completed, and the ice sequence measured.

(IG AS KazSSR)
The results of the ground radio echo-sounding of the thickness and volume of the Shumsky and Muravlev glaciers in Dzhungarsky Alatau were analyzed. A substantiation of the connection between glacier volumes and their area and morphology was suggested.

GEOCHEMISTRY OF GLACIERS
(IG SD AS USSR)
Geochemical, calorimetric, spectral, atomic-

absorptive and other analyses of ice, natural waters, alluvium and moraine deposits in the western part of the Akshijrak massif were completed. The cryogenic migration of chemical elements and compounds in glacial ice covering deposits of mineral resources was determined. It takes place in the form of ions in a liquid-like film, situated on the surface of ice crystals. The cryogenic geochemical areals are formed in glaciers with different temperature fields — from 0 to −6°. They reach the surface of the glacier field and are manifest in big sequences of covering ice. The contrast range of cryogenic geochemical anomalies within ice on the surface of glaciers over ore bodies varies from 20 to 10 with respect to the background characteristics.

FLUCTUATIONS OF GLACIERS

The Caucasian glaciers

(NC BHEC)

The mass balance of many glaciers was close to zero, and only with a few of them was it negative or positive. On the majority of glaciers the seasonal snow limit did not reach the average position observed for many years. In comparison with the previous year, the number of retreating glaciers reduced sharply and the number of advancing glaciers increased: thus, out of 34 glaciers investigated, 14 advanced and four were in a stationary state. The biggest valley glaciers of the Central Caucasus continued to advance: the Bezengi glacier advanced by 3.1 m, the Mizhirgi glacier by 10.5 m.

(IG AS GSSR)

On the Adishi glacier a phototheodolite survey was completed once again, and the velocities of its surface movement determined: they are 60–70 m/year at the height of 2600 m. From 1 September 1986 to 1 July 1987, this glacier retreated by 5 m.

(MSU: AML)

The ground stereophotogrammetric method of studying glacier dynamics was theoretically grounded. The methods of determining velocities of ice movement on the surface by photogrammetric methods (using pseudo-parallaxes) were improved. These methods make it possible to determine the horizontal component of the velocity, with the interval between surveys of up to one year. With the help of this method, the field of annual velocities of ice movement on the surface of the Dzhankaut glacier tongue for the years 1985–86 was obtained for the first time. Using phototheodolite survey methods, maps of the variations of some Elbrus glaciers for 1958–83 and velocities of the ice movement in summer 1983 were compiled, as well as a map of spatial variations of the Dzhankaut glacier for 1974–84. A ground stereo-photogrammetric survey of the Elbrus glaciers was carried out again. A numerical model for the northern slope of Elbrus was constructed, including 2500 points for which values of surface height variations were obtained. A negligible lowering from 1959 to 1986 was found.

The Middle Asia glaciers

(Enterprise No. 19 SBGC)

Map making of variations of 178 Akshijrak massif glaciers on the basis of aerophototopographic surveys of 1943 and 1977 on a scale 1 : 10 000 was completed, and a map prepared of glacier variations for 34 years on a scale 1 : 50 000, providing glacial limits at different times, variations of surface height, location of glacial lakes and extensive crevasse zones, and outlines of present day moraines, with horizontal lines at the average height of the glaciers in 1943. Diagrams of the distribution of volume variations along the vertical profile were presented for each glacier. Principles of graphic and numerical representation of glacier variations according to the materials of more than two topographic surveys were worked out. A series of maps of ice thicknesses at the end of the Davydov glacier was compiled for different years.

(IG AS KazSSR)

A catalogue of pulsating glaciers in the mountains of south-east Kazakhstan was compiled.

(IG AS)

In summer 1987, a reconnaissance investigation of the Pamir pulsating glaciers was carried out; three parts of their catalogue were compiled.

(TBHEC)

Observations over 17 Pamir glaciers were carried out: the majority of them continued to retreat, though the mass balance of four glaciers for the previous year was positive and the surface of their tongues increased by 2–5 m.

The Altai and Sayany glaciers

(TSU)

The linear reduction of the sizes of 11 Altai glaciers, which changed from 0.5 to 11.3 m/year, was measured. The Levy Karagem glacier advanced by 1.1 m.

(ASU)

Tacheometrical and phototheodolite survey of the glaciers in the Belukha massif, Severo-Tchu'sky mountain ridge (the Altai), the massif of the Topographs mountain peak (the Vostochny Sayany) and Tabyn-Bogdo-Ola (Mongolia) was completed; levelling of the transverse profiles of the Bol'shoi Maashei and the Rodzaevitch glaciers in the Altai and aerovisual investigation of the Belukha glaciers were carried out. It was determined that on the whole the degradation of the Altai-Sayany mountain area glaciers continued. The degradation velocity of the Gorny Altai for the year under consideration is 3–15 m, and the Vostotchny Sayany glaciers retreated on average by 3 m/year from 1982 to 1987. At

the same time some Gorny Altai glaciers were more active after conditions during the years 1983–86.

VOLCANISM AND GLACIATION

(IV FED AS SSSR)

The Klyutchevskoi volcano glaciers in the regions of eruptions in 1986–87 (south-eastern and western parts), the summit craters of the Ushakov volcano, the glaciers Ermana and Bogdanovitcha reservoirs, and the Tolbatchinsky volcano glaciers were investigated. The year 1986/87 was favourable for glaciation of the Klyutchevskaya group of volcanos. The height of the glacier reservoir boundary on the glaciers at the end of the ablation period reached 2600–2700 m. Methods of measurement of the erupted pyroclastics volume in field conditions were worked out, based on the preserving properties of snow cover. It is possible to map the pyroclastics distribution over the territory by individual measurements of the thickness of ash deposits in the snow. A map of the glacial zonality of the Klyutchevskoi volcano was compiled. Dendrochronological material for climatic reconstructions in the glacial zone of the Avatchinskaya group of volcanos was collected in collaboration with Kharkov University. Theoretical aspects of glacier thermal physics on the active volcanos were worked out in collaboration with Kazan University.

(IG AS ESSR. IV FED AS SSSR)

Isotopic analysis was carried out of the samples along the vertical profile of the Dal'nij Ploskij glacier. The isotopic variations are comparable with the metoerological data, and point to a relatively good safety margin of the initial information on the volcanic glaciers.

SNOW COVER AND AVALANCHES

FORECAST OF THE DESTRUCTIVE NIVAL-GLACIAL PHENOMENA

(SAMFPL)

A mathematical model of snow-melt water percolation in the snow–firn sequence was suggested for estimation of the effect of snow and ice melting on the runoff from glaciers and formation of the abnormally high floods. A model of glacial avalanche formation was also suggested. Principles of the methods of determination of the instance of the destructive effect of the avalanche air wave were worked out. A fundamental scheme for a system for registration of snow-avalanche parameters in Khibiny was compiled.

AVALANCHE AND MUD-FLOW DANGER IN MOUNTAIN REGIONS AND RECOMMENDATIONS FOR PREVENTING DAMAGE FROM THEIR DESCENT

(SAMFPL)

Field investigations were carried out of the snow cover in Adzharia in order to work out methods for the artificial triggering of avalanches. According to the materials on the snow-avalanche regime in the zone of unstable snow cover, regularity of recurrence of winters with much snow were revealed in the Trans-Caucasus region, which makes it possible to forecast previously unrecognised avalanche danger situations. Field work in Tajikistan on the estimation of avalanche danger in the border regions of the Pamir, some of which had not been investigated before, was undertaken.

Data were collected on the damage caused by avalanches and mud-flows on the territory of Armenia, Georgia, the northern Caucasus and Tajikistan. The state of avalanche-mud-flow protective constructions in some regions of Azerbaijan, Armenia, Georgia and northern Caucasus and the disastrous effects of the avalanche-mud-flows in winter 1986/87 were exposed. The monographs *Avalanches of the USSR and the world* and *A long-term avalanche forecast* were prepared. In insuffiently investigated regions using remote sensing (space, aerophoto and phototheodolite surveys), ground and calculated methods, the basis was worked out for the complex methods of investigating dangerous nival-glacial slope processes by stages. The methods were proved on the Tcharo-Udokansky aerocosmic range.

The Caucasus

(HMGRI)

Methods of active influence upon the snow cover were improved; aerovisual and expeditional observations over the snow-avalanche phenomena on the northern slope of the Bolshoi Caucasus were carried out, field hydrometeorological and snow-avalanche projects at stations and during expeditions in the Elbrus area and the Trans-Caucasian motor-car road were completed.

(IG AS)

A snow survey on the territory from Pasanauri village to Krestovy mountain pass was carried out. It was established that in winter of 1986/87 the snow storage exceeded the norm by 3–5 times.

(NCBHEC)

It was found that during the cold period of 1986-87, the quantity of precipitation in the high mountain area of the Caucasus was 120–150% of the norm, and in the low mountain area it was a little less than the norm. During the first half of the ablation period the air temperature exceeded the norm by 16–19%, and during the second half at the moment of maximum, it was lower than the norm by 17–19%. The results of the route snow surveys showed that the snow cover thickness at the end of March 1987 in the western Caucasus exceeded the average of many years by two or three times, though in the eastern Caucasus it was close to the norm. In the western Caucasus from Elbrus to Fisht numerous snow-patches in the headwaters of many river valleys remained unmelted from the previous year.

The Middle Asia mountains

(IG AS KazSSR)

The materials for investigation of the dynamics of structure and resistance properties of the snow cover in the avalanche area of the northern Tien Shan were summarized for many years. Methods of estimation of the effect of the slopes exposure on the distribution of the snow cover were worked out, and these methods make it possible to pass from the background values of snow accumulation on to the real ones. A methodical guide on calculation of indicators of snowiness and avalanche danger for average scale mapping was prepared. Maps of snowiness and avalanche danger of the Middle Asia and Kazakhstan territories on scales 1 : 500 000 and 1 : 200 000 are being compiled.

(KazBHEC)

Checking of the methods of the background avalanche forecast in different mountain regions of the republic was continued according to the calculated prognostic formulas using current data of 20 weather stations, processed by electronic computer.

(IG AS)

Following the example of the Bel'dersai urotchistche in the western Tien Shan, methods of integrated large-scale observations over the snow cover were worked out. The spatial variability of its sequence was determined, depending on the wind redistribution of snow and exposure of the slopes to microrelief.

Far east and north-east of the USSR and the area of the Baikal-Amur railway

(KBHEC)

Work on identifying dangerous avalanche zones in Kamtchatka oblast' as well as observations over the conditions of avalanche formation in different parts of the peninsula continued at stations. A statistical analysis was completed of the materials of the route and of airborne snow surveys which have been carried out since 1960 in the basin of the Avatch river and since 1971 in the basin of the Kamtchatka river, for defining the representativeness of the observational stations with a view to turning to the air a remote-sensing method of snow accumulation measurements. On the basis of the results obtained, 11 routes were equipped with air remote-sensing snow sampling stakes. The degree of avalanche danger in the region of Petropavlovsk-Kamchatsky was investigated in detail, and in the section where the future Mutnovskaya geothermal electric power station will be built at a height of 800–1450 m, the geodetic snow sampling routes for instrumental measurements of snow storage were organized for the first time. Analysis of the available data makes it possible to comment on the extreme snowiness of this region as well as of the whole south-eastern Kamchatka. A list was prepared of national-economic objects of the Kamchatka oblast' situated in the avalanche zones and the Kamchatka avalanches cadastre for 1980–85 containing data on more than 1000 avalanches.

(MARI)

The conditions of avalanche formation were investigated along the Bailkal-Amur railway along the wing branch of the main line near Severoamursky tunnel, as well as the possible route of a power line from Ust'-Ilimsk to Severobajkal'sk. Expeditionary works on Sakhalin in the region of the railway from Yuzhno-Sakhalinsk to Kholmsk were undertaken in order to make the methods of forecasting dry avalanching more precise.

The regime-reference data banks "The Snow Cover in Mountains" and "Avalanches" were put into industrial operation. A lay-out and instructions for preparation of the scientifically-applied reference book *The snow cover in the USSR mountains* as well as instructions for estimation of the economic efficiency of snow-avalanche investigations during geological surveys were worked out.

(NIRT)

Instructions on protection of the railways in mountains against snow avalanches was prepared. Projects were developed and work carried out on the installation of snow retentive fences on several avalanche trigger slopes in the area of the Baikal-Amur railway, on Sakhalin, in the mountain regions of Shoria and Kirghizia. Experiments were carried out on modelling of avalanche impact on a fixed obstacle and the interaction of snow masses with snow-retentive constructions. The volumes of snow drift transports according to data from six meteorological station on Yamal were calculated. Suggestions on the uncovering of railway cuttings on the western Khazakhstan railway were studied, and experimental investigations carried out on the aerodynamical modelling of snow-retentive constructions.

(SBHEC)

The conditions of formation and distribution of avalanches on Sakhalin Island and the Kuril Islands were studied, and snow avalanche investigations carried out in the Vostotchno-Sakhalinsky mountains.

(The snow avalanche group of the Northern Baikal Department of the Baikal-Amur Railway)

Two zones of avalanche activity were singled out according to the conditions of snow accumulation on the Baikal'sky mountain ridge: the western one in the basin of the Kunerma river and the eastern one in the basin of the Goudzhekit river. Correspondingly in the these zones, 75 and 50 avalanche focuses threatening the railway bed were registered. Since at present increased avalanche activity is observed in this region, a programme of avalanche control measures along the railway bed has been proposed.

MAP-MAKING OF AVALANCHES, MUD FLOWS AND SNOW COVER
(IRIEC, SAMFPL)
Maps of avalanche and mud flow trigger territories of the USSR on a scale 1 : 8 000 000, with an economic estimate of the rise in the cost of construction, were compiled.

("Nature" UzSSR)
A map of Kirghizia and Uzbekistan avalanches using space images was compiled, thus making it more possible than with traditional methods to single out limits of avalanche zones, especially in the high mountain area. In Kirghizia the avalanche zones occupy 54.3% of the total area. A map of snow cover for these republics was compiled, showing the position of isolines for the average dates of formation and destruction of stable snow cover over many years, as well as defining the limits of the area of its irregular formation.

STABILITY OF SNOW SEQUENCE
(WSRI, MARI)
Collection of materials and checking of algorithm and adjustment of the programme "Stability of snow sequence" at the snow avalanche station Dukant were carried out. These works are being completed within the framework of integrated investigations of the conditions of avalanching on the experimental grounds of the western Tien Shan and the northern Caucasus, using an automatized information system. For forecasting avalanching, a model of solid body (thin layer approximation) and a model of viscous fluid (where the stability of snow sequence is considered as a stable snow-creep along a slope) were used. Using the basis of the telemetric sytem TM-90 "Lavina", it appeared possible to measure physical properties of snow sequence in a real time scale in many avalanche catchments.

(SAMFPL)
A short series of studies into the processes of water steam diffusion in snow were conducted in the laboratory. Methods were prepared and an installation for research into mass transfer made. The analysis of results showed that in most cases the existing data on diffusion mass transfer had been overstated by 3–5 times; the main factors in bringing about such errors were determined. A mathematical model of mass transfer in a stratified snow sequence was developed and a numerical realization of the model carried out, the results of which correspond to the natural observations. The possibility of using basic characteristics of snow — size and morphology of grains, parameters of their distribtuion, etc. — as indices of the extent of recrystallization of snow was analyzed; methods of qualitative assessment of the latter are being elaborated.

CHEMICAL MONITORING OF SNOW COVER
(PIG)
As a result of regular (since 1980) sampling of snow at key sections of Central Sikhote Alin'sky biospheric reserve, and chemical analysis of contents of heavy metals, sulphur and other pollutants, regional background levels were established, and the influence of atmospheric transfer from neighbouring countries and the contribution from local sources identified. Using the chemical composition of snow cover on the basis of the criteria elaborated (relative acidity, correlation between couples of elements having similar geochemical properties, concentration and mineralization exceeding background characteristics by 2–3 times, and so on), values of marginal concentration in the southern Priamur'e background regions not affected by the direct influence of economic activity, as well as zones of active industrial influence and domestic pollution of the underlying surface, were identified.

STUDIES OF SNOW OPTICAL PROPERTIES
(KazPI)
A more reliable method of measuring snow parameters (compared with the electro-capacity, optical one) has been worked out, based on the use of a laser radiator. Field investigations were carried out on the slopes of Zailijsky Alatau.

ENGINEERING GLACIOLOGY

SNOW DEFORMATION PROPERTIES
(IG AS)
The elaboration of methods of field investigations of snow cover deformation properties and a set of instruments were tested in the Arctic, the Antarctic, on the plains of the European part of the USSR and Siberia, and in mountains of moderate and great heights.

CALCULATION OF DEFORMATION AND MELTING OF ARTIFICIAL ICE
(IRIEC)
In connection with the creation of ice platforms on the Arctic Ocean Shelf for drilling, prospecting and operating boreholes, a method was developed for calculating the formation and melting of artificial ice made by drop spraying, layer-by-layer freezing and volumetric freezing. For these types of ice, methods were proposed for sampling, studying the composition, structure and physical and mechanical properties. These methods included the modification of traditional methods as well as new geophysical ones. This makes it possible to carry out non-destructive monitoring of ice conditions in the massif.

ICE PROPERTIES ON THE INTERFACE WITH OTHER MATERIALS
(IPTPN)
With the help of adhesiometers and tribometers developed at the Institute in the naturally cooled glacial basin, ice properties on the interface with materials having different surface energy were investigated for the purpose of creating a cryophobious coating for vessels sailing in Polar regions, aviation constructions and sea structures. The methods of evaluation of the cryophobious materials and coatings according to the adhesion of the interface ice areas were worked out.

THE DYNAMICS OF THE GLACIER MARGIN AFTER REMOVAL OF ITS PART
(Kaz SU, IG AS)
A self-similating solution of the problem of the dynamics of the glacier margin after artificial removal of a part of it was obtained. Investigation into concrete practical situations showed, among other things, that with the margin thickness being 50 m the average additional diffluence velocity during the first two years is 11 m/year and considerably exceeds the velocity of the natural glacial flow.

GLACIAL GEOLOGY AND PALAEOGLACIOLOGY

PALAEOCLIMATIC AND PALAEOCRYOGENIC CONDITIONS OF SIBERIA
(IG AS ESSR, MSU, IRIEC)
Isotopic analysis of subsurface ice of the Novosibirsk islands, and layer ice over a large territory of the northern part of western Siberia was carried out. It was ascertained that some deposits of such ice could be of glacial origin. These investigations make it possible to obtain more specific information about the dynamics of the western Siberian glaciation in the late Pleistocene.

ANCIENT GLACIATION OF THE ALTAI
(TSU, IG AS)
On the southern slope of the western Sayan, 70 samples were taken for radiocarbon and thermoluminescence dating of paleoglacial formations. In the Sagan-Uzun valley the study of profiles of ice-laid, river and lacustrine deposits were continued. Lichenometric survey of the moraines from the Little Ice Age was carried out.

INVESTIGATIONS OF GLACIAL FORMS OF RELIEF IN THE CAUCASUS
(IG AS GSSR)
Present-day and ancient rock glaciers in the Adishura river basin were studied. Analysis of their forms permitted six periods of rock glacier development in the Holocene to be singled out. Traces of ancient glaciation were investigated in the Mulhra river basin.

LICHENOMETRY OF ELBRUS
(MSU)
Lichenometric surveys of moraines and Holocene lavas on the northern slope of Elbrus were carried out. A glaciomorphological map of the periglacial zone of the northern slope of Elbrus on a scale 1 : 25 000 was compiled, and the limits of two stages of glaciation in the historical period were shown.

DENDROINDICATION OF GLACIOLOGICAL PROCESSES
(IG AS)
A lichenometric survey of the moraines of the northern and southern slopes of Terskei-Ala-Too, and the Akshijrak massif was fulfilled. Sampling for dendroclimatological analysis was carried out.

(KSU)
Equations of relationship between the growth of archa growing near the Shumsky glacier in Dzhungarsky Alatau and the firn line elevation of this glacier were worked out, which makes it possible to calculate the dynamics of the latter for the period of more than 400 years. The closely correlated relationship was also determined between the density of annual rings, wood microcomponents and meteorological indicators, specifically between chronium content in fir-tree rings on the western Caucasus and the annual precipitation. Test investigations of the annual rings of dwarf birch on Kamchatka showed the possibility of using the luminiscence properties of its wood for reconstruction of not only annual or seasonal temperature variations but also of interseasonal ones.

LITHOLOGICAL INVESTIGATION OF MORAINES
(IG AS)
Moraines of the Tien Shan and the Caucasus were investigated using lithological methods. The work aimed at study of the recent moraine accumulation and on this basis, reconstruction of the glaciological characteristics of the past.

RIVER ICE AND ICINGS

ZONING ACCORDING TO THE ICE REGIME OF THE KAZAKHSTAN RIVERS
(KazPI)
The basis of zoning was the spatial-correlation analysis of ice phenomena and the analysis of maps of distribution of characteristics of ice regime of the Kazakhstan water objects using the programme of pattern recognition according to dates of beginning of freezing, break up and clearing of rivers from ice, the maximum ice thickness, and meteorological elements of the coldest six months.

GLACIAL PHENOMENA ON THE RIVERS OF THE EASTERN SIBERIAN MOUNTAINS
(IG SD AS)
Regularities of the development of the channel snow-ice complex were studied from the moment of its formation in autumn until its complete destruction in spring. The machinery of formation of stream-flow components during the period of melting and destruction of ice were determined, methods of investigation worked out and water-physical properties determined of the characteristic flow surfaces in thawed and frozen states.

IMPACT OF SOLAR RADIATION ON THE DEVELOPMENT OF ICE PHENOMENA
(KazPI)
Using evidence from the rivers and water bodies of the Kazakhstan arid zone and the rivers of the Kara Sea basin, the impact of solar radiation on ice phenomena dynamics was investigated. The relationship between the ice cover surface albedo and calendar date, locality latitude and correlation between direct and diffuse solar radiation was determined. For calculation of ice cover thickness it was suggested that the average values of solar radiation for rated periods of time should be used. The limits of periods for which the error of calculation is permissible were determined.

GLACIOCHEMICAL PROCESSES IN WATER BODIES AND WATERCOURSES DURING ICE AND SNOW COVER FORMATION AND MELTING
(KhabCSRI)
The role of glaciological factors and processes in creating the chemical composition of the ice cover of big rivers (following the example of the Amur) was established. The autumn ice drift, bringing frazil ice and icing, form the structurally determined heterogeneity of the chemical composition of big ice massifs. Biogenic processes — lysis of cells, fermentative decomposition of organic matter, accompanied by the freezing of bog vegetation into ice — pertain to the basic factors of formation of biogenic and organic matters of bog ice, where their surplus arises as compared to the iceforming bog water.

MEASUREMENT OF ICE THICKNESS AND DENSITY BY ULTRASOUND
(KazPI)
The dependence of sound velocity and distribution within ice on the mechanical properties of the medium (which in their turn are functions of temperature, density, crystalline structure of cover and so on) was determined. As the result of improvements in the portable construction of an acoustic thickness gauge worked out for crystal ice, an instrument for stationary measurement of the ice thickness of any structure was created (the transmitter is situated at a known depth at a certain point). A new construction of a piezoceramic ultrasonic vibrator for acoustic ice thickness gauge was worked out.

ECOLOGICAL SIGNIFICANCE OF AUFEIS
(IG SD AS)
The dynamcis of vegetation cover on aufeis parts of river valleys in the central parts of the Vostotchny Sayany were investigated. Data on the effect of vegetaion on the processes of aufeis ice destruction were obtained. A package of hydrometeorological observations on the basic aufeis sites and profiles was fulfilled. Sections of model trees for mass dendrological analysis were chosen.

GLACIAL MUD FLOWS

Middle Asia Mountains
("Nature" UzSSR)
A map of mud flows in the territory of Kirghizia and Uzbekistan was compiled; four categories of mud flow trigger areas were singled out; the genesis of mud flows, watercourses and the streams flowing along them was shown; and mud flow control constrictions and objects situated in the mud flow zones mapped. The total area of the mud flow trigger areas of Kirghizia accounts for 82% of the republic's territory, and 12% of Uzbekistan's.

(IG AS KazSSR)
The conditions of disastrous mud flowing in Kazakhstan and the experience of its control were analyzed; and also mud flow danger of each basin in Zailijsky Alatau mountain ridge.

The Caucasus
(SAMFPL)
Field materials on the distribution, genesis and types of mud flow basins in the western Caucasus were collected, a catalogue of mud flow beds compiled, whilst an average scale (estimated) map of mud flow activity is being prepared.

SUBSURFACE ICE

GEOCRYOLOGICAL MAP-MAKING OF THE BAIKAL LAKE AREA
(IRIEC)
Geological and engineering-geocryological zoning maps on a scale 1 : 100 000 were compiled. On the first of them there are quantitative data on ice content of the upper rock horizon within the limits of genetic types of deposits, and off-scale signs of ice content reflecting its main qualitative characteristic properties. This way of presenting ice content on a map of such a scale is applied for the first time. Tables showing the occurrence of cryogenic phenomena within the limits of each region, with further subdivision into interstream areas and valleys, are attached to the map of engineering-geocryological zoning. The set of cryogenic phenomena comprises recent and relic reformed ice wedges, seasonal and

perennial frost mounds, and aufeis of subsurface and river waters.

REFORMED ICE WEDGES AND POLYGONAL STRUCTURES AT KOLYMA
(PIG)
The machinery of growth of reformed ice wedges and of formation of polygonal vein structures were investigated. Field work in the region of the Kolyma river lower flow, started in 1980, comprised the study of typical grounds and frost cracks. Two basic types of polygonal reformed wedge structures were identified: epigenetic (growth of ice veins begins and occurs simultaneously on the total massif of grounds) and syngenetic (ice veins are slowly accrued in synchronization with lateral movement of landscape borders, for instance, along river or lake banks). In the latter case features with a tetrogon pattern are formed.

THE ARCTIC

ICE SOUNDING
(IG AS)
On the basis of the analysis of results of air radio echo-sounding of the eastern ice field at the north-eastern land, a conclusion was reached about the occurrence of bottom melting in the major part of the marginal zone of the cover. This is of considerable significance for assessing of the dynamic stability and forecasting decline of its various parts.

ICE DRILLING
(IG AS)
As a result of the deep thermal drilling undertaken in 1987 in the central part of the eastern ice field, the occurrence of the inverse temperature gradient in the ice thickness up to the depth of 165 m was established, which testifies to the warming, increased melting and warming-up of the glacier sequence for the past 100–150 years. Signs of bottom-melting were found in the bottom glacier part, shown by subvertical channels in the 2 m layer of the friction-regelation ice. The similarity of deep structures and the nature of temperature distribution in the massif of ice domes of the eastern ice field at the north-eastern land, and the Akademii Nauk on the Severnaya Zemlya makes it possible to arrive at a conclusion about the synchronous climatic changes in various areas of the Eurasian Arctic for the previous centuries.

(IG AS and IG AS ESSR)
While deep drilling on the eastern ice field about 1500 core samples were taken for isotopic-geochemical analysis. In different areas of the archipelago sampling of buried ice and permafrost was carried out for the purpose of studying the machinery of isotopic composition formation of various types of ice.

(AARI)
Meteorological, actinometric and balance glaciological observations on the Vavilov glacier on Severnaya Zemlya continued. On the Akademii Nauk glacier the Leningrad Mountain Institute, together with IS AS, drilled a borehole 761 m deep and carried out core sampling, together with a petrostructural study of it.

GLACIER FLUCTUATIONS
(AARI)
Expeditionary glaciological, geomorphological, palaeographic investigations on Bennet Island (De-Long islands) were carried out; a geomorphological map was compiled. It was determined that glaciation of the island did not considerably change during the last 30–40 years. Geodetic measurements brought the following results: the outlet glacier of the Zapadny Zeberg moves at a velocity of 1 m/month, and the marginal part of the Toll ice dome — 0.08–0.18 m/month.

(IG AS)
On the basis of the analysis of measured and estimated values of accumulation, ablation and mass balance of various types of Spitsbergen glaciers conflicting trends in their present-day regime were established: there are glaciers on the archipelago with prevailing positive and negative mass balance simultaneously. It is caused by such factors as glacier morphology, altitude and sizes of area of their reservoirs, and orientation with respect to the prevailing directions of air streams.

THE ANTARCTIC

ICE DRILLING
(AARI and IG AS)
At the Vostok station the drilling of a new borehole and sampling started in 1986 were continued: the depth of the borehole was 1474 m on 1 December 1987. Geophysical investigations of the borehole were undertaken, as well as of the structure, density and general content of gas in the ice of some parts of the borehole which were studied for the second time. Sampling for isotopic, geochemical and gas analysis was carried out, and the analysis will be completed at AARI, IG AS and the Laboratory of Glaciology and Geophysics of the Environment for the French National Centre for Scientific Research. The results of the previous joint geochemical and isotopic investigations of ice core from a borehole at Vostok station were reported at the International Glaciological Society symposium on Ice-Core Analysis in Bern, Switzerland in April 1987, and at the General Assembly of the International Geodetic and Geophysical Union in Vancouver in August 1987. In the reports the climatic changes and carbon dioxide content in the atmosphere for the last 150 000 years were described.

Theroetical investigations of the relationship

between ice parameters and changes of climatic conditions continued. According to the results of investigation of the core from the Vostok station, an inverse correlation of middle size ice crystals and concentration of aerosol microparticles in it was determined, and this, in its turn, is caused by their concentration in the atmosphere at the moment of precipitation.

The analysis of three years of observations over expansion of core samples taken from a deep bore hole made it possible to identify machineries of relaxational compression and expansion of ice aggregates containing air bubbles and to specify the conditions under which air hydrates in deep glacier covers are formed. The data obtained were used in theoretical calculations of vertical profiles of density of an Antarctic glacier at different global climatic conditions.

Analytic work on investigation of oxygen isotope composition of an ice core from a borehole to a depth of 2200 m at Vostok station was finished, and provided new data on the thermal regime evolution of central Antarctica within the interval 150 000–185 000 years ago. Isotope investigations of the core of a borehole at Komsomol'skaya station made it possible to reconstruct the evolution of ice temperature and accumulation for the last 11 000 years; synchronism and the global character of climatic changes for the last 1 000 years were shown. Empirical relationship between temperature parameters of recrystallization ice and the average annual air temperature for central Antarctica was calculated. On this basis, palaeotemperatures of air for 10 000 years were reconstructed.

MATHEMATICAL MODELLING
(AARI)
Numerical realization of mathematical models of thermodynamic processes in the glacier cover of eastern Antarctica continued. The basic thermo- and hydrodynamic characteristics on the basis of separate sectors of glacier cover were calculated, taking into account its isothermal and relative ice movement characteristics. Diagrammatic maps of thermo-hydrodynamic fields within the strata of the glacier cover of eastern Antarctica were compiled. Theoretical investigations of the effects of climatic factors and changes of the world ocean level on the dynamics of Antarctic glacier cover continued.

RADIOPHYSICAL INVESTIGATIONS
(AARI)
Amplitude-spatial characteristics of radio echo sounding signals of centimetric wave band reflected by the glacier surface with different angles of sight were investigated at Molodezhnaya station on two polarizations. Airborne radio echo-sounding survey of side view in the centimetric wave band with high resolution was undertaken. On the route Mirny–Komsomol'skaya the ground under-satellite measurements of their own thermo-microwave variation of the glacier cover in centimetric and infra-red wave bands were carried out.

ENGINEERING GLACIOLOGY
(AARI)
On the basis of the physical investigations carried out in the area of the airfield at Molodezhnaya station, the main characteristic properties of stratigraphy, heat and radiation regime of the horizons of artificially compacted snow–firn sequence, and the effect upon the strength properties of the runway were identified. Recommendations on improvement of construction of snow runways, technology of their develeopment and methods of control over runways for the purpose of extending the time of their use were worked out, and are being introduced. At Molodezhnaya station an experimental ice wharf was carried on by formation of ice by sea water freezing, applying the method of jet-like watering. The monolith, created in winter and measuring 200 × 20 m was put on the bottom of Opasnaya bay to a depth of 18 m; after the break-up of the fast ice it disintegrated.

ICEBERG TRANSPORTATION
(IG AS)
Investigation of scientific-engineering aspects of iceberg transportation from the polar regions as a source of fresh water and cold made it possible to suggest and prove the possibility of transportation of fresh water river ice from big rivers (for example, the Amur) for a distance of 500–700 km.

THE STUDY OF SHELF ICE
(IG AS)
Data were summarized on hydrodynamics and thermics of the lower surface of shelf ice and water of subglacial seas, as well as the processes at the grounding line of shelf ice.

INTERACTION BETWEEN CRYOSPHERE AND ATMOSPHERE AND THE OCEAN
(AARI)
Qualitative and quantitative characteristics of zonality of heat and moisture distribution in Antarctica, radiation balance of the surface of the glacial cover of the Antarctic, atmosphere over it and the system "surface–atmosphere", air circulation and hydrological cycle in atmosphere were worked out. In the region of Mirny station observations continued over the chemical composition of precipitation. Their marine origin during the whole year with defined seasonal change is confirmed, with minimum concentrations of ions in winter and stable maximum in summer.

GLACIAL GEOLOGY AND GEOMORPHOLOGY
(IG AS)
According to the data from geochemical analysis, the notion about the palaeogeographic situation of the Antarctic early glaciation was made more exact, characteristic properties of hydrology and palaeohydrology of periglacial water bodies were identified. Specifically, it

was determined that biogenic sediments found on the bank of River lake in the Prince Charles Mountains were formed in the early Micoene. During their sedimentation glaciation occurred at the marks close to sea level. Surface waters near the coast were warmer than today by 5–7 °C.

(AARI)
In the Bunger oasis in Eastern Antarctica geomorphological and palaeoglaciological investigations for the purpose of reconstruction of the main stages of its development were undertaken; a geomorphological map was compiled. It was found that the basic relief features of the oasis are caused by the tectonic structure of the land and not by glacial activity. In the late Holocene history of the oasis, the glacier-dammed fresh water basins played a considerable role. Spatial regularities of the last deglaciation were determined. It was also determined that the youngest parts of the oasis, free of ice, are situated not along the glacier margin, but in the centre of the land investigated.

UK

DYNAMICS OF THE WEST ANTARCTIC ICE SHEET

(Chris Doake, David Vaughan, Rock Frolich, Adrian Jenkins, and David Mantripp, British Antarctic Survey)
The West Antarctic Ice Sheet has been identified as an area likely to respond significantly to a change in global climate. Ice flowing from inland ice sheets, grounded on rock well below sea level, converges to form several fast flowing ice streams. These drain into large ice shelves which restrain the discharge of ice into the ocean. BAS glaciologists have been studying one of the major outlet glaciers, Rutford Ice Stream, and its subsequent progress along a flowline across Ronne Ice Shelf. Surface measurements of elevation, velocity, ice thickness, temperature and accumulation have been analysed to give preliminary results, showing that in parts of the ice stream basal drag is as important as shear from the sides in helping to balance the gravitational driving force. On the ice shelf, there appears to be strong basal melting where the glacier begins to float in the sea (the grounding region) and near the ice front. In the more central parts, small amounts of saline ice may be freezing on underneath. An unexpected discovery was made from the comparison of satellite images taken 13 years apart (Landsat in 1974 and SPOT in 1987). An area of strong surface undulations near the grounding region of Rutford Ice Stream was seen to have moved at the same rate as the measured surface velocity. The nature and origin of this undulatory region are being investigated, but it seems that these features are just one of several indicators that conditions on the ice sheet are changing on time scales of up to hundreds of years.

HEAVY METAL EMISSIONS FROM HUMAN ACTIVITY IN ANTARCTICA

(Eric Wolff, British Antarctic Survey, with Claude Boutron, Laboratoire de Glaciologie, Grenoble)
The polar ice sheets provide a unique laboratory for studying background levels of global pollutants such as the heavy metals. The composition of modern snow indicates the extent of human impact, while ancient ice can be used to elucidate the natural sources. Very low (pg/g) concentrations of heavy metals have been found in modern polar snow in recent years. This has led to worries that a significant proportion of the metals might originate within Antarctica, so an inventory of heavy metal emissions from human activity in Antarctica has been produced. The major emission sources are fuel and waste burning from Antarctic stations and vehicles. It has been possible to estimate approximately the amounts of metal emitted for each base, and for the whole of Antarctica. For lead, these emissions, particularly from piston-engined aircraft, are of greater magnitude than the entire natural fallout to the continent in previous centuries. This could obscure the record of global pollution that is potentially available for this metal. For other metals, it seems that emissions from within Antarctica can be important only in very local areas. Data from samples currently under study at BAS can now be interpreted with greater confidence

ICE CORES AND CLIMATE

(David Peel and Brian Davison, British Antarctic Survey)
Trends in climate affecting the West Antarctic ice sheet may be detected first in the Antarctic Peninsula region. Time series of air temperature and snow accumulation in the area over the past 50 years have been derived from stable isotope analysis of two ice cores. These were drilled in areas representing the principal climatic extremes encountered in the region. Mainly due to the high snow accumulation rate, the time series can be resolved in much greater detail than is possible elsewhere on the continent. Data averaged over periods as short as 5 years are sensitive to climatic shifts much smaller than trends that have actually occurred during the past 50 years.

The most notable trend is an increase of more than 30% in the snow accumulation rate that has occurred in parallel with an overall temperature increase of 0.06 °C/a. Increases of similar magnitude can be inferred from

less direct studies in East Antarctica, and may be related to a significant increase in precipitation rate that has been documented recently at mid to high latitude stations in the Northern Hemisphere. Evidently more extensive accumulation series must now be obtained in Antarctica as a basis for modelling the long-term balance of the ice sheet.

ICE CORES AND REMOTE SENSING

(John Moore, Robert Mulvaney, Andy Reid and Julian Paren, British Antarctic Survey)

Ice is nearly transparent to radio waves and this allows aircraft to sound thick polar ice sheets to reveal the thickness of the ice cover and some details of the bedrock beneath. The thinnest coastal ice is often the most difficult to penetrate. BAS research now fully explains why this is so. The evidence comes from the physical and chemical stratigraphy of a 133 m long ice core from Dolleman Island, bordering the Weddell Sea. A comparison between the AC electrical stratigraphy and the chemical record demonstrates an exceptionally strong interdependence; both salts and acids increase radio wave absorption, whilst salts alone affect the dielectric relaxation process. In coastal sites the sea salts predominate, leading to much higher radio wave absorption than would be expected on the basis of temperature alone. The form of the dielectric reaponse allows us to deduce both the salt and acid concentrations in ice cores by a fast electrical method. Since the technique requires no contact with the frozen ice core, the core remains in pristine condition for later chemical analysis. This exciting development will speed up the analysis of long ice cores, highlighting in the field, at the time of drilling, sections of the core of particular climatic interest.

ICE SHELF/OCEAN INTERACTION

The ocean circulation under the southern end of George VI Ice Shelf is largely unknown, as is the interaction between the basal ice and the sea-water.

As part of a programme to understand the ice dynamics and ice/ocean interactions in this region, two boreholes were drilled through the shelf using the BAS hot-water drill, one through 170 m and the other through 250 m of ice. Prior to the deployment of a salinity/temperature probe, a borehole caliper was used to determine the rate at which the hole was refreezing. Cables with thermistors distributed along their length were left in the boreholes to freeze into the ice shelf. The temperatures are being recorded every few hours by data-loggers which will be retrieved next season; the data will provide direct measurements of the basal melt-rate for a cold ice shelf. In the past, oceanographic work from ice shelves has been confined to either the ice-edge or natural openings such as polynyas, leads or rifts. This season was the first in which BAS has been able to retrieve oceanographic data from beneath an undisturbed area of shelf, and will allow a comparison with data retrieved from a nearby rift.

In addition to the oceanographic work strain rosettes were placed along a flow-line. This sequence of rosettes will provide ice-velocity, ice-deformation, and snow accumulaiton information, essential to a better understanding of the dynamics of the shelf and its interaction with the ocean beneath. Meanwhile in the north of George VI Ice Shelf, 3 sites were revisited where thermistor cables had been installed through the ice shelf in previous years, and a similar programme of dynamical studies was undertaken.

LOCATION OF IMPURITIES IN POLAR ICE CORES

(Robert Mulvaney and Eric Wolff, British Antarctic Survey, with Dr K. Oates, Institute of Environmental and Biological Sciences, University of Lancaster)

Ice cores at liquid nitrogen temperatures are examined on a scanning electron microscope fitted with an X-ray micranalysis facility, so that the location of individual elements can be studied. The studies confirm that sulphuric acid is located at the triple-junctions, the places where three grains meet, and that the acids are so highly concentrated at these places that they would remain liquid even at Antarctic temperatures. Sea salt appears not to be localized in this way. These findings are important to our understanding of the chemical processes that affect aerosol in the atmosphere and snowpack, and may be relevant to studies of the "acid flush" events that occur in temperate snowpacks each spring, causing ecological damage in streams and lakes.

RADIO-ECHO SOUNDING ON RONNE ICE SHELF

(David Mantripp and Hugh Corr, British Antarctic Survey)

D.R. Mantripp carried out 35 hours of airborne radio echo sounding over the Ronne Ice Shelf. Following modifications to the radar equipment by H.F.J. Corr, an improvement in system performance was achieved. The field programme was cut short because of turbulence damage sustained by the aircraft in bad weather. This season saw the experimental introduction of the Global Positioning System (GPS) satellite receiver which should allow greatly improved accuracy in the recording of aircraft position, thus allowing small-scale features to be investigated by means of airborne surveying.

BEHAVIOUR OF THE LAST EUROPEAN ICE SHEET INFERRED FROM GLACIAL GEOLOGICAL EVIDENCE

(Chris Clark and Geoffrey Boulton, Grant Institute of Geology, University of Edinburgh)

Satellite imagery provides an excellent tool for a study on an ice sheet-wide scale of the glacial geology and geomorphology of the last great ice sheets. Detailed mapping of all

visible lineations resulting from the Laurentide ice sheet in Canada has been made using LANDSAT imagery. This has revealed many cross-cutting lineations beneath the direction of last ice movement; even as many as four ice directions can be distinguished. Evidently the Keewatin ice divide had undergone considerable movement, and was far from spatially stable during the Wisconsin. Theoretical considerations on how an ice divide moves and the geological patterns it produces are under way.

HYDROLOGICAL CONTEXT AND GEOMORPHIC SIGNIFICANCE OF SHORT-TERM MOTION EVENTS IN GLACIERS

(Mike Sharp, K.S. Richards and I.C. Willis, Department of Geography, University of Cambridge, and J. Campbell Gemmel, Christchurch, University of Oxford)

Research was conducted at Midtdalsbreen. an outlet of the Hardangerjokulen ice cap in southern Norway, between June and September 1987. Measurements of rainfall and ablation rates and dye tracing experiments were used to investigate seasonal and weather-related changes in the pattern of water yield and flow routing through the glacier, and to identify periods when water was entering and leaving subglacial storage. The motion of the glacier was monitored and short term (less than one day) accelerations in glacier speed (assumed to be periods of enhanced basal sliding) were identified. The pattern of suspended sediment yield from the glacier was monitored and can be evaluated in terms of its relationship to short term water discharge fluctuations, changes in flow routing through the glacier and the occurrence of glacier motion events.

RADIO TECHNIQUES FOR GLACIER EXPLORATION

(Mike Walford, Department of Physics, University of Bristol, Mike Kennett, NVE, Oslo)

During July/August 1987 a radio-echo synthetic aperture experiment was successfully carried out, at Jostdalsbreen in Norway. A polarization impulse sounder was used. The data are to be analysed to produce a detailed map of the glacier bed, in the vicinity of a recent borehole, which shows the bedrock geometry and the distribution of radio reflectivity. The hope is to infer the distribution of water and/or saturated sediments at the glacier bed.

During the same field trip Mike Walford carried out further trials of underwater radio transmitters and receivers. (Earlier success is reported in *J. Glaciol.*, 33(114), 239-242.) They were successfully used to transmit radio signals over distances of up to 100 m in a turbulent proglacial river. Clearly the low conductivity and high dielectric constant of glacial water means that englacial waterways may make good radio waveguides. Working with NVE we hope to develop this observation and produce a useful new set of techniques for exploring and monitoring water in glaciers.

ROCK GLACIER INVESTIGATIONS

(Brian Whalley and H.E. Martin, Geography Department, Queen's University, Belfast)

An investigation of the formation and dynamics of small corrie glaciers and associated moraines and rock glaciers is being carried out at Trölaskagi in north Iceland.

Surveys of the Nautadalur rock glacier have been completed and these are being compared with aerial photographs from 1946 and 1963. Little change has been found except for some modification of the snout. The maximum rock glacier velocity is *ca* 25 cm a^{-1} (from eight years of observations) but the corrie glacier associated with the rock glacier has velocities also of this order. Structural evidence suggests that ice of glacier is now effectively decoupled from remnant glacier ice in the rock glacier.

ROCK GLACIER INVESTIGATIONS, WRANGELL MOUNTAINS, ALASKA

(Brian Whalley, Queen's University, Belfast, J.E. Gordon, Nature Conservancy Council, Peterborough)

The aim is to provide flow data from a variety of rock glaciers in a permafrost area with classic features. Comparisons will be made with long-term photographic evidence from *ca.* 1909. Visits are planned every two years to allow re-survey and continue geo-physical investigations.

This project was initiated in the summer of 1988 with the aid of groups from Operation Raleigh. Initial traverse lines and surveying were carried out on two rock glaciers above Kennicott. Other rock glaciers in the area were visited on an exploratory basis. Ice radar investigations were undertaken on rock glaciers and the investigations were extended to Kennicott glacier to look at ice wastage under debris of varying thickness.

SUBGLACIAL DRAINAGE SYSTEM OF THE GLACIER DE TSANFLEURON

(Mike Sharp, Department of Geography, University of Cambridge, J. Campbell Gemmell, Christchurch, University of Oxford, and Jean-Louis Tison, Laboratoire de Géomorphologie, Université Libre de Bruxelles, Belgium)

The project involves: (1) Field mapping of channel-cavity systems exposed on proglacial bedrock for analysis of their network properties and cavity storage capacities; (2) Detailed surveying of bedrock topography for analysis of relationships between cavity geometry and the morphology of bedrock bumps; (3) isotopic and geochemical analysis of subglacially-precipitated calcites from different parts of the drainage system for matching with possible source waters.

Mapping suggests a two-component drainage system of (a) linked step-cavities and Nye channels, and (b) a film/wave-cavity system. Nye channels apparently experience periodic

invasions by basal ice, during which they become part of the film/wave-cavity system. Two distinctive types of calcite are recognised: (a) Macrocrystalline calcite is calcium-rich, has spicular crystals aligned with ice flow, and forms in equilibrium with source waters isotopically less negative than any known source. It is believed to form by slow freezing from waters which have been progressively fractionated in the regelation process. (b) Microcrystalline calcites are magnesium rich, include clasts of non-calcite materials, and are 2.5% less positive ($\delta^{18}O$) than macrites. They are believed to form by more rapid freezing near the glacier margin where cold air can penetrate subglacial cavities. Source waters could be derived from either glacier ice or floor ice in cavities.

SUBGLACIAL GLACIOTECTONIC DEFORMATION

(Jane Hart, Environmental Sciences, University of East Anglia and Geoffrey Boulton, Grant Institute of Geology, University of Edinburgh)
Studies of subglacial glaciotectonic deformation have been made in Cora Island, Spitzbergen and in sediments in north-east Norfolk. The principal aim has been to interpret the glacial geology of north-east Norfolk.

THE ORDERED PHASE OF ICE Ih (ICE XI)

(Rachel Howe and Robert Whitworth, School of Physics and Space Research, University of Birmingham)
The transition from Ice Ih to Ice XI in which the protons become ordered, which occurs in KOH-doped ice after annealling below 72 K, is being studied by dielectric measurements and also by neutron diffraction at the Rutherford Appleton Laboratory. A cryostat has been built to provide access to the relevant temperature range. A system for computerised pulse measurements of dielectric properties has been developed, which reveal progressive changes as annealling proceeds below the 72 K temperature, and the dependence on dopant concentrations of the dielectric parameters. The structure of Ice XI has been confirmed as $Cmc2_1$.

ICE CORE DRILLING IN SPITZBERGEN

(Jefferson Simoes, Scott Polar Research Institute, Cambridge)
A shallow ice core recovered from Central Spitzbergen has been examined for climatological information, to study how post-depositional processes, such as melting, percolation and evaporation, have affected the initial environmental record.

ICE MECHANICS – RISK TO OFFSHORE STRUCTURES

(T.J.O. Sanderson, BP Petroleum Development Limited, London EC2Y 9BU)
Sea ice and iceberg forces on offshore structures have been analysed and measured. *Ice mechanics: risks to offshore structures* was recently published (London, Graham and Trotman, 1988). A paper presented at the IAHR Symposium in Sapporo highlighted the extent to which engineers disagree on the magnitude of the forces involved in the interaction between pack or icebergs with offshore installations.

OBSERVATIONS ON WATER VEINS IN POLYCRYSTALLINE ICE

(Heidy Mader, John Nye and Mike Walford, Department of Physics, University of Bristol)
Experiments are in progress on intercrystalline veins in laboratory-grown ice samples in order to understand better the thermodynamics of glaciers. The immediate object is to study what determines the size of the veins and their impurity content. Preliminary results indicate that the impurity content in the veins is of the order 10^{-2} to 10^{-3} mol l^{-1} for veins around 10 μm across.

PROBING ENGLACIAL WATER CHANNELS

(Mike Walford, A.R. Proctor, Department of Physics, University of Bristol, Mike Kennett, NVE, Oslo)
The objective is to discover the geometry of major englacial channels by releasing a transmitting probe into an active stream and receiving the signals at the surface of the glacier. Radio and acoustic probes have been built and have been tested in Storglaciären, Sweden. The radio transmitters were very promising and will be developed further in the year.

RADIO ECHO-SOUNDING STUDIES IN SVALBARD

(Jonathan Bamber, Scott Polar Research Institute, Cambridge, David Drewry, British Antarctic Survey, Julian Dowdeswell, University College of Wales, Aberystwyth)
Radio echo-sounding data collected during 1983 and 1986 from glaciers in Central Spitzbergen, Edgeøya, Barentsøya and Vestfonna have been analysed. Interpretation of returned power strengths has provided information on the bulk dielectric properties of the ice and characteristics of the ice/bed interface. A study of the small ice cap, Kvitøya, N.E. Svalbard has indicated a regional trend in dielectric absorption, and is potentially linked to anthropogenic impurities.

STUDY OF BED ROUGHNESS AND ICE-BEDROCK CONTACT

(Valerie Haynes, Department of Environmental Studies, University of Stirling)
Detailed measurements of bed roughness and ice/bedrock contact are being made at different spatial scales in areas of recent deglaciation, where previous glaciological activity is known. Nigårdsbreen in Norway has been the focus of the fieldwork and the observations will be compared with other areas of different proglacial geology and different glacier sliding velocities and hydrological patterns.

HAZARD ASSESSMENT IN THE CORDILLERA BLANCA, PERU

(John Reynolds, Department of Geological Sciences, Plymouth Polytechnic; Cesar Portocarrero, Alcides Ames, Marcos Zapata, Hidrandina S.A., Haurez, Peru; Georg Kaser, Institut fur Geographie, Innsbruck, Austria)

In conjunction with Hidrandina S.A., an assessment of the safety of the glacier lakes, moraine complexes and the glaciers themselves is being undertaken for two reasons. One is to protect life down-valley of identified hazards and the other is to provide safe reservoirs of water for possible use in the generation of electricity. The project includes the routine monitoring of the margins and the use of geophysical methods in the exploration of glacier/moraine complexes, and the establishment of mass and energy balance/measurements on several key glaciers.

Two seasons of field work have been completed and several key sites have been identified for more detailed investigation. Hatunraju, a prominent glacier embedded within a 200 m thick moraine, dams Laguna Paron. Geo-electrical measurements made at the base of the moraine have helped determine the deeper structure of moraine and its stability with respect to the lake. In Hulacan, a particularly dangerous proglacial lake was studied and consequently urgent remedial work is underway.

GEOPHYSICAL INVESTIGATION OF BURIED ROCK VALLEYS IN PLYMOUTH SOUND, S.W. ENGLAND

(John Reynolds, M.B. Hait, D.H. Tarling, R. Eddies, A. Eddles, F. Fitzpatrick, Department of Geological Sciences, Plymouth Polytechnic)

A systematic survey of Plymouth Sound, the River Tamar and major tributaries is being undertaken using high-resolution single channel seismic-reflection profiling with side-scan sonar. A series of rested buried channels has been identified in filling a 35–40 m deep rock valley. The very detailed seismic sections have revealed information about sea-level changes since about 15–18 000 yrs B.P. The project aims at producing information about the fluctuations in sea-level and the consequent estuarine environments since the end of the last major glaciation.

Following the identification of clear and distinctive stratigraphy from the seismic sections, two boreholes were drilled from a commercial jack-up rig with the recovery of more than 50 m of core material. The material has been sub-sampled and micro-palaeontological and geochemical analyses are currently being undertaken. Preliminary analysis suggests that it should be possible to construct a detailed model of the spatial and temporal development of Plymouth Sound from the Holocene.

DISLOCATION DYNAMICS IN ICE

(Robert Whitworth and Christopher Shearwood, School of Physics and Space Research, University of Birmingham)

Dislocations have been studied by synchotron radiation X-ray topography at the Daresbury Laboratory. Dislocation motion has been observed under stress in the very early stages of deformation. There is particular interest in the fast movement of edge (but not screw) segments on non-basal planes. This is responsible for much of the dislocation multiplication that has to occur before basal glide can proceed.

FREEZING FRONT PENETRATION

(Leslie Morland and Robert Kelly, School of Mathematics, University of East Anglia)

The propagation of a freezing front through a water-saturated soil is being studied theoretically. Initially the surface is at the freezing point and is then cooled, with a geothermal heat flux present at an impervious base. The analysis is one-dimensional, and is based on mixture theory with phase changes. Numerical tests to the model are being examined.

Submitted by J.C. Paren

USA

U.S. CONTRIBUTIONS TO THE STUDY OF ICE IN THE SEA: 1936–86

by W.F. Weeks and G. Weller, Geophysical Institute, University of Alaska–Fairbanks, Fairbanks, AK 99775-0800, U.S.A.

Note: This contribution should be read as an extension of the article by E. Lyn Lewis in *Journal of Glaciology Special Issue* 1987, published to mark the 50th anniversary of the International Glaciological Society. (The issue summarized progress of research in the various aspects of snow and ice studies in the period 1936–86.)

The original invited contributor for sea ice research had been unable to complete the task and E. Lyn Lewis nobly agreed to provide an article for that issue by summarizing the short contributions which had been solicited from research workers in several countries. From those contributions, he produced an article which conformed to the limits set for each subject in the *Special Issue*. We were grateful to him for rescuing the situation. We gladly now provide an opportunity for an enlargement of the necessarily much shortened U.S. section.

Ed.

In these few words we can give only the most general overview of the varied

contributions to the study of ice in the sea published by U.S. investigators during the last 50 years. We would like to start by adding to the impression that sea icers rarely follow orders by listing a few papers by our predecessors that largely predate 1936. Moreoever, these were written by non-U.S. authors, but they are papers that are worth reading from both a historical and a technical viewpoint: Weyprecht (1879) for observations on pressure ridges, Hertz (1884) whose contemplations of walking home over the frozen Danube would lead one to conclude that "the kid might amount to something", Nansen (1900) on ice drift, Malmgren (1937) on the properties of sea ice, Zubov (1945) for a masterly discussion of arctic ice, and finally Zukreigel (1935) on the history of sea ice studies, a subject that "has to be studied far away in the north or south, in white deserts of ice, where there is nothing, nothing else, no shelter, no help; and where, on those vast plains in which the chasms of the sea keep tearing open and unsurmountable obstacles in the shape of mountains of ice keep piling up, the Lord only is with man". (If we had read Zukriegel before starting to study sea ice, we clearly would have chosen some other subject, such as the beach morphology of tropical atolls.) Now to business. The primary set of basic references on the geophysics of sea ice can be found in the papers assembled by Untersteiner (1986) in a very weighty tome. Most of the contributors and contributions that we will mention can be tracked down in one of the reference lists in that volume. To avoid a vast reference list at the end of this paper, we will leave this detective job to the reader. The papers that we will reference in our bibliography will be either recent or of a review nature.

Sea ice research conducted by U.S. investigators has primarily been carried out in the Arctic. The reasons for this are clear. Access to U.S. and Canadian coastal sites was relatively easy. On the other hand, access to Arctic pack ice sites was more difficult and access to Antarctic pack ice sites was next to nonexistent, only recently reaching a level that could be described as sporadic. In general, research activity since 1955 has ben relatively low but continuous with occasional major bursts associated with logistic opportunities, many of which were necessitated by applied problems. Specific examples of such bursts start with the Joint Services Sea Ice Physics Program (1955–60) which operated in Labrador and Greenland and laid the groundwork for subsequent studies of ice properties and bearing capacity. This was followed by drift station Alpha during the IGY (1957–58) when studies of heat and mass balance and ice structure were undertaken, the T-3 and ARLIS stations, and finally the joint U.S.-Canadian Arctic Ice Dynamics Joint Experiment (AIDJEX, 1971–76) which brought major scientific resources to bear on advancing our understanding of ice dynamics. More recently extensive research has been conducted relating to environmental and engineering problems associated with exploration for offshore oil in the high Arctic. These have taken the form of major direct industry efforts as well as a variety of governmental efforts, the most important of which has been the Outer Continental Shelf Environmental Assessment Program (OCSEAP). The most important current program is the Marginal Ice Zone Experiment (MIZEX) which, as its name indicates, has focused on exploring the geophysics of the pack ice – open ocean boundary region. Experiments under this program have been carried out in both the Bering and the Greenland Sea areas (Muench, 1983). In the Antarctic, sea ice research has been confined to a few coastal and shipboard studies, including the joint cruises with the Soviets on the *Somov* and with the West Germans on the *Polarstern*. Satellite remote sensing of sea ice in both polar regions has also steadily increased in importance over the years.

Now to a more detailed consideration of specific contributors and contributions.

PHYSICAL PROPERTIES

The relationship between the sea ice phase diagram, the internal structure of the ice crystals and the bulk properties of the ice have been worked out, and verified on the basis of chemical studies by Nelson and Thompson, by Anderson, Assur and Weeks in a series of papers published between 1958 and 1964. Other important papers were by Ackley and Gow (Antarctic frazil ice), Lofgren and Weeks (substructure) and Weeks and Gow (crystal alignments). Studies leading to an understanding of the salinity profile and brine drainage mechanisms have been contributed by Bennington, Cox, Lofgren, Martin, Untersteiner and Weeks, and have recently led to realistic numerical simulations of salinity and brine volume profiles based on past meteorological conditions (Cox and Weeks, 1988).

A large number of U.S. investigators have studied the mechanical properties of sea ice. These include Assur, Butkovich, Cox, Dykins, Frankenstein, Kovacs, Mellor, Peyton, Richter-Menge, Sunder, Vaudrey, Wang and Weeks. Comprehensive discussions of these varied studies can be found in a series of reviews published by Weeks with Assur (1968, 1972), with Cox (1984), with Mellor (1983) and with Schwarz (1977). Work on thermal properties was initiated by the model calculations of Anderson which ultimately led to the more detailed models of Schwerdtfeger and Ono. A very useful review of this general subject has recently been published by Yen (1981). A varied set of excellent measurements and analysis of the optical properties of sea ice have been completed by Grenfell, Maykut and Perovich, and finally the electrical properties of sea ice have been explored by Cox, Hoekstra, Kovacs, Morey, Stogryn and Wentworth.

THERMODYNAMICS AND ENERGY BALANCE

This subject has received continuous attention for a variety of reasons, ranging from the practical to the esoteric. Important contributions to this field have been published by Ackley, Andreas, Badgley, Bilello and Bates, Fletcher, Hanson, Katsargs, Martin, Maykut, Lee and Simpson, Parkinson, Semtner, Untersteiner, Weller and Wittmann. Particularly useful efforts have been Fletcher's (1965, 1969) early studies of how the energy balance of both polar regions is affected by sea ice. Also of special merit are the Maykut (1978) and Maykut and Untersteiner (1971) papers on the growth and thermal aspects of young sea ice and of multiyear ice.

Recently the problem of how sea ice affects climate (or vice versa) has again become a matter of considerable scientific interest. Initial attention to this subject was the result of the famous Ewing-Donn (1956) hypothesis of an ice-free Arctic Ocean. This speculation, although now known to be incorrect as an overall generalization, nevertheless contained elements that have proven to be quite correct. More recent studies of the effects of sea ice extent and distribution on atmospheric circulation and vice versa have been carried out by Herman and Johnson, Walsh, Carlton, Barry and others. Sea ice amplifies the climatic changes due to the CO_2 "greenhouse" effect through feedback processes, which have been modeled by many including Manabe and others, and Washington and others, and have best been described by Parkinson and Kellogg, and by Barry (1984).

EXTENT AND MORPHOLOGY

A great deal of attention has been paid to this general area as its applicability to offshore operations and engineering design is obvious. The CRREL group (Ackley, Hibler, Kovacs, Mock, Tucker and Weeks) has been particularly active here, investigating varied aspects of the pressure ridging phenomenon. Also of importance are the Parmeter and Coon studies of the fundamental mechanics of rafting and ridging, Stringer's observations of the distribution of ridging and floe sizes along the Alaskan coast, and Le Shacks and Garret and Bourkes compilations of the sonar profiling results of a few of the many submarine cruises that have been carried out beneath the polar pack.

Any discussion of extent and morphology leads one to remote sensing, which is a very large subject indeed. We will just list a few of the more important workers beside the particular technique they have most frequently employed:

visual and infrared – Ahlnaes, Barnes and Bowley, Barry, Dey, Hall, McClain, Pulin, Stringer

passive microwave – Campbell, Carsey, Cavalieri, Comiso, Gloersen, Martin, Parkinson, Ramseier, Swift, Wilheit, Zwally

radar altimetery – Bindschadler, Zwally

imaging radar – Carsey, Elachi, Moore, Onstott, Rothrock, Shuchman

laser profilometry – Hibler, Tucker, Weeks

Of particular interest is the Zwally and others (1983) atlas of Antarctic passive microwave imagery, and Comiso's (1986) studies showing the many complexities of passive microwave data sets. A useful general reference to the results of recent microwave studies is Swift and others (1985). To close this section with an advertisement, we believe that the impending launch of the SAR system on ESA's ERS-1 satellite in 1990 will herald a decade of detailed sea ice studies that will greatly expand our understanding of pack ice behavior.

SEA ICE DYNAMICS

With the increase in the capabilities of computers, numerical modeling has become a major tool in science. This trend has also been strongly developed in sea ice studies with the recent growth of a variety of ice dynamics and coupled air-ice-ocean models. Sea ice modeling in the U.S. was initiated by Reed and Campbell (1962) and Campbell (1965) and developed further during AIDJEX (Pritchard, *ed.*, 1980). Major contributors to this development were Colony, Coon, Hibler, Parkinson, Pritchard, Rothrock, Semtner, Thorndike and Washington. An ice dynamics model that is currently under testing for operational applications was developed by Hibler (1979), who built upon concepts produced by AIDJEX. Perhaps the most important of these concepts is that the ice thickness distribution is the major parameter describing pack ice response to a specific applied stress (Thorndike and others, 1975). Recent efforts have focused on coupling a fully developed ice dynamics model to a multilevel ocean model. The preliminary results of this mating are just beginning to be published (Hibler and Bryan, 1987) and are extremely encouraging. It should also be noted that efforts are underway to modify existing models to enable them to accept remote sensing observations.

Coincident with recent advances in modeling has been the development of the increasingly sophisticated data buoy technology required to provide the environmental information needed to both drive and verify the models. Several recent papers describing the use of buoy movement data include those of Thorndike and Colony (1982) and Colony and Thorndike (1984, 1985).

PRACTICAL PROBLEMS

As mentioned, sea ice is invariably a headache for individuals and companies involved in offshore operations in the Arctic. Some important problem areas and the U.S. workers that have made significant

contributions to solving these problems include:

bearing capacity – Assur, Kerr, Nevel

ice forces – Blenkarn, Cox, Edwards, Gerwick, Kreider, Johnson, Ralston, Sodhi, Sunder, Wheeler, Vivatrat

ice gouging in the sea floor – Barnes, Reimnitz, Weeks

icebergs – Campbell, Mellor, Weeks

ice breakers – Edwards, Lewis

Of particular interest are the papers by Kreider and Vivatrat (1983), Ralston (1980), Wheeler (1981), several papers included in Barnes and others (1984), the overall discussions found in Ashton (1986) and in Coon and others (1981), and last the "science fiction" of Weeks and Campbell (1973) that renewed interest in icebergs.

In closing we would like to note that we have found preparing this brief paper to be difficult. There are two reasons for this. *First* is our inability to do justice to the many contributions that should be specifically discussed as having had a major effect on the thinking in this field. We have not even been able to refer to all of our own publications which, we assure the reader, are unspeakably profound (or at least unspeakable). *Second*, we do not think nationally. Sea ice knows no boundaries. It has never heard of the pie theory of the Arctic or the 200 mile limit. It is here today and somewhere else tomorrow. Sea ice programs are invariably populated by polyglot assortments of individuals from different corners of the world and with vastly different technical backgrounds. Much of the strength of the subject comes from this diversity. May this continue.

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SAR REMOTE SENSING OF LABRADOR SEA ICE DYNAMICS

(Mark R. Drinkwater, Jet Propulsion Laboratory, Pasadena, CA)

During the Labrador Sea Ice Margin Experiment (MIZEX) in March/April 1987, the first airborne C-band digital SAR data were collected by the Canadian Centre for Remote Sensing CV-580 aircraft. At the same time, a series of surface-truth measurements was undertaken from the Canadian ice strengthened vessel CSS *Baffin* by M. Drinkwater (formerly of Scott Polar Research Institute) in conjunction with personnel from JPL, Radarsat, C-core, NORDA, and BIO. These combined ice, oceanographic, and digital image data sets have motivated a series of initial studies at JPL to investigate and understand first, the controls of sea ice and snow/surface properties upon observed C-band microwave signatures, and second, the potential of SAR digital imagery in studies of air–sea–ice interactions in the marginal ice zone (MIZ).

This work is dedicated towards the analysis and interpretation of digital SAR imagery augmented by surface and oceanographic data acquired during LIMEX, and to applying these results to a study of Labrador Sea ice dynamics. Consideration is being given to exchanges of mass and changes in ice concentration and floe size distribution in relation to the kinematics of ice motion and the rheology of the ice pack. A variety of digital image processing algorithms are under development at JPL for tracking ice features and the automated generation of ice motion vectors from sequential imagery taken of the same region. Additional work is underway to classify ice types in the imaged portion of the Labrador Sea, Grand Banks region of the MIZ.

Mass transfers and the kinematics of ice motion can be related to the ice dynamics of the MIZ with the aid of the supporting data. Of particular interest are the surface signatures of mesoscale oceanographic processes such as eddies, fine structure, jets, and meanders, of which many were present during the period of the experiment. To date, very few data are available on the structure, development, and lifetime of such features, or indeed the resulting mass transfers of ice into and out of the ice edge. Thus, in conjunction with oceanographic and ice surface truth data, the interpretations from SAR images will prove a powerful insight into Labrador Sea MIZ ice dynamics.

Planning is already underway for another

major LIMEX experiment to take place in the Labrador Sea during March 1989. Several ships and aircraft will be involved in this campaign, and the data are expected to be of enormous benefit to the development of techniques and algorithms for the analysis of C-band SAR images collected by forthcoming satellites such as ERS-1 and Radarsat.

Submitted by M.R. Drinkwater

U.S. ARMY COLD REGIONS RESEARCH AND ENGINEERING LABORATORY

SYNTHETIC APERTURE RADAR PROGRAM

(J.P. Welsh, Polar Oceanography Branch Office, NORDA, located at USACRREL, Hanover, NH)

To obtain fundamental quantitative knowledge of the relationship between microwave signatures and the microwave properties of the snow and ice cover experiments are being conducted on naturally grown saline ice and naturally occurring snow. We need to understand the characteristics of microwave emission, surface and volume scatter and reflection, incidence angle, azimuth and polarization as they are affected by saline ice with different growth and deformation histories and metamorphism of the snow cover. Experiments are being conducted on the CRREL pond with microwave radiometers under a variety of conditions that can be reasonably well controlled. Recent results have shown statistically significant differences in microwave signatures at 10 GHz, vertical polarization, for the same ice sheet measured on different days. This suggests that short-term aging processes significantly affect the microwave signatures. Measurements at different incidence angles also show significantly different results, suggesting a scale of homogeneity related to the area of ice lying within the instrument footprint.

GLACIOCHEMICAL INVESTIGATIONS IN SOUTHERN VICTORIA LAND, ANTARCTICA

(P.A. Mayewski, W.B. Lyons, M.J. Spencer and M.S. Twickler, University of New Hampshire, Durham, NH)

Reconnaissance studies (radio-echo sounding, mass balance, snowpit) were conducted during the 1987–88 austral summer field season in order to identify a site for the recovery of two 250 m cores. The Newall Glacier, a localized accumulation basin in the Asgaard Range, was chosen and the cores will be recovered during the 1988–89 field season. The resultant record will provide a detailed record of atmospheric chemistry, volcanic history and climate change over a period of ≈2000 y based on the analysis of major anions, major cations, total β-activity, ^{210}Pb, organic acids and $\delta^{18}O$ ($\delta^{18}O$ to be developed by P. Grootes, University of Washington).

REGIONAL STUDY OF GREENLAND SNOW/ICE CHEMISTRY

(P.A. Mayewski, M.J. Spencer and M.S. Twickler, University of New Hampshire, Durham, NH)

During the 1988 and 1989 field seasons detailed sampling of major anions, major cations, organic acids, total β-activity and $\delta^{18}O$ ($\delta^{18}O$ to be developed by W. Dansgaard, University of Copenhagen) was and will be conducted on several snowpits in the vicinity of Camp Century, Summit, Dye 3 and Dye 2. The resultant records will provide an understanding of the regional distribution of the chemical composition of Greenland snow for use in measuring source and input timing of these species. This regional site scale perspective is essential to the proper interpretation of any time-series studies (e.g. deep cores) of these chemical species.

SOUTH ASIAN GLACIOCHEMICAL STUDY

(C. Wake, P.A. Mayewski and M.J. Spencer, University of New Hampshire, Durham, NH)

Based on previous studies conducted by us in Pakistan and India we will extend our detailed snowpit sampling program into other parts of Asia. The sampling program includes measurement of major anions, major cations, organic acids, trace metals, radionuclides and oxygen isotopes and is intended to provide a continental scale understanding of the distribution of these chemical species for purposes of providing a detailed record of atmospheric chemistry over the 4000–7000 m elevation range in Asia.

GLACIER RESEARCH GROUP ALPHA, BETA COUNTING FACILITY

(J. Dibb, P.A. Mayewski, W.B. Lyons and M.J. Spencer, University of New Hampshire, Durham, NH)

Samples of aersols, precipitation and glacial snow and ice from around the world are being analyzed in our alpha, beta, and gamma counting facility. The activity of natural and anthropogenic radionuclides in these samples will allow us to assess atmospheric transport pathways and processes, and provide an additional means for ice core dating.

ELEMENTAL TRACERS OF VOLCANIC EMISSIONS IN ANTARCTIC AEROSOL AND SNOW SAMPLES

(Julie M. Palais and Byard W. Mosher, University of New Hampshire, Durham, NH)

The primary object of this project is to establish whether a trace elemental signature charactersitic of Mt Erebus can be identified in both volcanic plume and snow samples collected in the vicinity of the volcano. Volcanic signatures in snow may serve as chronological markers as well as providing information regarding volcanic input to the Antarctic sulfur budget.

CLOUD WATER AND WET DEPOSITION CHEMISTRY IN THE WHITE MOUNTAINS, N.H.

(Byard W. Mosher, University of New Hampshire, Durham, NH)

The horizontal deposition of cloud water may have a profound influence on the hydrological, chemical, and ecological status in mountainous regions. This ongoing project is examining the acidity and ionic and trace element chemistry of cloud water collected at the summit of Mt Washington, NH. The rates and mechanisms of the removal of gaseous pollutants as well as the regional sources of acid deposition are also being studied.

CLIMATIC RECORDS IN ICE FREE VALLEY LAKES

(W.B. Lyons and P.A. Mayewski, UNH, W. Showers, North Carolina State University)

For the past few years our group has been interested in the utilization of sediment cores from closed basin lakes as paleoclimatic records. We are particularly interested in what geochemical and biochemical signatures are deposited in lake sediments in response to changes in air temperature and hydrologic balance in these closed basin systems. We hope to pursue this type of research in the future in the ice free valleys of Southern Victoria Land as well as in cooperation with our Australian colleagues in the Vestfold Hills area of East Antarctica.

SAMPLING AND ANALYSIS OF LARGE AEROSOL PARTICLES IN THE ANTARCTIC TROPOSPHERE AND NEAR SURFACE ICE

(R. Chuan, Mary Jo Spencer and Julie Palais, University of New Hampshire, Durham, NH)

Aerosol particles are being collected in the Antarctic troposphere using a multi-stage cascade impactor with pizeo-electric crystals for collectors. These samples will then be compared to the particles remaining after snow which we collected in the vicinity of Mt Erebus is freeze dried. This data will allow us to determine the importance of water soluble particles and the importance of Mt Erebus as a particulate source with respect to the Antarctic troposphere.

NORTHERN HEMISPHERE GLACIO-CHEMICAL/GREENHOUSE GAS TIME SERIES

(M.J. Spencer, P.A. Mayewski, and G. Holdsworth, Envir. Canada)

Detailed chemical analyses of cores collected from Mt Logan and southern Greenland will be carried out in order to examine the volcanic signatures, seasonal chemical inputs and anthropogenic inputs at two sites that are the same latitude but are one hemisphere apart over the time period 1760 to 1984. In addition, gases such as N_2O and methane contained in the bubbles of ice sections of the cores will be analyzed to produce a time record of these species back to approximately 1850.

ELECTROMAGNETIC GEOPHYSICAL INVESTIGATIONS OF RIVER ICE

(S. Arcone and A. Delaney, USACRREL, Hanover, NH)

Helicopter-borne short pulse radar and low frequency magnetic induction (MI) are being explored for use in detecting and measuring brash and frazil ice dams in rivers. The radar seeks to measure ice depth indirectly by measuring the ice freeboard while the induction system is more qualitative and seeks mainly to detect jams through measurements of electrical resistivity. Studies have been performed on the St Clair (radar), Tanana (radar and MI) and Connecticut (MI) rivers with very encouraging results. Model experiments are planned for this winter.

SNOW PHYSICS

(S. Colbeck, USACRREL, Hanover, NH)

Recent work includes measurements of the thermal response of skis to determine the role of heat flow in snow friction and a theoretical study of air movement in snow due to wind. A temperature increase of 5 to 6 °C was routinely observed in skis at speeds of 30–40 km/hr and is significantly greater than was expected. The results of the air movement model indicate that snow experiences a significant amount of air flow due to the pressure distribution around normal surface ripples.

WAVE PROPAGATION IN SNOW AND ICE

(K. Jezek, USACRREL, Hanover, NH)

The objective of this work is to understand the important mechanisms that affect wave propagation in cold snow and ice. To that end, detailed laboratory measurements have been conducted on acoustical scattering from the underside of sea ice. These measurements demonstrated the key role played by the dendritic interface present in growing congelation ice which, because of its porous, permeable structure, serves to couple the acoustic signal into the ice. Using similar analysis techniques, radar altimeter data over Greenland have been analysed to reveal significant seasonal differences in waveform shape over the central interior region of the ice sheet. This information may ultimately be used to determine when during the year altimeter performance is optimized for topographic applications.

REMOTE MEASUREMENT OF SEA ICE THICKNESS

(A. Kovacs, USACRREL, Hanover, NH)

We are evaluating the use of an airborne electromagnetic induction system for measuring the thickness of sea ice and the conductivity of the ice and underlying sea water. Initial trials begun in 1985 indicate that this technology is a promising one for sounding both thick and thin sea ice. Current efforts are directed at developing a sea ice sounding system having a capacity to operate over a wide frequency band under software control. The system will use a 3 m long, 0.35 m

diameter towed antenna and use recent advances in digital technology and processing software and hardware to achieve high sampling rates, low noise and drift and real time data interpretation.

TENSILE STRENGTH OF HORIZONTAL FIRST-YEAR SEA ICE SAMPLES

(J. Richter-Menge, USACRREL, Hanover, NH)

Direct tension tests have been completed on 130 horizontally cored (in the plane of the ice sheet) first-year sea ice samples. Tests were done at two strain rates (10^{-3} and 10^{-5} s^{-1}) and four temperatures (−20, −10, −5, −3 °C). Test temperatures were chosen according to the sample location in the ice sheet. Results to date indicate a strong relationship between temperature and strength (strength decreasing with increasing temperatures). There is also a tendency for the strength to decrease with a decrease in strain rate. We are currently investigating the influence of *c*-axis orientation on the strength.

COMPARISON OF THE COMPRESSIVE STRENGTH OF ANTARCTIC FRAZIL SEA ICE AND COLUMNAR SALINE ICE GROWN IN THE LABORATORY

(J. Richter-Menge, S. Ackley, USACRREL, Hanover, NH and M. Lange, AWI, Bremerhaven, FRG)

Unconfined, uniaxial compression tests were performed on frazil sea ice samples collected in the Weddell Sea near Antarctica. The tests were done at a constant strain rate of 10^{-3} s^{-1} and at temperatures of −5 and −10 °C. Data from the frazil ice tests were compared to results from tests done on transversely isotropic, columnar saline ice. The results indicate that the inversely proportional relationship between grain size and strength found in freshwater ice samples cannot be directly extended to sea ice. We speculate that this is due to either (1) a shift in the ductile-brittle transition of sea ice to a strain rate higher than 10^{-3} s^{-1} or (2) that another microstructural parameter (e.g. brine pocket distribution) may be the controlling factor in determining sea ice strength. We plan to test frazil and columnar ice at different strain rates to check these hypotheses.

COORDINATED EASTERN ARCTIC EXPERIMENT ICE PROPERTIES MEASUREMENTS

(W.B. Tucker, D.K. Perovich, A.J. Gow and D. Meese, USACRREL, Hanover, NH)

Measurements of a variety of ice properties are being made from the drifting research vessel *Polarbjorn* which began its drift at 82°41′ N, 32°26.4′ E in mid-September 1988. Biaxial vibrating wire stress sensors were emplaced in adjacent multi-year floes to measure *in-situ* ice stresses. Thermistor chains will provide ice temperature profiles which will allow the examination of ice cooling during the fall and the calculation of oceanic heat flux. Optical properties for a variety of ice types and snow surfaces are being measured. Ice cores are being obtained to measure the temporal variations of ice structure, salinity, major chemical species and nutrient content. Ice and snow thickness grids will allow examination of the temporal variation of the respective thicknesses.

CHEMICAL AND STRUCTURAL PROPERTIES OF ESTUARINE ICE IN GREAT BAY, NH

(D.A. Meese and A.J. Gow, USACRREL, Hanover, NH)

A long-term chemical and structural profile of the ice in the Great Bay, NH is continuing. Chemical analyses including Cl^-, Br^-, SO_4^{-2}, Na^+, Ca^{+2}, K^+, Mg^{+2}, PO_4^{-3}, SiO_4^{+4}, $NO_3^- + NO_2^-$ and NH_4^+ are being conducted on ice samples and water samples collected at the ice-water interface. In addition, thin sections of the ice are being made in order to determine structural ice types, their correlation to arctic ice and to define the sediment entrapment mechanism.

CHEMICAL AND STRUCTURAL PROPERTIES OF SEA ICE IN THE SOUTHERN BEAUFORT SEA

(D.A. Meese, USACRREL, Hanover, NH)

Ice cores and water samples from the ice-water interface were collected during April and May 1986 and 1987 in the southern Beaufort Sea. Chemical (Cl^-, Br^-, SO_4^{-2}, Na^+, Ca^{+2}, K^+, Mg^{+2}, PO_4^{-3}, SiO_4^{+4}, $NO_3^- + NO_2^-$ and NH_4^+) and structural analyses were performed in order to determine the relationship between chemical and structural properties, the relationship between major ions and nutrients and what, if any, fractionation patterns of the chemical species exist in the ice.

CHEMICAL AND STRUCTURAL PROPERTIES OF SALINE LAKE ICE IN DEVILS LAKE, ND

(D.A. Meese, USACRREL, Hanover, NH and R. Lent EOS/SERB, University of New Hampshire, Durham, NH)

During January 1988 ten ice cores were collected throughout the Devils Lake chain for chemical (Cl^-, Br^-, SO_4^{-2}, Na^+, Ca^{+2}, K^+, Mg^{+2}, PO_4^{-3}, SiO_4^{+4}, $NO_3^- + NO_2^-$ and NH_4^+) and structural analysis. The salinity of the lakes ranges from 0–150‰ and therefore provides a setting in which to determine salinity effects on the structural properties of the ice and on the major ions and nutrient concentrations.

Submitted by W.B. Tucker III

INTERNATIONAL GLACIOLOGICAL SOCIETY

SYMPOSIUM ON ICE AND CLIMATE

University of Washington, Seattle, Washington, U.S.A. 21 – 25 August 1989

CO-SPONSORED BY

American Geophysical Union
American Meteorological Society

SECOND CIRCULAR
July 1988

INFORMATION ABOUT THE SYMPOSIUM MAY BE OBTAINED FROM:
Secretary General, International Glaciological Society, Lensfield Road,
Cambridge CB2 1ER, UK.
Tel: Cambridge (code from outside U.K. = 223) 355974 Fax: (223) 336543

Registration for the symposium will take place on Sunday 20 August and sessions will be from Monday 21 to Friday 25 August on the campus of the University of Washington. A mid-symposium half-day tour and two post-symposium tours will take place.

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 1989. There will be a £15.00 surcharge for later registrations. *Participants'* registration fees cover organization costs, distribution of preprints of summaries, reception, ½-day tour, banquet and a copy of the Proceedings Volume. *Accompanying persons'* registration fees include organization costs, reception, ½-day tour and banquet. *There is an administration surcharge for participants who are not members of I.G.S., American Geophysical Union (AGU) or American Meteorological Society (AMS).

REGISTRATION FEES:

Participant (IGS, AGU, AMS) members	£100
*Participant (not a member of IGS, AGU, AMS) ...	£130
Junior Member (under 26 years of age)	£ 70
Accompanying person aged 18 or over	£ 40
(There is no fee for those under the age of 18, but if they wish to attend the banquet, a ticket must be purchased when registering on Sunday 20 August.)	
Surcharge for late registration (after 1 May).....	£ 15

Refunds on registration fees can be made on a sliding scale, according to date of receipt of notification, up to 1 August 1989. After that date it may be impossible to make any refund.

TOPICS

The Symposium will be concerned with natural forms of ice on land and sea, with focus on (1) information obtained from ice about past climates, (2) physical processes by which ice influences climate change, and (3) practical means by which ice effects can be incorporated into large-scale climate models.

Topics will include:

Deduction of paleoclimate from ice properties.

Advance and retreat of glaciers and ice sheets.

Climate effects of sea ice-ocean-atmosphere interaction.

Implications of seasonal snow cover feedbacks for long-term climate change.

PROGRAMME

A detailed programme will be given in the Third Circular. Both plenary and poster sessions are planned. Various local tours and visits will be available for accompanying persons, and may be booked when registering on Sunday 20 August. There may be opportunities for workshops to be held during the week of the meeting, subject to availability of space.

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 international size paper A4 (210 × 297 mm). References and illustrations are not required at this stage. Summaries should be sent to: Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, England. Place the title and authors' names and addresses at the top of the first page of your summary and not on a separate sheet. Please indicate poster presentation, if that is your preference.

LAST DATE FOR SUBMISSION OF SUMMARIES: 1 February 1989

(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 notify authors of papers in early April 1989 about acceptance (or otherwise).

(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 proceedings volume (*Annals of Glaciology* Vol. 14). Final typescripts of these papers should be submitted to the Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, England, by 1 June 1989. 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.

Acceptance of a summary implies that the paper based on that summary will be submitted to the proceedings volume and not to another publication.

LAST DATE FOR SUBMISSION OF FINAL PAPERS: 1 June 1989

ACCOMMODATION

Accommodation has been booked at special rates in dormitories of the University of Washington and in local hotels for the period Sunday night 20 August to Saturday morning 26 August. There will be no reduction for a shorter stay in the dormitories. The price includes full breakfast at the dormitories but not at the hotels.

University dormitories, with shared bathrooms; full breakfast: approx. $162 (single), $136 (shared room).

Hotel rooms with private bath are available in three categories at the following per night costs for single/double occupancy: (a) 1st class hotel ($78/$100), (b) intermediate cost hotel ($55/$62), (c) motor hotel ($45/$55). Breakfast is not included. Hotel (a) is conveniently located in the University District approx. 10 min. walk from the meeting room. Categories (b) and (c) are also located within walking distance or accessible by free motor shuttle service to the University campus.

A deposit of US$50 must be paid when booking accommodation, in accordance with the instructions given on **PART 2** of the booking form printed at the end of this circular. You will be billed for the balance of the dormitory accommodation in June 1989, when the final prices are notified by the University.

Cancellations: Hotels require at least 48 hours' notice of cancellation. The University by 1 August. Deposits will be refunded if cancellations are received by those dates. No deposits will be refunded after those dates.

CLIMATE AND CLOTHES

Seattle enjoys a mild maritime climate. During August mean daily maximum and minimum temperatures are 24 °C and 12 °C respectively. The weather is normally dry with mean August precipitation of 22 mm. However, in keeping with Seattle's rainy reputation, it is advisable to be prepared for rain.

Walking shoes will be needed for the mid-symposium tour.

EVENTS

There will be a RECEPTION on the evening of Sunday 20 August, and a boat trip and BANQUET on Thursday 24 August. The cost of these is included in the registration fees. If accompanying persons under the age of 18 wish to attend the Banquet, tickets should be purchased at the registration desk.

On Wednesday 23 August, from 1300 – 1830 h, there will be an excursion to examine margin and bed features of the Puget Sound Lobe of the former Cordilleran Ice Sheet. The cost of this is included in the registration fees.

POST-SYMPOSIUM TOURS

(A) A 2-day tour to **MT. RAINIER AND MT. ST. HELENS** on 26 and 27 August will provide an opportunity to view volcano — glacier interactions and effects from the 1980 eruption of Mt. St. Helens. The tour will depart on Saturday morning and return on Sunday evening at approximately 6 p.m. Transport, admissions, accommodation for Saturday night and box lunches on both days are included in the tour price. Other meals are not included.

The cost will be approximately $95 (shared facilities), $105 (private facilities).

A deposit of US$40 must be paid when booking this tour, in accordance with the instructions given on **Part 2** of the booking form printed at the end of this circular. You will be billed for the balance of the cost in June 1989. Notice of cancellation will be required by 1 August. If later than that, the deposit cannot be refunded.

On the return journey, the bus will stop at SeaTac Airport and at hotels. If you require accommodation for the night of 27 August, please make your needs known at the Symposium registration desk.

(B) There will be an 8-day tour of the **TIDEWATER AND OTHER GLACIERS IN SOUTHERN ALASKA**. Participants will see spectacular glaciers, wilderness areas, wildlife, fjords, and mountains, using commercial and chartered aircraft, bus, boat and train. There will be opportunities to spend time on several glaciers, and to present summaries of their own work in non-technical terms to some local communities.

The cost of the tour is approximately $1600, which includes all transportation from Seattle to Anchorage, accommodation, maps, field guides, and some of the meals. (Where accommodation is in lodges or hotels, the cost of meals in restaurants is not included, so that participants are free to make their own selections.)

Waterproof rain clothing, rubber boots, a small day pack, and camera protection are STRONGLY advised. Temperatures will be above freezing, but wind and rain may produce chilly conditions. Hikes will be easy. Because we will be travelling by smaller aircraft and boats in Alaska, baggage not required on the tour will be shipped directly to Anchorage.

Saturday, August 26
Fly to Juneau, the capital of Alaska. Walk to the face of Mendenhall Glacier. Discussions with local scientists about avalanche activity in Juneau. Overnight at University of Alaska-Southeast.

Sunday, August 27
Fly,boat and hike to Hole-in-the-Wall Glacier, a distributary of the advancing Taku Glacier system. Alaska salmon bake near the glacier. Fly to entrance of Glacier Bay; reception at Glacier Bay Lodge. Overnight at lodge.

Monday, August 28
All-day cruise in Glacier Bay fjords, observing wildlife, vegetation succession following recent deglaciation, and recent readvance of Margerie and Grand Pacific Glaciers. Overnight at lodge.

Tuesday, August 29
Fly by amphibious aircraft through spectacular mountains and over numerous large glaciers along Gulf of Alaska shore. Land in Russell Fiord and hike into the Hubbard and Variegated Glaciers. Overnight in Yakutat.

Wednesday, August 30
Bus and hike from Yakutat to south end of Russell Fiord, where forests were drowned during 1986 Hubbard Glacier advance. Visit archaeological sites on the Situk River. Evening event with the Tlingit people of Yakutat. Overnight in Yakutat.

Thursday, August 31
Two-hour flight to Valdez by specially chartered turbo-prop aircraft through the St. Elias Mountains; see Malaspina and Bering Glaciers, and Mt. Logan. By boat to a lodge near Columbia Glacier. Hike to calving glacier terminus, or fly by helicopter ($50 optional extra) to top of a high nunatak overlooking Columbia Glacier, which began rapid retreat in this decade. Overnight at lodge.

Friday, August 31
Cruise by chartered boat to advancing Meares Glacier and then to Whittier. Train and bus transportation to Alyeska ski resort. Overnight at lodge.

Saturday, September 2
Visit Portage Glacier, which is retreating rapidly. Then to the top of the Alyeska ski area, where the group will hold the "final symposium" before departing for Anchorage. Arrival in Anchorage will be about 1800h. This will complete the tour.

Participants will be given assistance in arranging for transportation to the airport for domestic or international departures and for lodging.

Continuation of the tour can be arranged if participants wish to travel more in Alaska. If you are interested in these opportunities, please mark the box on the booking form. Possible extensions include:
(1) Denali National Park and its superb wildlife, mountains (including Mt. McKinley), and glaciers.
(2) Glacier research facilities in Fairbanks, a walk-in tunnel in ice-wedge permafrost, and a unique University-owned rocket range.
(3) Chartered glacier sightseeing flights.

The cost of the tour will be US$1,600 for 8 days, finishing in Anchorage at 1800h approximately on September 2. The cost is subject to any variations in prices for transport and hotels occurring in 1989. A deposit of US$150.00 must be paid when booking this tour, in accordance with the instructions given on **Part 2** of the booking form printed at the end of this circular.
You will be billed for the balance of the cost in June 1989.
Notice of cancellation will be required by 1 August. If later than that, the deposit cannot be refunded.

Retain this copy for your records

IGS SYMPOSIUM in Seattle, WA, USA, August 1989

PART 1 REGISTRATION
The following registration fee/s and form were sent to the Secretary General in Cambridge, England on ...../...../1989.
(day) (month)

Participant....£100 Participant: not a member of IGS, AGU, AMS....£130
Junior Member....£70 Accompanying person....£40

Surcharge for each late registration....£15 TOTAL fee/s sent £.....

PART 2 ACCOMMODATION & TOURS
The following deposits for accommodation/tours and form were sent to C.F. Raymond in Seattle, WA, USA on ...../...../1989.
(day) (month)

Accommodation deposit/s ($50 per person) $ .....
Accommodation requested: *dormitory
*hotel – requested category
*(a)/(b)/(c)
Tour deposit/s:
*2-day Rainier/St. Helens ($40 per person) $ .....
*8-day Alaska ($150 per person) $ .....

TOTAL fee/s sent $ .....

*delete as appropriate

NOTE: Fee/s and deposit/s are returnable on a sliding scale, according to date of receipt of notification, up to 1 August 1989. After that date it may be impossible to make refunds, because of rules laid down by accommodation managements and tour operators.

IGS SYMPOSIUM ON ICE AND CLIMATE

21 – 25 August 1989

PART 1 REGISTRATION

Mail this part to: Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, U.K. — to arrive by 1 May 1989. If you send it later, the surcharge of £15 should be added for each person.

Name of participant ....
(family name) (initials)

Address .....

.....

Accompanied by (indicate age if under 18)

Name ..... Name .....

I send registration fees as follows:

Participant (member of IGS/AGU/AMS)(£100 each) .....
Participant (not a member of the above)(£130 each) .....
Junior member(£70 each) .....
Accompanying person (£40 each) .....
(no charge if under 18) TOTAL registration fees = ...
Surcharge for late submission (£15 each) TOTAL submitted = ...

Please pay by sterling cheque, Eurocheque or sterling bank draft to the address given above. **Make payable to: International Glaciological Society.** Please pay the bank charges yourself — we need the full amount for each person's fee.

PART 2 ACCOMMODATION AND POST-SYMPOSIUM TOURS

Mail this part to: C.F. Raymond, IGS Symposium Committee, Graduate Program in Geophysics, University of Washington, Seattle, WA 98195, USA — before 1 May 1989.

Name of participant ....
(family name) (initials)

Address .....

.....

Accompanied by (indicate age if under 18):

Name ..... Name .....

I send deposits as indicated below.

Accommodation — US$50 per person ..... total $.....

I prefer *Univ. Washington dormitory
*hotel: (a) / (b) / (c) } *single / *shared occupancy

Tours

*A. Mt. Rainier and Mt. St. Helens (US$40 per person) ..... total $.....
*B. Alaska (US$150 per person) ..... total $.....

TOTAL DEPOSITS = ...

*I wish to book helicopter flight for August 31 _
*I am interested in presenting short talk during tour _
*I wish to receive information about extension to Denali and/or Fairbanks _
*Delete those items not required

Please pay by US$ check or bank draft to the address given above. **Make payable to: International Glaciological Society.** Please pay the bank charges yourself — we need the full amount for each person's deposits.

JOURNAL OF GLACIOLOGY

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

P HOLMLUND:
Is the longitudinal profile of Storglaciären, northern Sweden, in balance with the present climate?

E M SHOEMAKER:
On the formulation of basal debris drag for the case of sparse debris.

J W GLEN AND D J IVES:
Fish antifreeze protein and the creep of polycrystalline ice.

J L BAMBER:
Enhanced radar scattering from water inclusions in ice.

B ERLINGSSON:
Two-dimensional deformation patterns in sea ice.

W H THEAKSTONE:
Temporal variations of isotopic composition of glacier river water during summer: observations at Austre Okstindbreen, Okstindan, Norway.

I J JORDAAN AND G W TIMCO:
Dynamics of the ice-crushing process.

P G JOHNSON AND D LACASSE:
Rock glaciers of the Dalton Range, Kluane Ranges, south-west Yukon Territory, Canada.

J OERLEMANS:
Simulation of historic glacier variations with a simple climate–glacier model.

R W JACOBEL, S K ANDERSON AND D F RIOUX:
A portable digital data-acquisition system for surface-based ice-radar studies.

S C COLBECK:
Snow-crystal growth with varying surface temperatures and radiation penetration.

J F NYE:
The geometry of water veins and nodes in polycrystalline ice.

G B CROCKER AND P WADHAMS:
Modelling Antarctic fast-ice growth.

M O JEFFRIES, H R KROUSE, W M SACKINGER AND H V SERSON:
Stable-isotope ($^{18}O/^{16}O$) tracing of fresh, brackish, and sea ice in multi-year land-fast sea ice, Ellesmere Island, Canada.

J L BAMBER:
Ice/bed interface and englacial properties of Svalbard ice masses deduced from airborne radio echo-sounding data.

ANNALS OF GLACIOLOGY

The following papers are published in Volume 11, Proceedings of the Fourth SCAR International Symposium on Antarctic Glaciology, held at Bremerhaven, FRG, 7–12 September 1987.

R B ALLEY, C.R. BENTLEY
Ice-core analysis on the Siple coast of West Antarctica.

R A BINDSCHADLER, P L VORNBERGER, S N STEPHENSON, E P ROBERTS, S SHABTAIE, D R MacAYEAL
Ice-shelf flow at the boundary of Crary Ice Rise, Antarctica.

J DETERMANN, F THYSSEN, H ENGELHARDT
Ice thickness and sea depth derived from reflection-seismic measurements on the central part of Filchner–Ronne Ice Shelf, Antarctica.

R M FROLICH, C S M DOAKE
Relative importance of lateral and vertical shear on Rutford Ice Stream, Antarctica.

W GRAF, H MOSER, H OERTER, O REINWARTH, W STICHLER
Accumulation and ice-core studies on Filchner–Ronne Ice Shelf, Antarctica.

K HERTERICH
A three-dimensional model of the Antarctic ice sheet.

H HINZE, G SEEBER
Ice-motion determination by means of satellite positioning systems.

H HOPPE, F THYSSEN
Ice thickness and bedrock elevation in western Neuschwabenland and Berkner Island, Antarctica.

K HUTTER, H ENGELHARDT
The use of continuum thermodynamics in the formulation of ice-sheet dynamics.

P HUYBRECHTS, J OERLEMANS
Evolution of the East Antarctic ice sheet: a numerical study of thermo-mechanical response patterns with changing climate.

K C JEZEK, R B ALLEY
Effect of stratigraphy on radar-altimetry data collected over ice sheets.

M A LANGE, D R MacAYEAL
Numerical models of steady-state thickness and basal ice configurations of the central Ronne Ice Shelf, Antarctica.

D R LINDSTROM
Formation of the West Antarctic ice sheet.

D R MacAYEAL, R A BINDSCHADLER, K C JEZEK, S SHABTAIE
Can relict crevasse plumes on Antarctic ice shelves reveal a history of ice-stream fluctuation?

J McDONALD, I M WHILLANS
Comparison of results from Transit satellite tracking.

D MOLLER, B RITTER
Glacial geodetic contributions to the mass balance and dynamics of ice shelves.

J C MOORE
Dielectric variability of a 130 m Antarctic ice core: implications for radar sounding.

R NARUSE, F OKUHIRA, H OHMAE, K KAWADA, M NAKAWO
Closure rate of a 700 m deep bore hole at Mizuho Station, East Antarctica.

H NISHIMURA, N MAENO
Characteristic growth processes of ice crystals on the Antarctic ice sheet.

O ORHEIM, B K LUCCHITTA
Numerical analysis of Landsat Thematic Mapper images of Antarctica: surface temperatures and physical properties.

QIN DAHE, N W YOUNG, R J THWAITES
Growth rate of crystals within the surface-snow/firn layer in Wilkes Land, East Antarctica.

S SHABTAIE, C R BENTLEY
Ice-thickness map of the West Antarctic ice streams by radar sounding.

S SHABTAIE, C R BENTLEY, R A BINDSCHADLER, D R MacAYEAL
Mass-balance studies of ice streams A, B, and C, and possible surging behavior of Ice Stream B, West Antarctica.

C SWITHINBANK, K BRUNK, J SIEVERS
A glaciological map of Filchner–Ronne Ice Shelf, Antarctica.

S TAKAHASHI, R NARUSE, M NAKAWO, S MAE
A bare ice field in east Queen Maud Land, Antarctica, caused by horizontal divergence of drifting snow.

M H TALBOT
Oceanic environment of George VI Ice Shelf, Antarctic Peninsula.

R H THOMAS, S N STEPHENSON, R A BINDSCHADLER, S SHABTAIE, C R BENTLEY
Thinning and grounding-line retreat on Ross Ice Shelf, Antarctica.

F THYSSEN
Special aspects of the central part of Filchner– Ronne Ice Shelf, Antarctica.

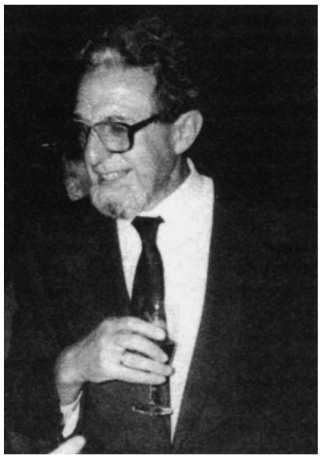
F THYSSEN, K GROSFELD
Ekström Ice Shelf, Antarctica.

H TUG
A pulse-counting technique for the measurement of drifting snow.

I M WHILLANS, R A BINDSCHADLER
Mass balance of Ice Stream B, West Antarctica.

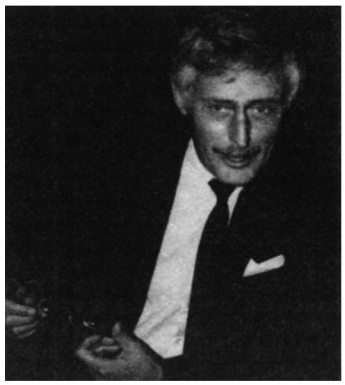
E W WOLFF, R MULVANEY, K OATES
The location of impurities in Antarctic ice.

Seen at the SCAR Symposium on Antarctic Glaciology at Bremerhaven –

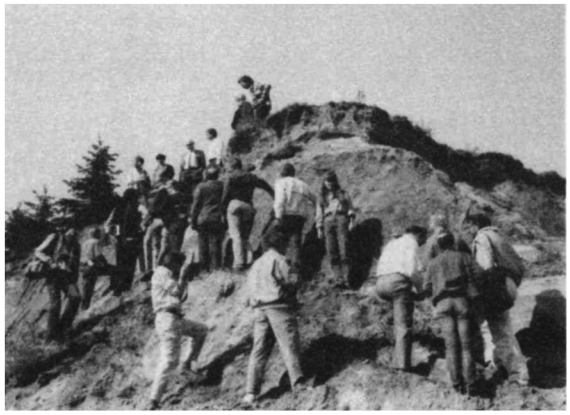


← George Hempel, Director Alfred-Wegener-Institute

Heinz Kohnen, AWI Local Committee Chairman →



Field trip ↘



←What did they find?

(Photos by Julian Paren)

GLACIOLOGICAL DIARY

** IGS Symposia
* Co-sponsored by IGS

1989

5-7 February
Symposium on Okhotsk Sea and Sea Ice, Mombetsu, Hokkaido, Japan. (Masaaki Aota, Scientific Program Committee, Okhotsk Symposium-89, Sea Ice Research Laboratory, Hokkaido University, Minamigaoka 6-4-10, Mombetsu, Hokkaido 094, Japan)

13-17 March
Fourteenth General Assembly of the European Geophysical Society, Barcelona, Spain. (E.G.S. Office, c/o MPI für Aeronomie, D-3411 Katlenburg-Lindau, Federal Republic of Germany)

16-17 March
* Meeting on Glacimarine environments: processes and sediments, London, UK. (Marine Studies Group of the Geological Society of London. J.A. Dowdeswell, Department of Geography, University College of Wales, Llandinam Building, Aberystwyth, Dyfed SY23 3DB, U.K.)

19-23 March
OHMAE Europe 1989 – Eighth International Conference on Offshore mechanics and Arctic engineering, The Hague. Ice mechanics: (Dr Nirmal K. Sinha, Chairman, Ice Mechanics Committee, Offshore Mechanics and Arctic Engineering (OHMAE/ASME), Institute for Research in Construction, National Research Council of Canada, Ottawa, Ontario, Canada K1A 0R6)

20-23 March
Fifth Conference of the European Union of Geosciences, Strasbourg, France. (Jan Høst, Geological Survey of Norway, P.O. Box 3006 – Lade, N – 7002 Trondheim, Norway)

May
6th Symposium on Glacitectonics, Zielona Góra, Poland (Jerzy Kotowski, Komitetu Organizacyjnego VI Sympozjum Glacitektoniki, Wydzial Budownictwa i Inzynierii Sanitarnej, Wyzsza Szkola Inzynierska, ul. Podgórna 50, 65-246 Zielona Góra, Poland)

12-14 April
QRA Discussion meeting on Environmental change in Iceland: past and present, Aberdeen, Scotland. (Judith Maizels, Dept. of Geography, University of Aberdeen, AB9 2UF, UK)

10-19 May
3rd IAHS Scientific Assembly (Symposium S5: Stochastic processes and time series analysis in glaciology) Baltimore, Maryland, U.S.A. (A. Ivan Johnson, Chairman, Third IAHS Scientific Assembly Organizing Committee, 7474 Upham Court, Arvada, CO 80003, U.S.A.)

12-16 June
10th International Conference on Port and Ocean Engineering under Arctic Conditions, Luleå University of Technology, Sweden.

9-19 July
28th International Geological Congress, Washington, D.C., U.S.A. (B.B. Hanshaw, Secretary General, 28th International Geological Congress, P.O. Box 1001, Herndon, VA 22070-1001, U.S.A.)

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

21-25 August
** IGS Symposium on Ice and Climate, Seattle, Washington, U.S.A. (Secretary General, IGS, Lensfield Road, Cambridge CB2 1ER, UK)

4-8 December
American Geophysical Union Fall Meeting, San Francisco, California, U.S.A. (A.G.U. Meetings, 2000 Florida Avenue, N.W., Washington, DC 20009, U.S.A.)

1990

12-15 June
International Symposium on Water Resources Systems Application, Winnipeg, Canada. (S.P. Simonovic, Civil Engineering Department, The University of Manitoba, Winnipeg, Manitoba, Canada, R3T 2N2)

26-31 August
** IGS Symposium on Ice–Ocean Dynamics and Mechanics, Hanover, N.H., U.S.A. (Secretary General, IGS, Lensfield Road, Cambridge CB2 1ER, UK)

1991

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

September
** IGS Symposium in Lanzhou, China. (Date and topics to be announced early 1989.) (Secretary General, IGS, Lensfield Road, Cambridge, CB2 1ER, U.K.)

NEWS

AUSTRALIA: TASMANIA - BEN LOMOND

A research student, Peter Faulkner (Geography Department, University of Tasmania), has completed a six year study of the climate and environmental factors affecting snowmelt on the Ben Lomond ski fields. The results form the basis of an M.Sc. thesis.

Papers arising include: The winter climate of Ben Lomond. *Meteorology Australia*, Summer 1988; and The effects of the natural environment upon snowmelt distribution and the energy balance in the Ben Lomond ski field area. In press. *Australian Glaciological Research*, Proceedings of the May, 1987 Conference, Melbourne University.

DATA BASES

(a) QL Systems Limited has announced an expansion of its collection of data bases concerning the north with the addition of the data base from the Scott Polar Research Institute at the University of Cambridge in Cambridge, England. The new data base, called "*SPRI*", contains over 12,000 bibliographical references concerning political, industrial, scientific, social and other aspects of the polar regions. New publications will be added at the rate of 6,000 per year and the retrospective conversion of 90,000 cards catalogued at the institute will be added at a planned rate of 5,000 per year.

In dealing with the pressure for exploitation of the natural resources of the Arctic and Antarctic, this data base may be used in conjunction with the *Arctic Science and Technology (AST)* data base, the *Boreal Northern Titles (BNT)* data base and the *Yukon Bibliography (YKB)* data base. Together, these four data bases comprise the largest collection of cold region bibliographic data in the world.

The "*AST*" data base, compiled by the Arctic Institute of North America at the University of Calgary, covers all aspects of the north from 1978 to the present. The Institute abstracts and indexes recent literature about the Arctic and provides descriptions of recent and on-going Arctic research projects.

The "*BNT*" and "*YKB*" data bases are compiled by the Boreal Institute for Northern Studies at the University of Alberta. "*BNT*" is a comprehensive collection of indexes to articles from 1972 to the present covering the Arctic and Antarctic regions and the North American north, including Alaska and Canada, as well as Scandinavian countries, Iceland and Sibera. Emphasis is placed on native peoples and the Canadian north. The "*YKB*" data base abstracts articles, periodicals, theses and other publications pertaining to the Yukon.

Searching the data bases has been made even easier with QL's new global data base capability. Researchers may now combine the data bases and search for all four collections in one search.

Other QL data bases will also be useful to researchers interested in cold region studies. Our ever-increasing collection includes bases on the environment, mining, news reports, press releases, law and much more. Anyone interested in receiving more information about these data bases should write to QL at Box 4036, 250 – 6 Ave. S.W., Calgary, Alberta, T2P 3H7, Canada, or call toll free at 1-800-387-0899 for more information.

(b) The Ocean engineering Information Centre (OEIC) is well known for its technical collection in cold ocean engineering. This collection, containing over 20,000 items, is a valuable resource for industry, government and university groups undertaking off-shore engineering studies. Over the last six months, all the bibliographic records have been transferred onto an online database management system, SPIRES; the OEIC collection is now available for online searching at the Centre.

Memorial University Library has selected the SPIRES database management system for the organization of biblographic information. SPIRES is used by two Canadian northern online databases: ASTIS (Arctic Sciences & Technology Information System) at the Arctic Institute of Northern Studies; and at the Boreal Institute of Northern Studies, Edmonton. The selection of the SPIRES data-base management system will increase the ability of northern institutes to share resources.

BIBLIOGRAPHY

Radio echo-sounding as a glaciological technique: a bibliography, compiled by Ailsa D. Macqueen. 1988. £5.

This bibliography has been compiled by World Data Centre "C" for Glaciology from the computerized database of the Library and Information Service of the Scott Polar Research Institute, University of Cambridge. The database includes all items on radio echo-sounding that have been received and indexed by the World Data Centre "C" for Glaciology up to the end of 1987. Items are arranged in chronological order within eight subject sections, and a separate alphabetical author index is provided. Each reference is cited once only. Subject sections include: General articles; Instruments and methods; Theory of radio echo-sounding; Applications to land ice; Applications to floating ice; Ancillary methods and observations; Popular articles; Theses and abstracts of theses.

HANS WEERTMAN'S "FAMILY TREE"

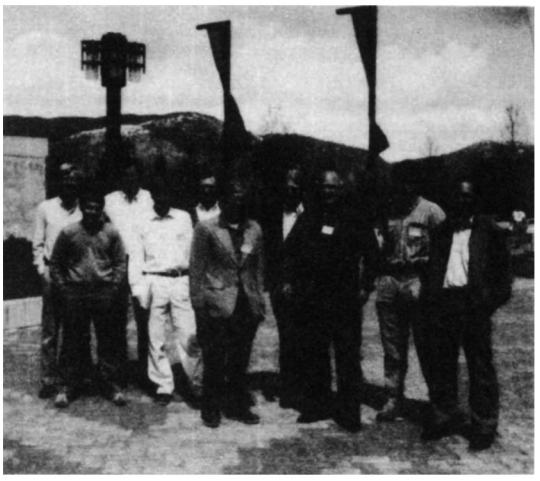
Not present are Douglas MacAyeal, Rajiv Joshi, Judith Chapman, and Douglas Roberts, who also were introduced to glaciology at the University of Maine. Doug MacAyeal and Mauri Pelto also have glaciological roots to Robert Thomas and Maynard Miller, respectively.

It is worth mentioning that everyone in the picture, and Doug MacAyeal as well, are all still practising glaciologists except Mark Hyland, who is employed as a groundwater hydrologist – not that far removed from glaciology.

Hans Weertman has three others in his family tree: Sivan Parameswaran, who worked for CRREL briefly, and at NRC in Ottawa for many years studying permafrost; Namio Urabe, who works on sea ice problems on offshore structures for a steel company in Japan; and along with Ed Birchfield, Isabelle Muszynski, who is working at NCAR on glaciation and climate.

The picture was taken by Gordon Robin at the Chapman Conference on Fast Glacier Flow in 1986.

Submitted by Terence J. Hughes



The Maine branch of Hans Weertman's glaciological family tree. Left to right: Mark Hyland, Dean Lindstrom, John Scofield, Mauri Pelto, David Schilling, Hans Weertman, James Fastook, Terry Hughes, Tad Pfeffer, and Craig Lingle.

NEW MEMBERS

S. Ackley, US Army CRREL, 72 Lyme Road, Hanover, NH 03755, U.S.A.

Gunnar Atteraas, G. Schjelderupsvei 35, 0485 Oslo 4, Norway.

Steinar Bakkehøi, Norwegian Geotechnical Institute, P.O. Box 40, Tåsen, 0801 Oslo 1, Norway.

Gerard Brugnot, Div. Nivologie, CEMAGREF, BP 96, 38402 St Martin d'Hères Cedex, France.

L. Buisson, Div. Nivologie, CEMAGREF, BP 96, 38402 St Martin d'Hères Cedex, France.

Claude Charlier, Div. Nivologie, CEMAGREF, BP 96, 38402 St Martin d'Hères Cedex, France.

Ulrik Domaas, Taarnbyvn. 260, 2013 Skejetten, Norway.

Neil F. Glasser, 6 Elgin Terrace, Edinburgh EH7 5NN, U.K.

Gordon S. Hamilton, Department of Geography, University College of Wales, Llandinum Building, Penglais, Aberystwyth, Dyfed, SY23 3DB, U.K.

Karl Gunnar Holter, Tiurvn. 49, 3700 Skien, Norway.

Ragnhild Housnæs, Austikkeren 7, 1156 Oslo 11, Norway.

Eivind Hovin, Leirveien 19, 2322 Ridabu, Norway.

D. Elisabeth Isaksson, c/o Alf Isaksson, Rackarbergsg. 36-215, 752 82 Uppsala, Sweden.

Arni Jonsson, Grenimel 17, 107 Reykjavik, Iceland.

Tron Laumann, Asenhagen 316, 2020 Skedsmokorset, Norway.

Isabelle M.L.F. Marsiat, Institut d'Astronomie et de Géophysique G Lemaître, 2 Chemin du Cyclotron, 1348 Louvain-la-Neuve, Belgium.

Tavi Murray, Department of Geography, University College of Wales, Llandinum Building, Penglais, Aberystwyth, Dyfed, SY23 3DB, U.K.

Véronique Place, c/o ANENA, 15 rue Ernest Calvat, 38000 Grenoble, France.

François Rapin, Div. Nivologie, CEMAGREF, BP 96, 38402 St Martin d'Hères Cedex, France.

Gunhild Rosqvist, Department of Physical Geography, University of Stockholm, 106 91 Stockholm, Sweden.

Kristin Tandberg, Parkvn. 15, 0350 Oslo 3, Norway.

Fiona Tweed, Department of Geography, University of Keele, Keele, ST5 5BG, U.K.

Cameron P. Wake, Glacier Research Group, EOS-SERB, University of New Hampshire, Durham, NH 03824, U.S.A.

Mark W. Williams, University of California/Santa Barbara, P.O. Box 15007, Santa Barbara, CA 93107, U.S.A.

William D. Winsor, C-Core, Memorial University of Newfoundland, St John's, NF, A1B 3X5 Canada.

INTERNATIONAL GLACIOLOGICAL SOCIETY

Lensfield Road, Cambridge CB2 1ER, England

SECRETARY GENERAL H. Richardson

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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 1989

Private members	Sterling £30.00
Junior members	Sterling £15.00
Institutions, libraries	Sterling £80.00 for Volume 35 (Nos.119, 120, 121)

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

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

ICE

Editor: H. Richardson
Assisted by 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 £10.00

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.