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CONTENTS

COVER PICTURE: The Vernagtbach gauging station, Oetztal Alps, 2640 m a.s.l., September 1979. Photograph by Hans Oerter.

FRANCE

CEMAGREF: (Ministry of Agriculture) BP 76, F. 38402, St Martin d'Hères, Cédex
CEN: (Center of Research on Snow) -Météo France, BP 44, F. 38402, St Martin d'Hères, Cédex

Snow cover modelling

(E. Brun, CEN)
A numerical model of snow cover has been developed for operational avalanche forecasting. This model simulates the evolution of internal characteristics of snow cover at a given location as a function of weather conditions. It computes temperature, density and liquid water profiles and also stratigraphy using laws of metamorphism. Snow albedo is predicted directly from the type of snow simulated at snow cover surface. The model has been tested successfully on different locations and it is now used by French operational avalanche forecasting services.

Radiative properties of snow

(C. Sergent, E. Pougatch. M. Sudul, CEN and E. Cachier, Centre des Faibles Radioactivités)
An original device has been developed to make accurate measurements of snow radiative properties (albedo and absorption) on the wavelength range (0.3–1.1 µm) with a 10 nm resolution. Measurements are made on various types of snow in a cold room. The snow samples are taken from natural snow layers or from a controlled metamorphism of fresh snow samples in a cold room. Snow pollutants are measured to take into account the effects of soot on snow albedo. Preliminary results point out that the effect of grain shape are as important as the effect of grain-size.

Avalanche activity measurements

(J.P. Navarre, A. Taillefer, J.M. Panel, Y. Danielou and B. Lesaffre, CEN)
In order to get unbiased measurements of avalanche activity, a seismograph has been installed in a mountain to collect seismic signals emitted during avalanche events. Research is conducted to allow automatic recognition of these signals among the other seismic signals that can be collected in mountain areas. The goal of this project is to build up a network of seismographs in order to get a real-time measurement of avalanche activity to help operational avalanche forecasting and also to control its quality.

Snow erosion by wind

(G. Guyomarch, L. Mérindol, CEN, F. Naaim and M. Roussel, CEMAGREF)
A high altitude field (2700 m a.s.l.) has been instrumented to measure snow erosion by wind. The aim of this project is to characterize the threshold of wind velocity that is necessary to make snowdrift as a function of snow surface characteristics: density, snow type and grain-size, and snow temperature. The experimental field includes an anemometer, a snow-depth sensor, a rain gauge and all sensors necessary to compute snow-cover energy balance (air temperature and humidity, wind velocity, short-wave and long-wave radiation). Once a week or during drift events, snow samples are taken and characterized under a microscope to get a perfect description of the characteristics of eroded snow surface and of the grains carried by wind.

Computer-based analysis of avalanche paths

(Laurent Buisson, CEMAGREF)
The ELSA system, dedicated to the analysis of avalanche paths, is being developed by means of a knowledge-based system. With a representation of the terrain, ELSA uses several analysis methods (numerical, statistical and symbolic methods for snowdrift, fracture propagation and avalanche flow). They are integrated in a procedure based on the methodology of senior snow consultants in order to help an engineer in his analysis. Further developments will take into account comparison with field investigations and decision-making support.

Snow-drift analysis with a knowledge-based system

(Fabrice Moutte, CEMAGREF)
The CLER system is a knowledge-based system currently developed in order to help snow specialists in charge of snowdrift analysis for the solution of ground transportation problems. Using a representation of the terrain, a description of the equipment to protect and some meteorological parameters, CLER selects the threatened zones of the equipment and provides the location of the snowdrifts. Several methods of analysis are integrated in CLER.

Numerical models to simulate wet snow avalanches

(Gilbert Martinet, CEMAGREF)
The Nivologie Division of the CEMAGREF in Grenoble has developed numerical models to simulate wet snow avalanches. They are very useful for experts and give them a teaching aid which can confirm their decisions. These models consider the snow as a Bingham fluid and include its rheological properties, which are essentially a function of its percentage of water and density. They are constructed on the Shallow Water conservation equations and guarantee some robustness in the front discontinuity modelling. The bidimensional model WETSNOW1D used for simulating channalized avalanches has already been calibrated on the Taconnaz avalanche (20 March 1988) and other ones. The friction coefficients used for the calibration are of the same order as those found in the literature. The three-dimensional version, which can simulate avalanches in any type of topography, has been used for the first time on a real site in 1990 and is now operational.

Dynamics of dense snow avalanches: a new group of measurements

(Olivier Marco, CEMAGREF)
The density and velocity in the body of a dense snow avalanche are being studied in the field. Data are obtained

with three kinds of new sensor based on the principles of the snowtrap, the dynamometer and ultrasonic telemeter. They would allow the French numerical models called WETSNOW1D and WETSNOW2D to be calibrated and to complete them with an experimental relation between the density and the velocity.

Water waves generated by avalanche fall into a reservoir

(Mohamed Naaim, CEMEGREF)
Sine 1983, CEMAGREF Nivologie Division has been working out a programme of research on the hydrodynamic effects caused by avalanches falling into natural or artificial lakes. Two angles of research have been developed, experiments performed on a hydraulic scale model and development of numerical models (2-D and 3-D). A three-dimensional numerical model based on shallow water equations has been developed. Van Leer schemes have been applied. The validity of the numerical models has been investigated, comparing the numerical results with those obtained from hydraulic scale model (2-D) and those from a three-dimensional scale model of the Grand'Maison dam.

Numerical models to simulate snow transport

(Claire Solignac, CEMAGREF)
To model snow transport, it is necessary to elaborate an atmospheric mesoscale model. The model developed now in CEMAGREF of Grenoble, Nivologie Division, requires starting from the hypothesis of non-hydrostatic, Boussinesq flow over some complex topography, in three dimensions, where vertical motion is important.

A diphasic wind-tunnel

(Florence Naaim, CEMAGREF)
The diphasic wind-tunnel is designed to simulate drifting snow. Several types of study are in progress: on the one hand particle paths in fluid are analyzed, thanks to laser visualization and image processing, on the other hand small-scale models are tested in a wind-tunnel in order to predict drift patterns and to establish possible control by means of snow fences, vegetation and other devices — this last application concerns roads, buildings and ski runs.

A new avalanche-blasting device: the GAZEX

(Michel Gay, CEMAGREF)
Physical measurements: we have undertaken three periods of measurements, September 1988, June 1989 and July 1990. We have measured the blast effects by means of accurate pressure gauges. The overpressure generated by 2.5 kg of dynamite was 15 mb at a distance of 50 m. The overpressure measured by the 4.5 m^3 GAZEX was 33 mb at the same distance. We have observed a longer low-pressure time with the GAZEX of 30 ms, instead of 20 ms with dynamite.

Mathematical model: we have used a mathematical model to calculate the shock wave generated by the GAZEX. This is different from the shock wave generated by a classical explosive.

Submitted by L. Reynaud

GERMANY

RECENT GLACIOLOGICAL WORK IN GERMANY

It is some years since the last report about German activities in glaciology was published in *ICE*. Meanwhile a lot of projects have been initiated or carried out, a new institute for polar research was founded in 1980 at Bremerhaven, and last year the unification of the Federal Republic of Germany and the German Democratic Republic took place. This report will present mainly current projects, but to show the interrelation between them it seems necessary to give also some general information, e.g. about the German Antarctic stations, or past projects, like the glaciological maps edited during the last years which were the results of very good co-operation in glaciology on a national and international basis. The future of glaciological activities within the polar research of the former DDR is not yet clear. There were a lot of activities, and plans are being developed to continue them. The structure of this report displays at first the main areas of investigation for the various glaciological projects on land ice (including ice shelves): the European Alpine area, Swedish Lapland, Greenland, (most recently the German scientific engagement in the Arctic is increasing), and Antarctica, mostly the Weddell Sea sector. But single institutes have been engaged also elsewhere in the world in mountain regions. A last chapter summarizes the sea ice activities.

The work was carried out by the following institutions, sometimes in co-operation with foreign institutes:

AWI: Alfred-Wegener-Institut für Polar- und Meeresforschung
BAdW: Bayerische Akademie der Wissenschaften, Kommission für Glaziologie, München
BGL: Bayerisches Geologisches Landesamt
FHM: Fachhochschule München, Fachbereich Vermessungswesen und Kartographie
GSF: GSF-Forschungszentrum für Umwelt und Gesundheit, München, Institut für Hydrologie, Neuherberg
IfAG: Institut für Angewandte Geodäsie, Frankfurt/Main
IfG: Universität München, Lehrstuhl für Geographie
IfKR: Technische Universität München, Lehrstuhl für Kartographie und Reproduktionstechnik
IfM: Technische Hochschule Darmstadt, Institut für Mechanik
IfP: Technische Universität München, Lehrstuhl für Photogrammetrie
IfV: Technische Universität Braunschweig, Institut für Vermessungskunde
IGMS: Universität Münster, Institut für Geophysik, Forschungsstelle für Physikalische Glaziologie
IPG: Universität Frankfurt, Institut für Physische Geographie
IUPH: Universität Heidelberg, Institut für Umweltphysik
UBW: Universität der Bundeswehr München, Institut für Photogrammetrie und Kartographie
ZfI: Zentralinstitut für Strahlen- und Isotopenforschung, Leipzig
ZIPE: Zentralinstitut für Physik der Erde, Potsdam

EUROPEAN ALPS

Vernagtferner

Since 1986 research at the Vernagtferner in the Oetztal Alps has been reduced to a programme comprising standard glaciological mass-balance measurements, continuous recording of glacier runoff and photographic control of the state of the glacier surface during the ablation season, nearly all the year round recording of meteorological elements and intensive surveying and mapping work. During the preceeding 12-year period scientific research was mainly focused on glacio-hydrological investigations in order to study the entire drainage system of the glacier, yielding a reasonable modelling of the runoff from the Vernagt drainage basin, which is glacierized to 84%. This part of the Vernagt programme was specially funded by the German Research Association.

Mass balance

(O. Reinwarth, BAdW)
Mass-balance data of Vernagtferner show a nearly continuous mass loss since 1982, with the maximum negative value for the 1981–82 balance year, balanced or moderate negative values in 1983–84 and 1984–85 and a persistent strong mass loss since then. In 1986 the whole mass increase of the recreation period 1965–81 was compensated and the net shrinkage of the glacier with respect to the state of 1964 continued. The present conditions are characterized by a disintegration of the entire firn area into scattered firn patches, reducing the equilibrium line altitude to a questionable term.

Glacier runoff and meteorological data

(O. Reinwarth, BAdW, in collaboration with GSF)
The serious mass losses of Vernagtferner were connected with extraordinary high runoff values in the preceeding summer seasons and in particular with enhanced daily amplitudes due to the exceptional share of bare ice area conditions the additional contribution of heavy precipitation to runoff implies a danger of overburdening the drainage system. This indeed was the case at the catastrophic flood on August 25–26 1987, which caused heavy damage throughout the whole Oetztal area and also damaged the gauging station Vernagtbach, giving rise to the first two-week break in the runoff record during summer since the stream gauge was installed in 1973. Contrary to the rather complete time series of runoff data, those of the meteorological elements suffer from occasional failure of the data logging system, installed at the gauging station, which operates all the year round, but without any maintenance from November to March.

Surveying and mapping

(O. Reinwarth and H. Rentsch, BAdW, in collaboration with IfKR, IfP, UBW, FHM)
Surveying and mapping at the Vernagtferner is not in any way confined to providing actual stake positions or new maps as a basis for current work on the glacier. Digital terrain models derived from photogrammetric evaluations of aerial photographs allow analysis of the areal distribution of elevation changes throughout the glacier as well as specification of cumulative values. Comparison of the 1979 and 1982 terrain models reveals a surge-like behaviour of the glacier in 1982 with pronounced rising of surface elevation in the tongue area, remarkable lowering in the upper part and an increase of flow velocity by a factor of 2 for 1982, connected with the maximum total runoff amount for an ablation period so far. Areal distribution of the elevation changes for the time interval 1979–82 is presented on a thematic map, derived by the computerized subtraction of digital terrain models. A new coloured orthophotomap at a scale 1:10 000, based on aerial photos from August 1990, is now in preparation. In addition to the already existing maps of 1889, 1912, 1938, and 1969, aerial photographs from 1954 were evaluated to intersect the period of 31 years before 1969. The attempted interpolation of volume changes for different time intervals by reconstructing mass-balance series, based on climatological data of the nearby weather station in Vent/Tyrol, should yield realistic figures for annual changes of Vernagtferner in past decades.

EMR measurements

(F. Thyssen, N. Blindow, IGMS)
Ice thickness and inner structure of the Vernagtferner have been revealed by high resolution electromagnetic reflection measurements (EMR) with a monopulse sounder at 35 MHz. Continuous profiling results show firn layering marked by melt water and the water table in the accumulation area, internal scattering by water pockets and channels, and a detailed bedrock topography which was further enhanced and improved by the process of migration. The project was carried out in cooperation with BAdW and GSF.

Surveying and mapping

(H. Rentsch, BAdW, in cooperation with IFKR, IFP)
Annual surveys by means of terrestrial photogrammetry continued for selected glaciers, i.e. Schwarzenstein-, Horn- and Waxeggkees in the Zillertaler Alps, Tyrol, Northern and Southern Schneeferner in the Bavarian Alps, and at time intervals of several years Grünau- and Sulzenauferner, Stubaier Alps, Tyrol, and Blaueis and Watzmanngletscher, Bavarian Alps. From these repeated mappings mean changes of surface elevation for separate altitude intervals were derived by evaluating the shift of contour lines, comparing corresponding maps.

Late-glacial and Holocene glacier fluctuations in the Zugspitz area

(G. Hirtlreiter, F. Wilhelm, IfG, H. Jerz, BGL)
In an INQUA-type area for Würm glaciation, the late glacial retreat stages of the Isar/Loisach glacier system were mapped. The variations of local cirque and valley glaciers in Late-glacial and Holocene times were investigated in the Wetterstein mountains. In the last centuries there were at least 7 small glaciers. Two of them have remained: the Schneeferner, which has lost about 90% of its area since its maximum in the Little Ice Age, and the avalanche-fed Höllentalferner, which has lost only about 40% of its area since the same period. A dated fossil soil underneath a moraine proved that Schneeferner had an advance at the end of boreal or the turn of preboreal/boreal, with a remarkable ELA depression of about 140 m compared to the 1850 ELA. The younger Dryas Egesen advance (local name "Anger") had relatively high ELA depressions of 350–450 m in the Wetterstein mountains.

Holocene glacial history of the northern limestone Alps (Bavaria and Tyrol)

(G. Hirtlreiter, F. Wilhelm, IfG, H. Jerz, BGL, O. Reinwarth, BAdW)
Earlier results from the Zugspitz area indicate that the Holocene history of some small glaciers of the northern rim of the Alps sometimes showed an individual response in comparison to the central Alpine glaciers. This may be induced by a higher sensibility to changes of main wind directions or to shorter climatic variations. Thus, climatic interpretation in general can be supported by a regional diversification of the Alpine glacial history. For this reason, the northern limestone Alps between the river Salzach and Lake Constance are investigated as an example of an area with high precipitation at the northern margin of the Alps. The interpretation of historical sources and the mapping of moraines is concentrated on areas where small glaciers still exist (Alps of Berchtesgaden, Wetterstein, Lechtal, Allgäu Alps), or existed during the Little Ice Age (Karwendel, Mieminger Alps)

Glacio-chemical records at a high altitude alpine drilling site (Colle Gnifetti, Swiss Alps)

(D. Wagenbach, K. Geis and N. Beck, IUPH, in collaboration with W. Haeberli, ETH-Zürich, Switzerland and U. Schotterer, Universität Bern, Switzerland)
Within the Alpine Wide Snow Sampling Program ALPTRAC (a glacio-chemical subproject of EUROTRAC), ice-cores drilled at the summit range of Monte Rosa, Swiss Alps, are being examined to evaluate the anthropogenic change in the continental aerosol chemistry of the mid-latitudes (see also Recent Work: Switzerland in *ICE*, 3rd issue 1990).

Present field work is directed at: (1) automatic recording of glacio-meteorological parameters including snow deposition, (2) shallow firn-core drilling in the vicinity of the bore-holes to establish the spatial pattern of stable isotopes ($\delta^{18}O$, δD), aerosol deposition and firn temperature, (3) aerosol and fresh-snow sampling for subsequent analyses of major ions, radionuclides and trace elements, (4) collection of pre-industrial cold ice from the ablation zone of Grenzgletscher for chemical base-line studies.

Comparing 100 year records of "solid state" conductivity (proxy data for acidity), pH, liquid conductivity and mineral dust measured in the Colle Gnifetti saddle core with those derived from the slope core shows reasonable agreement. This is particular true for the dominant Saharan dust spikes as well as for the systematic long-term trends of the acidity and background conductivity level (both reflecting the anthropogenic increase of mineral acids during this century). At least on the 100-year time scale we expect, therefore, no substantial disturbance of Colle Gnifetti ice-core records by glacier flow effects or by the irregular snow deposition sometimes prevailing at this drilling site. The anthropogenic effect on the Colle Gnifetti snow chemistry will be reconstructed for mineral acid components, heavy metals and, if possible, for black carbon aerosol.

Theory and laboratory experiments on flow avalanches

(K. Hutter, T. Koch and R. Greve, IfM)
We have developed a theoretical model that treats flow avalanches as a granular continuum with freely evolving surface whose constitutive response is that of a Mohr-Coulomb plastic material. Laboratory experiments in which a finite mass of plastic particles or sand moves down a curved chute or a curved inclined surface mimic the motion in nature. The geometry of the moving mass and the velocity distribution within it are observed and compared with results from theory. Agreement in chute flows is excellent. First comparisons with three-dimensional flow configurations give signs for optimism. (This work was initiated jointly with Prof. S. B. Savage, McGill University, Montreal)

SWEDISH LAPLAND

Permafrost hydrology in a sub-arctic high mountain catchment area, 68° N

(Andreas Lueck, Department of Geohydrology, University of Bonn)
During the Arctic summer of 1990 the hydrodynamics of a permafrost-underlain catchment area were investigated by the author. The basin is located in the Scandic Mountains, Swedish Lapland. Due to the altitudinal position the local climate can be classified as truly Arctic. At the end of the snowmelt development of the active layer was initiated by energy fluxes of percolating water in the middle of July. After some warm rain showers the permafrost table receded quickly. At the end of August the average thickness of the active layer ranged between 1.0 m and 1.5 m. At the same time the runoff was changing from surface flow to interflow. The latter was associated with the discharge of a partly channelized water-track flow in the coarse material on the steeper slopes. Hydrochemical analysis could be used to separate water out of glacial and periglacial drainage basins as well as special permafrost–hydrological phenomina like thermokarst processes.

Frost dynamics and geocryology in a sub-arctic high mountain area, 68° N, Lapland.

(Andreas Lueck, Department of Geohydrology, University of Bonn)
The formation of patterned ground was investigated in a sub-arctic high mountain area in Swedish Lapland. The surveys revealed various types of morphogenetic processes within one large catchment (20.6 km^2). Depending on the storage capacities of the substrata, active and fossil forms were closely associated. The frost-shattering zone was strongly influenced by the seasonal availability of water and the given petrological situation as well as by the local climate. Exposed areas to the west were much affected by the processes of frost shattering. Gelifluction lobes and frost-creep features show high mobile horizons due to a distinct water saturation on those parts of the slopes which show an angle of repose ranging between 10.5° and 20.5°.

Seasonal deposition of anthropogenic pollutions in sub-arctic regions

(Andreas Lueck, Department of Geohydrology, University of Bonn)
During the Arctic winter 1989–90 and early spring 1990, snow samples were taken for eco-toxicological analysis in a sub-arctic high mountain basin in Swedish Lapland, 68°N. Sampling in the winter was carried out by the

Department of Physical Geography, University of Stockholm, Sweden. The late winter surveys and hydrochemical analysis were done by the author. He proceeded with the sampling of precipitation through the Arctic summer 1990. The hydrochemical data of precipitation analysis indicate that the catchment is severely influenced by anthropogenic pollutants which are mainly deposited as sulphate, probably originating from Norway. Sulphate is frequently found as a product of secondary atmospheric chemical actions in the troposphere. Heavy metals were not detected except for lead on one single site, probably caused by leaking gas from the refilling of snowmobiles.

GREENLAND

The mass balance of the Greenland ice sheet

(D. Möller, H. Kock, C. Homann, IfV)
Based on former EGIG-expeditions, the line (a profile marked every 10 km across the ice sheet) was recovered and reconstructed between the west coast (T1: 72°27'N, 37°47'W) and Jarl-Joset Station (T53: 71°21'N, 33°47'W). Velocity vectors and strain rates, as well as heights, have been determined by geodetic methods. The line is connected to the location of the European deep ice-core drilling GRIP (72°34'N, 33°38'W) at the summit site by a profile between GRIP and T43 (78°07'N, 37°19'W). A strain net between GRIP and the US drill site GISP-II (28 km apart) is installed and will be extended around GRIP. GPS reference sites established at Constable Pynt and Jacobshavn are part of the European reference network EUREF.

EMR measurements along the EGIG line

(F. Thyssen, M. Jonas, L. Hempel, IGMS)
After a pre-survey in 1987, high resolution EMR measurements were carried out in the central part of Greenland in 1989 and 1990. The positions of the 1959 EGIG balises (aluminium stakes) which are buried up to 10 m underneath the present surface were located with a 200 MHz monopulse EMR sounder so the EGIG line could be reconstructed. The precision of the method was checked by digging down to the stakes at some locations. It ranged from 0.1–1 m depending on the depth of the balises. Along the whole EGIG line and the track to the European deep-drilling site GRIP and the American site GISP II at Summit, measurements with a 35 MHz high resolution monopulse sounder were performed to trace internal layering (isocrones) and structures, which may partly be correlated to ice core stratigraphy. In 1987 and 1990 airborne EMR was carried out in an area centered by the EGIG line to get information about the electromagnetic reflectivity of the bottom layer of the ice cap.

Glacio-chemical survey along the EGIG line

(D. Wagenbach, and K. Geis, IUPH, in collaboration with Physikalisches Institut der Universität Bern, Switzerland)
In the course of the current geodetic and geophysical activities along the EGIG line, shallow ice-core drilling and snow-pit sampling for chemical measurements were performed. Along the 1990 east–west transect, starting from Summit camp and ending at T1, ten firn cores were drilled to a depth of approximately 9 m. Fieldwork has been concentrated on high resolution hydrogen peroxide profiling (University of Bern), liquid conductivity measurements, documentation of stratigraphical features, fitting out of the bore holes with temperature sensors, and the aliquotation of the firn cores into well defined seasonal sub-samples. Major objectives of the programme are the evaluation of systematic spatial and temporal trends in annual snow deposition (via seasonal H_2O_2 cycle), stable isotope signature C$\delta^{18}O$, δD), as well as in the deposition rate of aerosol species (radio-isotopes, major ions, MSA, and crustal dust).

Ice margin studies at Pâkitsoq, West Greenland

(N. Reeh, H. Oerter, A. Letréguilly, H. Miller, H.W. Hubberten, AWI)
About 2000 surface-ice and water samples for $\delta^{18}O$ analysis were collected in July–August 1988 on the West Greenland ice sheet margin at Pâkitsoq, about 40 km northeast of Jakobshavn/Ilulissat. About 1450 of these samples were collected in a 750 m-long profile transverse to the ice margin. The samples were analysed for $\delta^{18}O$, yielding a palæoclimatic record reaching probably more than 150 000 years back in time, i.e. into the previous glacial. Besides detailed sampling of the profile, other surface investigations were performed: (1) collection of surface ice and water samples from five other sites on the ice margin, (2) collection of precipitation and water samples from lakes in the ice-free foreland for $\delta^{18}O$ analysis, (3) surveying work for ice movement studies and location of sampling sites, and (4) measurement of the conductivity of surface waters along profile lines on the ice-sheet margin. Analysis of the data is still in progress.

Surface ice coring at Pâkitsoq, West Greenland

(H. Oerter, N. Reeh, H. Miller, AWI)
In May 1989, eight shallow ice cores were drilled to depths of between 1 and 3 m on the West Greenland ice sheet margin at Pâkitsoq, about 40 km northeast of Jakobshavn/Ilulissat. The main purpose of the programme was to obtain ice from some of the numerous blue bands on the ice margin, in order to study the origin of the bands. Analysis of the cores for $\delta^{18}O$, δD (in collaboration with University of Reykjavik, Iceland, and GSF), crystal size, and fabrics is in progress. In collaboration with University of Utrecht, the Netherlands, a ^{14}C dating experiment was carried out on a core consisting of normal glacier ice. The surface coring programme was continued in May 1990. Ten cores to 4.5 m depth were retrieved from the same area. The main purpose was to retrieve ice cores originating from different periods of the last glacial cycle. These cores, consisting of normal glacier ice, will be analysed for $\delta^{18}O$, solid conductivity, trace elements (microparticles, chemistry, gas composition, etc.), ice crystal size and fabrics, and the results will be compared with information from existing (Camp Century and Dye 3) and future (GRIP and GISP) deep ice cores from Greenland. A continuation of the ^{14}C dating experiment (in collaboration with University of Utrecht, the Netherlands) is also planned.

Ice margin studies in Germania Land, northeast Greenland

(N. Reeh, H. Oerter, H. Miller, H.W. Hubberten, AWI)
In July–August 1989 and 1990 a glaciological programme was carried out on the margin of Storstrømmen Glacier

(77°N, 22°W), northeast Greenland. The investigations were made possible by participating in and sharing logistics with an expedition to northeast Greenland organized by the Geological Survey of Greenland, Copenhagen, Denmark. More than 4000 surface ice and water samples were collected for $\delta^{18}O$ analysis. The major part of the samples were taken in two parallel profiles transverse to the ice margin about 500 m apart. The length of the profiles was 2000 m and 1500 m, respectively. The results obtained so far indicate that the transition from ice deposited in the last glacial to ice deposited in the present interglacial is located about 1500 m from the ice margin, and that the palæoclimatic record covers most of the last glacial cycle and probably more. Moreover, the ice dynamics along the flow line leading to the sampling location on the ice margin were investigated: surface ice velocities were measured by means of repeated satellite positioning (Doppler as well as GPS, in collaboration with Kort- og Matrikelstyrelsen, Copenhagen, Denmark) and standard surveying methods along a more than 80 km section from the equilibrium line at about 1100 m elevation to the ice margin at about 200 m elevation.

Ablation studies, northeast Greenland

(H. Oerter, N. Reeh, AWI)

During the 1989 and 1990 expedition to Storstrømmen glacier, northeast Greenland, all the stakes used for surveying and marking the sampling sites were handled as well as the ablation poles. The 2 km-long stake line at the margin (spacing 50 m) was observed almost daily, the 80 km-long stake line (spacing 10 km) several times during the summer period. Meteorological observations at the same time in the area provide data to calculate degree day factors, the elevation interval of 900 m makes it possible to derive a correlation between ablation and altitude. Some stakes may be remeasured in 1992.

Parameterization of melt rate and surface temperature on the Greenland ice sheet

(N. Reeh, AWI)

Melt rate and surface temperature on the Greenland ice sheet was parameterized in terms of snow accumulation, mean annual air temperature, and mean July air temperature. Melt rates were calculated using positive degree-days, and firn warming (i.e. the posititive deviation of the temperature at 10–15 m depth from the mean annual air temperature) was estimated from the calculated amount of refrozen melt water in the firn. A comparison between observed and calculated ablation rates on the West Greenland ice sheet margin between 61°N and 76°N shows good agreement. The average equilibrium line elevation is estimated to be c. 1150 m and 1000 m for West and East Greenland, respectively. The total annual melting from the ice sheet is found to be 280 km^3 of water equivalent per year. The melt-rate model predicts significant melting and consequently significant firn warming even at the highest elevations of the south Greenland ice sheet, whereas a large region of central Greenland north of 70°N experiences little or no summer melting. These findings agree well with observations.

Ice dynamic model studies of the Greenland ice sheet

(N. Reeh, AWI, P. Huybrechts, AWI and Vrije Universiteit, Brussels, A. Letréguilly, AWI)

The dynamics of the Greenland ice sheet were investigated by means of the three-dimensional, time dependent, fully coupled thermo-mechanical ice-sheet model developed by P. Huybrechts. Boundary conditions were the basal topography of the ice sheet as determined by means of airborne radio-echo soundings, and parameterizations of surface mass balance and surface snow/ice temperatures in terms of mean annual air temperature, mean July air temperature, and annual snow accumulation. The present state of the ice sheet was investigated, using present distribution of air temperatures and snow accumulation. The calculated ice-sheet topography was in excellent agreement with observations. The sensitivity of the mass balance and dynamics of the ice sheet to a temperature perturbation (greenhouse warming) was also investigated. Studies were also performed of the steady-state ice sheets that would develop in Greenland under various climatic conditions. Among other things, these studies indicate that if removed, the ice sheet would still reform under the present climatic conditions, and that a climate warming of more than 6 K would be necessary in order to make the ice sheet disappear completely. Model runs with a climatic forcing simulating the last glacial climate cycle indicate that the Greenland ice sheet survived the last interglacial (the Eemian), though with a reduced volume. Very likely, the ice sheet had at that time split up into a large north-central ice sheet and a much smaller southeast ice sheet. Model studies of the Greenland ice sheet will be continued.

Time-dependent response of the Greenland ice sheet to climatic forcing

(K. Hutter and R. Calov)

Finite difference routines for the shallow ice equations that were developed by Herterich and Calov, and are applicable to wholly cold ice, are used and extended in time-dependent runs for the Greenland ice sheet. We are interested in a three-dimensional temperature and flow response through ice-age cycles to identify possible "hot spots" at near base layers. Presently, the thermal regime of a rigid lithosphere is incorporated; future activities will concentrate upon incorporation of a thermo-viscoelastic lithosphere, a viscous asthenosphere and comparison with observed surface temperature and mass balance.

Physical properties of the GRIP ice core

(S. Kipfstuhl and H. Miller, AWI)

In 1989 on the Greenland ice sheet at summit the European Greenland Ice Core Project (GRIP) started. Amongst the participating eight European nations the German activities are represented at the moment mainly by AWI. The investigations concentrate on the physical properties of the ice core. During the 1990 field season an ice-core bench was set up for measuring density (using gamma absorption), p-wave velocity, magnetic susceptibility and AC-conductivity. The measurements were continuously performed at intervals of between 3 and 20 mm. Vertical thick sections were cut to determine *c*-axis orientation and grain-size distribution. From 10 different depths the mechanical relaxation of the core was registered for periods of 1–7 days. It is planned to continue these measurements in the 1991 field season.

LAND ICE AND ICE SHELVES IN ANTARCTICA

General

The German stations in Antarctica

(H. Kohnen, AWI)

1. **Georg-von-Neumayer-Station** (Ekstrømisen, 70°36′S, 8°22′W)
Just 10 years ago, in 1981, the Georg-von-Neumayer-Station was constructed as a wintering base. It comprises of an observatory for meteorology, geophysics, and air chemistry. Furthermore it provides the logistic base for glaciological and other work on Ekstrømisen and in Queen Maud Land. In 1990 an all women team spent the winter at the station. A new station will be constructed in 1991–92 nearby to replace the old one.
2. **Georg-Forster-Station** (70°47′S, 11°50′E)
Georg-Forster-Station was the wintering base of the former GDR. For the future this station will be run as a summer base only from where geoscience studies will be carried out at Schirmacheroasen and in the nearby mountain region. Some parts of the former winter programme will be shifted to Georg-von-Neumayer-Station, whereas other parts of the programme will be carried out in cooperation with the Soviet station Novolazarevskaya as a joint venture project.
3. **Filchner-Station** (Ronne Ice Shelf, 77°6′S, 50°18′W)
Filchner-Station was built as an over-snow construction in 1982, and is used as a summer base only. It is the main basis for the long-term glaciological work on the Filchner–Ronne-Schelfeis.
4.**ERS1/VLBI station** (Antarctic Peninsula)
Adjacent to the Chilean station O'Higgins, Antarctic Peninsula, a tracking station is under construction for the European scientific satellite ERS 1 and for similar succeeding satellites. There especially the SAR data (Synthetic Aperture Radar) will be received besides the usual bands. They will be used to investigate continuously and without being influenced by weather conditions the sea-ice dynamics of the Weddell Sea, as well as the greater art of the West Antarctic ice shelves and ice sheet. Connected to the programme of this station is a VLBI (Very Long Baseline Interferometry) experiment to study the continental drift as well as sea level variations. The station will be run as an joint venture project with Chile.
5. **Dallmann Laboratory** (King George Island)
At the planning stage is a laboratory for biological and geoscience studies on King George Island. This lab is an annex station to the Argentine station Jubany, and means a joint venture project with Argentina.

Satellite image mapping

(J. Sievers, IfAG)

IfAG is producing topographic image maps at scales of 1 : 1 000 000 and 1 : 250 000, based on digital Landsat imagery. Map projection parameters have been used in accordance with the recommendations of the SCAR Working Group on 'Geodesy and Geographic Information'. After preprocessing and geocoding of the digital satellite image data the images are mosaicked and radiometricly adjusted. To offer maximum information for further visual interpretation, only the geographic graticule, selected place names and spot height information are superimposed.The following maps are published:

SS 28-30 Ritscherhochland 1 : 1 000 000
SS 25-27 Brunt Ice Shelf 1 : 1 000 000
and 13 maps at 1 : 250 000 scale (subdivisions of map sheet SS 28-30).

Aerial photogrammetry

(J. Sievers, IfAG)

During four German Antarctic expeditions (1983–84, 1985–86, 1986–87, 1988–89) about 15 000 aerial photographs were taken. The regions covered are documented in survey flight index maps published by IfAG. The aerial photographs are used to produce orthophoto maps and digital elevation models of mountainous regions with a grid spacing of 50 m × 50 m. A map index is available at IfAG.

Geocoded information system of Antarctica (GIA)

(H. Schmidt-Falkenberg, H. Bennat and J. Sievers, IfAG)

IfAG is preparing GIA to provide a tool for managing multidisciplinary scientific information.

The greatest amount of data will be built by satellite-image data of the different systems, like NOAA AVHRR, LANDSAT MSS, LANDSAT TM, SPOT HRV, KOSMOS KATE 200, ERS-1, etc. Furthermore, we will have data bases of aerial photos, control points, maps, geographical names, digital elevation models etc. Within GIA all data will be available in a form geocoded to a uniform reference system which is the prerequisite for universal utilisation of GIA.The Antarctic region covered ranges from 10°E to 90°W.

Antarctic topographic database — the coastal region from western Neuschwabenland (3°E) to Filchner–Ronne-Schelfeis (85°W)

(J. Sievers and B. Heidrich, IfAG, H.W. Schenke and M. Thiel, AWI)

To prepare a digital coastline together with other digital topographic data (formlines, inland glacial features, ice fronts, etc.) derived directly from satellite imagery, more than 80 geocoded Landsat MSS images (nominal scale 1 : 400 000) were interpreted at IfAG and digitized at AWI to serve as a basis for navigational, glaciological and other scientific purposes. Additionally this database should become the German contribution to the 'Antarctic Digital Database Project' initiated by the World Conservation Monitoring Centre (WCMC), British Antarctic Survey (BAS) and Scott Polar Research Institute (SPRI) and supported by the SCAR Working Group on Geodesy and Geographic Information.

Geomorphological-glaciological map 1 : 50 000, Neuschwabenland

(K. Brunk, IPG)

As a result of the expeditions in 1983–84 and 1984–85, this map was compiled using a new mapping concept which in part follows the legend of the German geomorphologic map series at 1 : 25 000 scale (GMK-25) and the concept of Hirakawa and others (1984, Antarctic geomorphologic map of Langhovde, explanatory text. Spec. Map. Ser. Nat. Inst. Polar Res. 1, 63 p., Tokio). On the basis of contour lines and orthophotos provided by IfAG the surface is characterized by its morphometric, genetic and dynamic features.

Maps of ice shelf kinematics of Ekstrømisen

(J. Sievers, IfAG, K. Grosfeld and F. Thyssen, IGMS, B. Ritter, IfV, H. Hinze and H.W. Schenke, AWI)

Ekstrømisen extends east–west from Unneruskollen (6° W) to Auståsen/Söråsen (10° W) and southwards to 71° 40′S latitude. The ice shelf covers 8700 km^2 of this area, including the ice rise (27 km^2) at the south side of Atka Iceport as well as ice rumples (76 km^2). The map sheet published in 1989 comprises a satellite-image map and a topographic map at 1 : 500 000 scale as well as of five inset maps at various scales. The map shows some kinematic glaciological parameters of Ekstrømisen and summarizes geodetic-photogrammetric results obtained since 1980–81, during the period that Georg-von-Neumayer-Station has been operating.

Glaciological traverse across Ekstrømisen to Ritscherhochland, 1986–87

(O. Reinwarth, BAdW, in collaboration with AWI, GSF, IfV, IUPH)

This traverse, leading straight to the south from Georg-von-Neumayer-Station into Ritscherhochland was originally planned as Filchner III campaign with comprehensive fieldwork on the eastern part of Ronne Ice Shelf. Yet adverse ice conditions in the region southwest of Halley prevented RV *Polarstern* from reaching the ice shelf. As a consequence the whole schedule had to be modified and was finally carried out as a complex field programme extended to the Ekstrømisen, the adjacent slope and marginal zone of Ritscherhochland.

For nearly 6 weeks 19 scientists and technicians operated in this area, split into several groups. Five two-man groups took care of geodetic measurements in order to derive strain and movement data related to a net of grid points, as well as precise altitudes by trigonometric levelling along the traverse line. Tilt records, gravimetric, magnetic, and seismic measurements completed this part of the programme in order to describe the dynamics of the ice shelf. The main group was concerned with a glaciological programme including snow pit measurements and 10 m drillings, as well as stake readings along the entire 270 km traverse line. Substantial effort was devoted to drilling operations yielding two ice cores of 43 and 48 m from Ritscherhochland, and a 205 m core from Ekstrømisen.

The glaciological work aimed to study accumulation and its dependence on distance from the ice edge and altitude. As far as possible annual rates were derived from stable isotope stratigraphy. They ranged from close to 30 g cm^{-2} to less than 6 g cm^{-2}, scattering remarkably with locality and time. Because of the very low accumulation rates at the Ritscher Plateau, the isotopic signal does not show any more distinct annual variations. Accumulation rates here are based on profiles on the tritium content, other dated reference horizons, and finally on stake readings. Intense studies of trace element distribution should help to support or improve the interpretation of isotope profiles.

Glacial geodetic contributions to the mass balance and dynamics of Ekstrømisen

(D. Möller, B. Ritter, A. Karsten, IfV)

During the campaigns of 1986–87, 87–88 and 89–90 on Ekstrømisen, repeated determinations using TRANSIT and NAVSTAR observations of absolute positions (latitude, longitude, height) of 25 selected points at distances of 10–20 km gave the basis for the determination of the velocity field. The strain field of Ekstrømisen was evaluated from 25 deformation figures measured twice during the above mentioned campaigns. Three hundred sea-level heights at point intervals of 1 km were determined by motorized trigonometric levelling on the ice-shelf and along the traverse to the Ritscherhochland.

EMR measurements on Ekstrømisen and Ritscherhochland

(F. Thyssen, N. Blindow, K. Grosfeld, IGMS)

During five field seasons from 1980–81 to 1989–90, about 23 000 km of airborne and about 1000 km of high resolution ground-based EMR measurements were carried out in the area of Ekstrømisen and Ritscherhochland. The airborne measurements yielded data of surface elevation and ice thickness, which are compiled in maps.

Ground based measurements depict firn layering and detailed bottom topography, which is complicated in the inner part of the Ekstrømisen.

Icequakes and ice shelf moving

(U. Nixdorf, AWI)

North of Georg-von-Neumayer-Station two concentric observation networks were built up and maintained around the tip of an inlet from February 1987 to February 1988. One of the networks, a circle with a radius of 500 m, consisted of a net of up to eight seismological stations with digital, event-triggered registration. The other was a deformation figure in the form of a pentagon with side lengths of 600 m. The opening of the inlet and its development with time could well be determined. Approximately 1000 micro-icequakes were recorded from February to April 1987. Twenty events out of them could be located in or close to the seismological net, another 30 events are closely related to them. The registration of those events located in the net supports the hypothesis that seismic events at inlet areas are due to tension faults because of ice-shelf moving.

Glaciological map of Filchner–Ronne-Schelfeis

(C. Swithinbank, Cambridge, K. Brunk, IPG, J. Sievers, IfAG)

The map is based on a glaciological interpretation of a mosaic assembled from 66 Landsat-5 MSS images showing the Filchner–Ronne-Schelfeis and adjacent regions in early 1986. All linear features on the map like grounding lines, strand cracks, rifts, flow lines, ice stream margins, ice fronts and margins between ice rises, ice rumples and the surrounding ice shelf etc. are traced directly from image mosaic. The map was published in 1987 at a scale of 1 : 2 000 000.

Dynamics of Filchner–Ronne-Schelfeis

(D. Möller, B. Ritter, A. Karsten, IfV)

In the course of the Filchner–Ronne Ice Shelf Programme (Campaigns I (1983–84), II (1985–86) and IIIa (1989–90)) observations extended over three field seasons. A pattern of observation points and deformation figures covers the eastern part of Ronne Ice Shelf and the ice front region at point intervals of 50 and 100 km, respectively. Ice velocities and strain-parameters are evaluated in 15 of these locations. The programme will be continued in 1991–

92. Snow-surface heights (600 points at 1.25 km distance) were levelled for the first time in 1990.

EMR measurements on Filchner–Ronne-Schelfeis and Berkner Island

(F. Thyssen, N. Blindow, K. Grosfeld, IGMS)

During the field seasons 1983–84, 1985–86, and 1989–90, 50 000 km of airborne and about 1500 km of high resolution surface EMR measurements were carried out, mainly in the central part of the Filchner–Ronne-Schelfeis. The airborne measurements yield data of surface elevation by high resolution radar, barometric altimetry and EMR ice thickness, which is the total ice thickness in areas where no or only a thin bottom layer exists. In areas of active bottom freezing and a thick basal layer the ice thickness is calculated from surface elevations by the buoyancy relation. From these results, about 30% by volume of the central part of the Filchner–Ronne-Schelfeis consists of basal marine ice. Surface EMR measurements show internal layering and remnants of former crevasses in the upper meteoric part, details in the transition to the marine ice and, in some areas, layers within the basal ice. The areas south of Henry Ice Rise and Doake Ice Rumples as well as the entire Foundation Ice Stream consist of meteoric ice. Several profiles over Berkner Island give details of its double domed bedrock topography with different reflectivities and the surface elevation. The data of the first two field seasons have been compiled in maps.

Ice-core drilling

(H. Oerter, C. Drücker, H. Miller, AWI)

At AWI facilities for shallow ice-core and near surface firn-core drilling are available. They were used during the 1989–90 Antarctic field season to recover the 215 m deep ice core B13 (diameter 72 mm) from the Filchner–Ronne-Schelfeis as well as 10 m firn cores along a traverse route upstream of the drilling site B13 on Berkner Island. B13 was located at 76°58′ S, 52°16′ W, approximately 50 km west of the German summer base Filchner, and 30 km away from the ice edge. The borehole penetrated the meteoric ice and met the saline ice layer at a depth of 152 m. The drilling came to an end 25 m above the very bottom of the ice shelf, which was determined by EMR measurements (c.f. Thyssen and others, above) to be 239 m thick. A new 100 mm drill is under construction which will be used during the next Antarctic field season in summer 1992. The favorite drilling site most probably will be on a flowline, about 80 km upstream of B13, where we assume accumulation of saline ice under the ice shelf. Furthermore, an advanced hot water drilling device is also under construction to pierce the ice shelf at the same location.

Physical properties of ice

(H. Oerter, H. Eicken, S. Kipfstuhl, AWI)

Investigation of the physical properties of both the meteoric and the saline ice of the ice core B13 is in progress at the labs of AWI, comprising so far mainly: (1) thin sections for ice fabrics analysis, (2) ultra sonic measurements (p-wave), and (3) electric conductivity (AC with varying frequencies). The aim of these investigations is to study the differences between meteoric and saline ice, and to find out under which conditions freezing underneath the ice shelf may take place.

Isotope studies

(W. Graf, GSF, O. Reinwarth, H. Moser, BAdW)

Measurements of stable isotope content of samples from snow pits and shallow ice cores form the basis of the glaciological research programme on the Filchner–Ronne-Schelfeis since its very beginning in 1980. Depth profiles of $\delta^{18}O$ and δD show well developed annual variations, clearly recognizable also to greater depths as proved by analysis of a 100 m core, drilled in 1984 at a distance of 220 km from the ice edge. These profiles allow for a reliable determination of annual accumulation rates. Results of four field seasons provide a detailed picture of areal distribution of accumulation for the eastern part of the ice shelf, the rates decreasing with distance from the ice edge, and being less pronounced from west to east. They also reveal the pattern of mean isotope values of near surface layers, characterized by an enhanced continental effect as compared to other ice shelf regions. The relation of the isotope values to the 10 m temperatures yields a very large isotopic gradient of $\delta^{18}O$ values with mean surface temperatures of 1.15‰ per 1 K. This temperature relation was applied to analyse climatic informations stored in the isotope profile of the 100 m core covering 520 years as dated by isotope stratigraphy. Variations of the accumulation rates were also derived. The 215 m-deep ice core B13 (see above) confirmed accretion of sea water ice to the ice shelf which is encountered as accumulation below 153 m depth, with $\delta^{18}O$ and δD values of 2.15 ± 0.18‰ and 15.4 ± 1.4‰, respectively. The meteoric ice of the upper 153 m of this core provides the possibility for further climatic investigations of accumulation rates, and temperature variations in the past. The recent near surface values in the catchment area of the core can be deduced from 10 m cores taken on a flow line through the drilling site up to 500 km upstream.

Glacio-chemical investigations

(D. Wagenbach, A. Minikin, IUPH)

Our investigations are based on the chemical analysis of shallow firn cores drilled at increasing distances from the coastal line, and on the 215 m-deep ice core B13 (drilling of an additional, about 350 m-deep ice core is planned for 1991–92). The chemical analysis of sea-salt ions, nitrate, nss sulfate and methanesulfonic acid (MSA) is supported by measurements of natural radio-isotopes, and microparticles, electrical conductivity profiling (ECM method), and quasi continuous measurement of pH and electrolytical conductivity by flow injection.

Our main objectives are: (1) to reveal the distribution of the various impurity concentrations, particulary upstream from the B13 drilling site, (2) to evaluate representative deposition fluxes of sea-salt, nitrate, and the biogenic sulphur componds (nss sulfate, MSA) adjacent to the south polar ocean, (3) to reconstruct the sea-ice conditions (via sea salt), and the palæoproductivity (biogenic sulphur) of the Weddell Sea over the last 300 years, approximately, and (4) to characterize the chemical properties of the marine part of the ice shelf and their systematic variation.

Essential support for the interpretation of recent snow chemistry is provided by our long term aerosol record from the coastal Georg-von-Neumayer-Station.

Important results concerning the glacio-chemistry of the Filchner–Ronne-Schelfeis are: (1) there is a clear seasonal cycle of the nss sulfate and MSA concentrations as well as the ECM signal within the firn layer, (2) in the marine ice the sea-salt concentration is rather low

(< 90 ppm); the sulfate-to-chloride ratio is significantly below the sea-water ratio and decreases with increasing depth.

Permittivity of meteoric and marine ice

(N. Blindow and S. Gross, IGMS)

The dielectric properties of meteoric and marine ice from a core of the central part of the Filchner–Ronne Ice Shelf have been measured in the frequency range from 10 Hz to 100 MHz at temperatures from -40° C to -2° C. The results show distinct differences in Debye relaxation and high frequency conductivity, indicating the permittivity of marine ice is similar to that of doped laboratory ice. Values for activation energies and RF propagation constants have been derived from the data.

Hot water drillling

(K. Grosfeld, N. Blindow, L. Hempel, IGMS)

In 1985–86, the first hot-water drilling was performed in the central part of the Filchner–Ronne-Schelfeis by Engelhardt and Determann. It pierced the ice shelf at a depth of 465 m and proved the existence of a thick basal layer of saline ice, as predicted by Thyssen. During the field season 1989–90, about 50 km west of Filchner Station, several hot-water drillings enabled access to the bottom of the ice shelf and the sea underneath. The holes were mainly used to insert five chains equipped with 65 Pt-100 elements to measure the temperature–depth profile down to the bottom of the ice shelf and in the sea water. Three boreholes were used to insert cables for time-domain reflectometry measurements, a new technique to measure the bottom melting rate with high reliability. Access to the sea water was used for water sampling and to try the installation of a current meter.

Ice-shelf modelling

(J. Determann, AWI)

A new model for ice-shelf flow was established (2D, horizontal). Finite-difference simulations of Filchner–Ronne-Schelfeis on a 10 km × 10 km grid can reproduce observed flow patterns. The model includes an attempt to simulate restrained flow due to basal friction over ice rumples. On the basis of the mass conservation equation, the calculated flow field is used to derive basal melting rates underneath the ice shelf necessary to maintain the extent of a basal layer of saline ice which is up to 400 m thick. Thereupon, though locally restricted, basal accumulation rates in excess of $2\,\mathrm{m\,a^{-1}}$ are obtained. Different assumptions on basal melting rates enter into prognostic studies representing 2000 years of future ice-shelf evolution revealing that the steady-state thickness profile strongly depends on ice shelf/ocean interactions. Prognostic simulations stress that all ice streams feeding into Filchner–Ronne-Schelfeis underlie extensive basal melting. The fact that the overall melting underneath Filchner–Ronne-Schelfeis amounts to about 50% of the incoming ice stresses the importance of ice/ocean interactions on the mass budget of the Antarctic Ice Sheet. Further, the model is used to simulate the flow of Ekstrømisen, Antarctica, on a 2.5 km × 2.5 km grid.

Glaciological features and satellite image maps of Herzog-Ernst-Bucht and Filchnerschelfeis

(Th. Wintgens and H. Schmidt, FHM; O. Reinwarth, BAdW; B. Heidrich and J. Sievers, IfAG)

As a multidisciplinary approach of glaciology, remote sensing and cartography, two thematic satellite image maps at 1 : 250 000 scale were published in 1990. The maps are the experimental result of preserving the image character of the satellite imagery in the maps and of enhancing the thematic glaciological information content by graphical elements.

Geodetic–glaciological investigations in the vicinity of Schirmacheroasen

(R. Dietrich, ZIPE)

The GEOMAUD traverse runs from Schirmacheroasen south to Wohlthatmassiv (Insel mountain) along a length of about 70 km. It is connected to a geodetic network on bedrock in the Schirmacheroasen and on nearby nunataks. Based on repeated theodolite observations and electro-optical distance measurements in 1989–90 and 1990–91, the altitude of the ice surface, horizontal and vertical ice velocities, and deformation rates were determined. Accumulation measurements were also performed along GEOMAUD. The horizontal ice velocities of up to $70\,\mathrm{m\,a^{-1}}$ underline the dynamics of this region.

In 1990–91 a second traverse was established which goes southeast from Schirmacheroasen to the Wohlthatmassiv (Untersee region). Remeasurements are planned for 1991–92 and they will be combined with subsurface mapping by radio-echo soundings (project EISMAUD). These activities (determination of surface and subsurface geometry, accumulation, ice velocity and deformation) are one part of the complex glaciological investigations to be done in this region.

Isotope–glaciological and palæoenvironmental studies in northern Dronning Maud Land, near 12° E

(W.-D. Hermichen, ZfI)

Since 1978 scientists of the Central Institute of Isotope and Radiation Research, Leipzig, in collaboration with colleagues from Soviet Antarctic Expedition and from Estonian Academy of Sciences, have been studying the isotopic composition of ice and snow as well as the isotope-hydrological characteristics of periglacial lakes of the area surrounding the base Georg-Forster, Schirmacheroasen. δD- and/or δ^{18}O-profiles from Soviet deep drilling ice cores from the ice shelf to the north of the Schirmacheroasen and from an accumulation area at 1000 m a.s.l. from the surface of large blue-ice fields and ablation areas at the margin of the inland-ice near 12° E were used to establish a preliminary model of recent ice-sheet structure and late-Quaternary evolution of this marginal part of the East Antarctic ice sheet. A δ^{18}O-temperature relationship, which differs significantly from that of the I.A.G.P. area, was elaborated to reconstruct palæotemperatures from isotope data of old ice. The last ones point to differences between late-Pleistocene and Holocene regional temperatures of 4 to 12 K, whereas Holocene long-term means of surface temperatures seem to have varied only by 1 K. These data are supplemented by δ^{18}O values of dead ice from old lateral moraines covering the flanks of the Wohlthatmassiv and the Humboldt Mts. Thus, we conclude that during the late-Quaternary increases of ice volume in northern Dronning Maud Land were linked with cold (sub-) stages, exclusively. In places the minimum age of moraines was dated by ^{14}C studies on fossil organic material from breeding colonies of petrels. Complementary palæoenvironmental information is expected from lake sediment cores, which will be gained in the area of Schirmacher-oasen during a joint German-Soviet field campaign in 1991–92.

MISCELLANEOUS

Thermo-viscous Stokes flow in glaciers and ice sheets

(K. Hutter, S. Qin and A. R. Sepehri, IfM)
It is known that the shallow ice approximation is invalid close to the margins, at an ice dome and in fast ice streams. In order to better account for these regions and better predict mass loss in fast streams, but also to be able to model, for example, the confluence of two cold glaciers, a finite element program for thermo-viscous Stokes flow in a three-dimensional domain with freely evolving free surface has been developed. Preliminary computations show it to be suitable for the problems considered, but its suitability for real glacier/ice sheet problems must still be demonstrated.

Mixture theory applied to glacier and ice-sheet flows

(K. Hutter and J. Schneider, IfM)
The temperature ice region in polythermal ice masses, temperate ice (saturated and unsaturated with water) in wholly temperate glaciers, "dirty" ice, water saturated sediments, etc. are treated as continuous mixture bodies. At present, the analysis is chiefly theoretical but we aim to answer specific problems related to flow of glaciers, emphasizing both a global and a local point of view.

Glacier inventory of Tröllaskagi Peninsula, northern Iceland

(J. Stötter, F. Wilhelm, IfG)
The results of the Little Ice Age glaciation of about 30 small glaciers of the Tröllaskagi peninsula show a complex relationship between climatic changes and glacier behaviour. Using a lapse rate of 0.65 K/100 m the mean rise of the ELA from Little Ice Age to present ELA of about 50 m does not fit with a change in mean summer temperature of about +1.5–2.0 K for the same period. An increase in (winter) precipitation is required to offset the warmer temperatures. The variations of both temperature and precipitation parameters seem to be strongly influenced or even controlled by the changing extent of the sea ice around the northern coast of Iceland. As basic work for a better understanding of this complex system it is planned to establish an inventory of the glaciers of Tröllaskagi peninsula, which contains both the present and the Little Ice Age extent of glaciation.

It is intended to do this research programme in co-operation with World Glacier Inventory Programme, C. Caseldine (University of Exeter), T. Häberle (University of Zürich), and Icelandic authorities.

Glaciological activities in Alaska

(Walter M. Welsch, UBW, in cooperation with BAdW)
The Juneau Icefield Research Program (JIRP) in Alaska was organized by M.M. Miller, University of Idaho, in 1946 to pursue long-term research on the interrelationships of scientific disciplines necessary to understand the total environment of arctic and mountain regions. The Summer Institute of Glaciological and Arctic Sciences was organized in 1959 to provide combined academic and field training, both at the graduate and undergraduate level, so essential to the solution of these multi-varied problems. The aim is total systems competence in potential polar and mountain scientists, and practical field training for geologists, geophysicists, atmospheric scientists, resource planners, ecologists, and surveyors.

Since 1981 UBW in cooperation with BAdW, supervised by W.M. Welsch, have been in charge of the geodetic measurements necessary for JIRP, i.e. terrestrial geodetic and photogrammetric measurements, lately also satellite supported observations (GPS). These measurements are applied for recording the velocity and deformation behaviour of various glaciers of the icefield, and for monitoring glacier termini and glacier lakes. The aim of the geodetic activities is to contribute to the investigation of the dynamics and mass balance of the Taku Glacier system in particular.

Glacier retreat in the Cordillera Real (Bolivia) since 1928

(R. Finsterwalter, IfKTUM)
For the northern part of Cordillera Real glacier maps exist of the glacier around Illampu (6368 m) based on surveys in 1928, 1963, and 1975 and of glaciers surrounding Illamani (6420 m) indicating the states of 1975 and 1983. From these maps changes of the glaciers for the different time intervals between 1928 and 1983 have been evaluated. The amount of retreat and areal shrinkage is less compared with Eastern Alpine glaciers. Contrary to the advance of Alpine glaciers between 1965 and 1980, no growth of glacier was observed in the Cordillera Real. A map *CORDILLERA REAL NORD (*Illampu) 1 : 50 000, representing the glacier state of 1963, was recently published.

SEA ICE

Physical, chemical and biological properties of sea ice

(M.A. Lange, H. Eicken, G. Dieckmann, M. Spindler, R. Gradinger, AWI)
We have extensively studied the properties of Antarctic sea ice during six expeditions into the Weddell Sea area in winter, spring and summer. Our investigations have been centered on the assessment of ice texture, which serves as a guide for subsequent analyses of physical, chemical and biological properties. Our aim is to find empirical relations between different ice properties in order to define sea-ice properties as a function of external parameters in the surrounding ocean and atmosphere. In the course of our investigations, we identified a number of basic processes which lead to the rapid advance of the sea-ice cover in Antarctica during fall and winter (the so-called pancake-cycle), as well as processes that prevail during the further development of the sea ice throughout the year. We were also able to show that sea-ice properties vary significantly on a small scale, largely following the textural stratigraphy of each ice core and comparable to larger scale variations on a meter-to-kilometer scale of the ice cover under investigation. These studies are continued, now focussing on the assessment of the role of sea-ice properties and processes in global environmental changes, as well as on

the effects of those changes on sea-ice properties. While our investigations have been primarily carried out on Antarctic sea ice, we have participated in an expedition into the Arctic and have analyzed a great number of ice cores from the Arctic. One of our aims in these investigations is the identification of sediment-laden sea ice and its role for sedimentation processes in the Arctic basin and in Fram Strait. We also address the question of possible effects of sediment-laden sea ice on the global radiation budget in past climatic changes.

^{18}O measurements on sea ice

(M.A. Lange, H.W. Hubberten, AWI, in co-operation with P. Schlosser, LDGO, Palisades, NY, USA)
During the past three years we have started a programme assessing the distribution of ^{18}O in sea ice of the Arctic and Antarctic. The major goal is the quantitative assessment of meteoric ice on the overall mass of the sea-ice cover. This contribution to the sea-ice component in the coupled system ocean–ice–atmosphere is of considerable importance in global mass balance studies of this system. We have shown that meteoric ice does indeed occur in considerable quantities in Antarctic sea ice, amounting to between 3 and 6 Vol. % of the overall ice cover as a mean. While this might not seem overly important, one has to keep in mind that congelation growth underneath the primary ice sheet is minimal in large parts of the Antarctic. Another, as yet unexplained observation, regards the spatial distribution of ^{18}O within the sea ice floes. We find that ^{18}O in many cases steadily increases with depth within the ice regardless of the texural distribution of the floe under investigation. On the other hand, we find pronounced ^{18}O-signals, caused by meteoric ice at the top of rafted floes. Thus, ^{18}O also serves as a tool for unraveling the developmental history of a particular ice floe.

Ice thickness distribution of sea ice

(M.A. Lange, H. Eicken, AWI, in co-operation with Scott Polar Research Institute, Cambridge, GB and CRREL, Hanover, NH, USA)
As part of our field programmes, we have assessed the sea-ice thickness distribution in the Arctic and in Antarctica by means of direct measurements in mechanically drilled holes. One of our major findings is the fact that undeformed first-year sea ice in the Antarctic amounts to only 0.4–0.6 m in thickness, i.e. considerably less than first-year ice in the Arctic. We have also shown that sea ice thickness distributions can be classified into four distinct thickness classes based on their propability density functions (pdf's) for snow and ice thicknesses. These classes correspond to particular developmental histories for each of the classes. In addition, we have shown that assessing sea-ice thicknesses by measurements in mechanically drilled holes along straight profiles gives results which are compatible to measurements done by means of upward-looking sonars from submarines. We also find close correspondence between probability density functions of sea ice thicknesses derived through random sampling and through our technique.

Surface characteristics of Antarctic sea ice

(M.A. Lange, H. Eicken, AWI, in cooperation with NASA Goddard Space Flight Center, Greenbelt, MD, USA and Center for Research in Experimental Space Science, York University, North York, Ontario, Canada)
In an attempt to calibrate passive microwave measurements on sea ice, obtained through satellite remote sensing, we have carried out an extensive programme of surface characterization of sea-ice floes. We look at detailed snow characteristics (temperature and density distribution, stratigraphy, ^{18}O, H_2O_2) as well as at detailed physical and chemical characteristics of the top 10 to 20 centimeters of the sea-ice floe. Through standardized measurement techniques, we are able to assess the spatial variability of surface properties on a scale of 10–20 m. This lies in the same range as the footprint of measurements done at the same time by ship-borne microwave sensors. One of our results allows the assessment of brightness temperatures as a function of snow thicknesses for different frequencies.

Ice core analysis bench

(M.A. Lange, A. Frenzel, U. Wieschollek, AWI)
During the last few years, we have designed and tested a semi-automatic ice core analysis bench for the assessment of physical ice properties. One of our major objectives is the assessment of internal ice structure by means of ultrasonic measurements which will be utilized for acoustic tomography. Our intensive tests have demonstrated the feasability of such measurements on sea ice as well as on fresh-water ice. We will be designing a second bench, which uses natural gamma-rays as source, thus enabling a much higher spatial resolution of the features to be analyzed. The analysis bench is fully controlled by a personal computer, which also serves as a means for data acquisition and data analysis.

X-ray tomography

(M.A. Lange, H. Eicken, S. Gerland, AWI)
Thanks to the cooperation of a local hospital, we have been able to experiment extensively with a full body x-ray tomograph as a means for assessing internal ice structure in both sea ice and fresh-water ice. Aside from analyzing the internal structure of ice, we have also looked at the density distribution in the cores as well as the amount of and the geometry of pore space within the ice cores under investigation.

Submitted by H. Oerter

ICELAND

IMO = Icelandic Meteorological Office, Bústaðavegur 9, 150 Reykjavík
NEA = Orkustofnun (National Energy Authority), Grensásvegur 9, 108 Reykjavík)
SI = Science Institute, University of Iceland, Dunhaga 5, 107 Reykjavík

Mapping of bedrock and surface topography of ice caps

(Helgi Björnsson, SI)
Radio-echo soundings and precision barometric altimetry are being used to map glacier surfaces and bedrock topography of Icelandic glaciers. In 1990, the surveying was continued on southwest Vatnajökull (Síðujökull and Skaftárjökull). Digital maps of the surface and bedrock

have now been prepared of about 70% of the ice cap, i.e. of the western and northern Vatnajökull. The surveying is carried out by the Science Institute, University of Iceland, in collaboration with the National Power Company. The maps are used for studies of the geomorphology and volcanology of the subglacial part of the neo-volcanic zone in Iceland, of subglacial reservoirs in geothermal areas and the triggering and subglacial routes of jökulhlaups, of the estimation of the area and location of water-drainage basins and for modelling of ice dynamics.

Volcanoes beneath Vatnajökull: evidence from radio-echo sounding, earthquakes and jökulhlaups

(Helgi Björnsson and Páll Einarsson,SI)
During the past ten years, the bedrock topography beneath the ice has been mapped extensively using radio-echo sounding. At the same time, increased seismography coverage has led to more precise epicentral locations. Integration of this recently acquired knowledge of subglacial topography, earthquake activity and jökulhlaups has contributed to more precise locations of the volcanic systems beneath Vatnajökull. Seismic activity in conjunction with topographic highs reveals active volcanoes. Ridges, presumably built up by subglacial fissure eruptions, show the location of fissure swarms. Five active centres of volcanic systems have been identified beneath the western part of Vatnajökull and seven fissure swarms radiate from the volcanic centres. Eruptions have led to tephra fall and floods of meltwater, often damaging vegetation, farms and roads in coastal areas. Paths of meltwater produced in eruptions are traced beneath the glacier to the various rivers draining the glacier. Information on historical eruptive activity is reconsidered in the light of this evidence.

Jökulhlaups from subglacial lakes at geothermal areas

(Helgi Björnsson, SI)
Observations of the water level of the Grímsvötn lake indicate that the next jökulhlaup from the lake may be expected in 1991.

Experience amassed over the past 50 years is now being collected to explain the form of the various hydrographs for jökulhlaups from Grímsvötn, i.e. for known water levels at the start of the jökulhlaups, known distributions of the lake volume with height, and given lake temperature. A program is planned for measuring the lake temperature. Hot water drilling has been done successfully through the 110–250 m-thick ice cover of Grímsvötn.

Variations in heat flow and volcanic activity in the subglacial Grímsvötn volcano, Vatnajökull, 1919–90

(Helgi Björnsson and Magnús T. Guðmundsson, SI)
Field observations in the Grímsvötn caldera over the last 50 years indicate that considerable changes have occurred in the size and geometry of the subglacial lake within the caldera over this period. Aerial photographs, map sketches, repeated trigonometric levelling and written sources have been analysed and the changes that have occurred in the size of the subglacial lake and the thickness of the ice shelf deduced from these data. The record of changes in water level has been extended back to 1934. The data show that the size of Grímsvötn lake was more or less stationary from 1934–55, but after 1960 it began to decline. This decline was especially rapid between 1972 and 1986. Between 1954 and 1986 the area of the lake, at highest water level, declined from 33 km^2 to 17 km^2. A thickening of the ice shelf covering the lake from 130–160 m to 240–260 m occurred over this same period. This implies a drastic decrease in the volume of the subglacial lake. The volume of water released from Grímsvötn in jökulhlaups over this period is also decreased markedly. During the period examined, the amount of ice melted annually in Grímsvötn has decreased from 05–0.8 km to 0.2–0.3 km. These figures demonstrate a marked decline in geothermal heat flow. This occurs at the same time as the volume and frequency of volcanic eruptions has fallen markedly. This demonstrates that heat flow in Grímsvötn depends strongly on the long-term volcanic activity.

The volume of the ice-dammed Lake Grænalón and changes in the size and frequency of jökulhlaups

(Helgi Björnsson and Finnur Pálsson, SI)
A digital map has been compiled of the ice-dammed Lake Grænalón and the area and volume distribution with elevation has been calculated. Changes in the size of the lake and the ice barrier have been derived back to 1937 and they explain increased frequency of the floods and the decline in volume.

The long-term effect of glacier surges on the drainage of ice and water in Vatnajökull

(Helgi Björnsson and Magnús T. Guðmundsson, SI)
The outlets of western Vatnajökull seem to be building up to a surge. Observations have shown that the velocities of the outlets Tungnaárjökull and Síðujökull are lower than the balance velocities required to transport accumulated mass downglacier. Data for the last surge of Tungnaárjökull in 1945 have been compiled to evaluate the effect of the surge on the size of the catchment area and the drainage of ice and water towards the glacial rivers. The work is done in collaboration with the National Power Company.

Forthcoming surge of outlet glaciers from Vatnajökull

(Helgi Björnsson and Tómas Jóhannesson: collaboration between the SI, National Energy Authority, Icelandic Geodetic Survey, National Power Company and Icelandic Road Authority)
One or both of the outlet glaciers Síðujökull andTungnaárjökull, which flow to the southwest and west from the ice cap Vatnajökull, are expected to surge in the near future. Sporadic seismic activity, originating from the upper part of the glaciers and perhaps associated with mini-surges, has been observed since June 1990. New crevasses were also observed in the accumulation areas in July and August 1990. The glaciers have histories of surges affecting approximately 480 km^2 of the ice cap in the case of Síðujökull. The last surges of Síðujökull and Tungnaárjökull occurred in 1945 and 1963–64, respectively. The pre-surge geometry of Síðujökull was mapped with radio-echo sounding last autumn. The surge will be monitored with aerial photographs, seismic measurements and GPS velocity measurements. In addition, fluctuations in glacier river runoff and sediment discharge will be monitored during the surge.

Stable isotopic measurements in Iceland on glacier ice

(Árny Sveinbjörnsdóttir and Sigfús J. Johnsen)

Stable isotopic analyses are performed on glacier ice on the Finnegan MAT 251 mass spectrometer of the Science Institute. Surface snow samples and samples from shallow drillholes have been measured from the Vatnajökull ice cap, southeast Iceland, for both oxygen and deuterium. The most interesting results suggest that the deuterium excess, which is defined as $d = 8 \times \delta^{18}O - \delta D$, is higher in precipitation falling on the ice cap than on the lowlands.

As the stable isotopic composition of polar ice reflects the local temperature at the time of precipitation, these analyses can be used as palæoclimatic indicators. Several ice cores have been recovered from Greenland and Antarctica for palæoenvironmental studies. In the summer of 1988 a 325 m-long ice core was drilled by a Nordic group in the Renland ice cap in the Scoresbysund Fjord, East Greenland. The stable isotopic composition of this core has now been measured at the Science Institute. The results show that the Renland core contains continuous information on climatic variations during the last 130 000 years and good correlation is observed with the former deep Greenland ice cores, Dye-3 and Camp Century. Furthermore, Iceland is a member of the GRIP drilling project, which started in the summer 1990 and aims at drilling a 3 km-long core at Summit, central Greenland, within the next two years. This core is expected to reveal information on palæoclimate during the last 200 000–300 000 years. We have already analysed hundreds of samples from the first part of the drilling, but our main goal is to study the deuterium excess of the ice.

In connection with a ^{14}C dating study, the oxygen isotopic ratios of marine molluscs have been measured on the mass spectrometer, as they can be used as palæoclimatic indicators. The preliminary results indicate a good correlation between palæotemperatures calculated from $\delta^{18}O$ measurements of shells from marine sediments of known age (9000–12 000 BP) in southern and western Iceland and the palæotemperatures revealed by the Greenland ice.

Climatic significance of glacier variations in Iceland and their potential value for climate reconstruction

(Hreggviður Norðdahl, SI)

The mass balance of Icelandic glaciers is very sensitive to climatic changes and thus to changes in the North Atlantic Ocean current and atmospheric circulations. Given a comparable sensitivity for the glaciers at the end of the last glaciation (the Weichselian) and the beginning of the Holocene, all knowledge on variations in the extent of glaciers would be of benefit to our understanding of climatological changes in the period between 18 000 BP and 9600 BP. During the last decade or two, deglaciation studies in Iceland have increased markedly and the main result is that the period 18000–9600 BP is characterized by repeated climatologically induced glacier advances. In north Iceland, the glaciers advanced at least eight times in this period and during an advance, at about 10 600 BP, the Icelandic ice sheet covered the whole of the country except the outermost peninsulas. Later, at about 9700 BP, the glaciers advanced again but did not become as extensive as before and considerable parts of the present day dry land area, although at that time submerged in the sea, protruded beyond the glacier margins. In a period of about 1500, ^{14}C years the Icelandic ice sheet wasted down very rapidly. At about 8000 BP, very extensive lava-flows reached from the interior of the country and beyond the present coastline in north and south Iceland, clearly demonstrating that the interior of the country was ice-free at that time. The Late Weichselian and very rapid early Holocene deglaciation of Iceland is symptomatic of a sudden amelioration of the climate in the North Atlantic region. A correlation between the Skógar Thepra in north Iceland and the Vedde ash bed in western Norway and ash layer zone 2 in North Atlantic deep-sea sediment cores enables a comparison between the terrestrial and oceanic climatological records to be made and increases our understanding of the interaction between land and ocean, and thus of past glacier variations in Iceland.

The chemistry of precipitation on the Vatnajökull Glacier and chemical fractionation caused by the partial melting of snow

(Sigurður R. Gislason, SI)

The chemistry of Icelandic precipitation is dominated by the marine aerosol contribution with the exception of sulfate and calcium where some "excess concentration" is present. The "excess concentration" of sulfate may be partly attributed to anthropogenic activities. The average pH of Icelandic precipitation is 5.4. The snow on the Vatnajökull glacier is far away from any anthropogenic aerosol source, thus its chemical constituents are primarily of marine origin. The concentration of chloride in snow from the Grímsvötn area on the Vatnajökull glacier equals one drop of seawater mixed with about 19 000 drops of pure water. The concentration of salts in the snow, collected in June 1988 on the glacier, increases with increased elevation, contrary to what has been documented for precipitation in Iceland and other parts of the world. The average salt concentration of the 1987–88 snow layer in the Grímsvötn area is two to three times greater than the average salt concentration of the 1986–87 snow layer below, and there the average pH of the 1987–88 layer is 0.28–0.14 pH units lower than the pH of the 1986–87 layer below. The increase in salt concentration with increased elevation and the downcore changes in chemistry is attributed to chemical fractionation caused by the partial melting of snow. During partial melting, the chemical constituents are preferentially leached from the snow into the meltwater, leaving behind purified snow. However, some ions are more readily released than others. The order of preferential release of ions from the partially melted snow is:

$H^+ > Mg^{2+} > Cl^- \geqslant Na^+ > SO_4^{2-} > K^+ > Ca^{2+}$.

The most readily released cations, with the same charge, are the ones with the greatest effective hydrated diameter. the smaller the hydrated cation at a given charge, the more strongly is adheres to the snow. the preferential release of protons from the snow causes the pH of the meltwater to be lower than the pH of the residual snow. This is reflected in the relatively high pH of residual snow compared to pristine snow. The pH of meltwaters can be derived from the measured pH of snow and residual snow samples. Theoretical melting of about 10% of the original mass of a snow, using constraints from the Vatnajökull glacier, produces a meltwater with a pH that is more than 1 pH unit lower than that of the original snow. The lowering of the pH of meltwaters can happen by partial melting of unpolluted snow. That is to say, snow that consists of pure water and salts but no strong acids. This is caused by the relative mobility of anions and cations balanced by the release of protons. The higher the concentration of the immobile relative to the mobile cations, the greater the lowering of the pH of the meltwater.

Mass balance, glacier variations, glacier runoff and sediment discharge

(Oddur Sigurðsson, NEA)

Mass balance measurements are being carried out on the northern outlets of the ice cap Hofsjökull, central Iceland, and along profiles on the eastern and southern sides of the ice cap. Local reports on the results are published by the NEA and the main results are published in WGMS *Glacier Mass Balance Bulletin.*

Glacier variations were measured at 46 sites. The year 1990 marked the end of the second 30 year period of glacier variation measurements in Iceland. During the period 1930–60, all measured glaciers in Iceland retreated. In 1990, 12 glacier snouts (about 25% of those measured) had advanced since 1960. Data on glacier variation in Iceland are collected by members of the Iceland Glaciological Society, stored by NEA and reported annually in the periodical *Jökull.* They are also published in WGMS *Fluctuations of Glaciers.*

NEA operates 50 water gauges in 24 glacial rivers and monitors 5 glacial rivers for jökulhlaups. Reports of jökulhlaups are published in *Jökull* at intervals of a few years. Suspended material is sampled regularly in 19 glacial rivers.

Modelling the effect of CO_2-induced warming on the Hofsjökull ice cap

(Tómas Jóhannesson, NEA)

A time-dependent, cylindrically symmetric computer model of the Hofsjökull ice cap, central Iceland, has been developed in order to investigate the time-scale of possible CO_2-induced climatic variations. The model was forced with a set of hypothetical mass-balance scenarios, chosen to span the range of the plausible mass-balance variations of Hofsjökull caused by CO_2 effects. The response time of the ice cap was found to be on the order of 50–100 years. The model indicates that the increased runoff from Hofsjökull, caused by a possible CO_2-induced warming, will be significant for 100–200 years after the climate starts to change. A mass-balance scenario produced by raising the equilibrium line by 200 m (corresponding roughly to a warming of 1–1.5°C) over a 50 year period leads to a maximum runoff increase of $\approx 40\, m^3\, s^{-1}$ occurring 50 years after the equilibrium line starts to rise. This amounts to $\approx$25% of the present discharge of the glacier rivers that issue from Hofsjökull. Digital maps of Hofsjökull were made available for this study by the Science Institute and the Iceland Power Company.

Avalanche division

(Magnús Már Magnússon, IMO)

The first automated weather station has been installed at a site especially chosen to represent mountain weather near high risk avalanche areas. A telephone link provides up to date weather information that greatly assists in avalanche hazard evaluation. Installation of more stations is planned, pending funding.

Some experimental snow fences have been erected in collaboration with the Icelandic Road Authority. The idea being, if the fences can withstand the Icelandic weather, to recommend installation on the plateau to reduce snow accumulation on the slopes above the villages. Funding has been obtained to upgrade the computer facilities, and the feasibility of using GIS (geographic information systems) to archive and map avalanches, is being investigated. Work is being continued on the collection of historical records and avalanche reports and avalanche maps are being produced for towns and villages with an avalanche history. With the increased computer facilities it is hoped that a more thorough comparison can be made between the various avalanche runout models and their suitability for Icelandic conditions.

The division is also taking part in the revision of government regulations relating to the avalanche hazard assessments for individual towns and villages.

Sea Ice Research Division

(Thor Jakobsson, IMO)

Activities in the Sea Ice Research Division at the Icelandic Metoerological Service are much the same as reported in *ICE* vol. 90 in 1989. The operational sea ice information and warning service is running fairly smoothly in cooperation with the Icelandic Coast Guard and Marine Institute.

Additional oceanographic and meteorological data for sea-surface energy flux calculations have been collected. Data and charts for the study of the atmospheric blocking high effect on the movement of sea ice in Denmark Strait have been prepared.

Further, classification of the annual distribution of sea ice at the Icelandic coasts in the present century has been worked out. The grouping points out the great variability which has occurred during the last 90 years.

More powerful computer facilities made available recently due to the cooperation of the University of Iceland and the Meteorological Service, along with financial support of the National Science Foundation of Iceland, promises to be of considerable importance in the effort of promoting sea-ice and atmospheric–ocean interaction modelling studies in Iceland.

International cooperation in this research area as well as in the application of remote sensing of sea ice in Icelandic waters is being planned, particularly with Canadian and American scientists.

Climatic Division

(Trausti Jónsson, IMO)

The main activities of the Climatological Division are as follows:

1. Data collection from all Icelandic weather stations and Icelandic ships. This is incorporated into a database on a routine basis.
2. Quality checking of meteorological data.
3. Extension of the database to include data from the early part of the century and eventually also of the last century.
4. General climatological reserach is ongoing in connection with the aforementioned database. Preliminary work has been done in construction of a climatic-type classification scheme. This scheme will be used in the interpretation of climatic model results from abroad. It is also in use in the search for climatic change signatures.
5. The Climatological Division answers hundreds of enquiries each year in the form of written reports or statements used in legal controversies and also numerous questions from the general public concerning various aspects of climate.
6. The Climatic section is involved in international cooperation, mainly on a rather modest basis.
7. The Division publishes a monthly report on the weather in Iceland, *Veðráttan.*

Submitted by Helgi Björnsson

JAPAN

Abbreviations used in the text

DHM: Department of Hydrology and Meteorology, Ministry of Water Resources, His Majesty's Government of Nepal.
IGUT: Institute of Geoscience, the University of Tsukuba.
ILTS: Institute of Low Temperature Science, Hokkaido University.
IAA: Instituto Antartico Argentino.
JARE: Japanese Antarctic Research Expedition.
LIGG: Lanzhou Institute of Glaciology and Geocryology, Academia Sinica.
NGI: Norwegian Geotechnical Institute.
NIPR: National Institute of Polar Research.
NISIS: Nagaoka Institute of Snow and Ice Studies.
OSU: Ohio State University.
WRI: Water Research Institute, Nagoya University.

AVALANCHES AND SNOW

Observations of avalanche dynamics

(K. Nishimura, ILTS)
The internal structure of avalanches has been investigated by making observations at Kurobe Canyon, central Japan, since 1988. Front velocities are measured with several video cameras and internal velocities are derived from the impact pressure data. The avalanche wind which precedes the front of the avalanche itself is measured with an ultra-sonic anemometer.

The Japanese-Norwegian joint project of avalanche dynamics, 1990–92, was organized by N. Maeno (ILTS) and K. Lied (NGI). It has been planned to carry out full-scale experiments at the Ryggfonn avalanche path, western Norway, by recording impact pressure, front velocity, sound, seismicity, avalanche wind, atmospheric pressure and so on. Although the amount of snowfall in the winter of 1990–91 was extraordinarily low in Norway, the avalanche released artificially on 20 March ran down the path at a velocity of 20–30 $m\,s^{-1}$ and reached the observation site. Numerous data obtained during the project are now being analyzed.

Results obtained from these observations will be applied to construct and calibrate numerical avalanche models.

Laboratory experiments on snow avalanches

(Y. Nohguchi, Y. Yamada and T. Nakamura, NISIS)
To gain further understanding of the avalanche dynamics in granular flow, a specific tube (40 cm in diameter and 50 cm long) was constructed and preliminary experiments are being carried out. Their aim is to obtain the internal and wall friction angles from the steady state of the finite granular flow.

Experiments on pneumatic conveyance of snow through a tube

(T. Kobayashi and M. Kumagai, NISIS)
In some cities in Japan with heavy snowfalls of more than 3 m in depth, very narrow streets exist through which no vehicles for snow removal can pass. It is, therefore, necessary to develop new techniques to remove snow from these streets. Experiments on pneumatic conveyance of snow are now being carried out by using two differing types of equipment for ordinary snow and for snow compressed into lumps.

GLACIER RESEARCH

Asia

(Y. Ageta, WRI)
The China-Japan Joint Glaciological Expedition to Qingzang Plateau 1989–90 was organized by Xie Zichu (LIGG) and K. Higuchi (WRI). The expedition aimed to study the characteristics of glaciers in different climates, glacier variations and the role of the cryosphere in meteorological and hydrological processes on the inland high plateau. Field observations were carried out by Yao Tandong and seven scientists (LIGG) from China, and Y. Ageta, T. Ohata (WRI) and five scientists from Japan, during two periods, May–June and September–October 1989, in the east Kunlun Mountains, Tanggula Mountains and Nyainqentanglha Mountains. Intensive observations of glaciology, meteorology and hydrology were made in the Tanggula Mountains. Automatic meteorological stations in this area have been maintained since 1989.

Research by the Glaciological Expedition of Nepal has been continued as a joint work between DHM of Nepal and Japanese glaciologists. In 1989, T. Yamada (ILTS), with four scientists from Japan and B. Rana (DHM), observed glacier fluctuations over 10 years in the Khumbu, Shorong and Langtang regions. The hydrological and meteorological station in Langtang Himal has been continuously maintained since 1985.

Patagonia

(R. Naruse, ILTS and M. Aniya, IGUT)
Research on recent glacier variations was carried out in Patagonia, South America, from November to December 1990. The project was organized by R. Naruse, with two glaciologists and two geomorphologists from Japan, P. Skvarca (IAA) and two geomorphologists from Argentina, G. Casassa (OSU) and a hydrologist from Chile. The primary objective is to obtain the thickening or thinning rates of glaciers by repeated geodetic surveys within an interval of a few years.

Measurements of surface heights were then made at the ablation areas of Upsala, Moreno and Tyndall Glaciers. Resurveys are planned for 1993. Additional research was also conducted on and around glaciers on ice-flow velocity, ice thickness, ablation rate, heat balance and glacial geomorphology. Flow velocities obtained in the lower reaches of these glaciers were estimated to be about 2 $m\,d^{-1}$, 1 $m\,d^{-1}$ and 0.5 $m\,d^{-1}$, respectively. Ice thicknesses were successfully measured at Tyndall Glacier with a radio-echo sounder developed by OSU, showing the increase in thickness to 510 m from the margin to about one-fifth of the glacier width. Upsala and Tyndall Glaciers show remarkable retreats in recent years.

Glacier variations in southern Patagonia were investigated using Landsat MSS (1976) and TM (1986) digital data, and a map showing glacier conditions in 1947. Jorge Montt glacier retreated at a fairly constant rate of about 36 m a^{-1} between 1947 and 1976, and O'Higgins Glacier retreated extensively, up to 9.8 km in these 39 years, which is by far the largest amount of retreat in Patagonia; whereas Bruggen (Pio XI) Glacier showed an unusual advance between 1947 and 1976, blocking a fjord and forming two snouts.

Deep drilling project at Dome F in East Antarctica

(O. Watanabe, NIPR and R. Naruse, ILTS)
It is planned to conduct a deep drilling from 1994–96 at the summit of the second highest dome in East Antarctica. The dome, located at 77°22'S and 39°37'E, is provisionally called Dome F (Fuji) by JARE, although Valkyrjedomen has been inscribed in a map (Folio-series, Scott Polar Research Institute). A reconnaissance survey made around Dome F in 1985 by JARE-26 gave the surface elevation as 3807 m at the top, the ice thickness about 2800–3000 m and the mean annual temperature −58°C.

The primary aim of the project is to reveal, through analyses of the chemical/physical properties and compositions within ice-cores, the evolution of the global climate and the atmospheric environment in the past. Due to very low accumulation rate (30–35 mm a^{-1} in water equivalent), a long record can be expected, namely the age of ice at 2000 m depth is estimated as 100–150 k year B.P. Two glacial cycles will possibly be found, if the drilling is successful down to 2500 m depth.

In summer of 1992–93 (JARE-33), an operation is planned to survey the sub-ice topograpahy and observe the glaciological and meteorological features in the Dome F area; results of which provide important information to the final selection of a drill site. Transportation and establishment of Dome F camp is to be accomplished in the following summer. During two full years from 1994, the drilling will be carried out with an electromechanical drilling system which is being developed and tested at present.

Submitted by R. Naruse

NEW ZEALAND

Glacier inventory

(T. J. Chinn, Department of Scientific and Industrial Research, Geology and Geophysics (DSIR GEO))
The New Zealand Glacier Inventory was finally completed early in 1991, when the final data for the total of 3153 glaciers was checked and compiled into a single dataset. Maps for the all-glaciated areas have been machine plotted at a scale of 1 : 150 000 (this scale fits the 1 : 63 360 base maps on an A4-size sheet). A copy of all inventory data has been forwarded to World Glacier Monitoring Service Zürich, Switzerland.

Towards the end of the work, financial restrictions threatened cancellation of the project, and the computer system (discs and programme) used to digitise the glacier outlines became obsolete. Although the job has been completed, the original digitised map data is virtually inaccessible.

End of summer snowline surveys

(T. J. Chinn, DSIR GEO)
It is proposed to continue monitoring the end-of-summer snowline observations on 36 selected glaciers by oblique aerial photography. Flights for the past two years (1990 and 1991) were not made due to departmental restructuring and persistent unsuitable weather, culminating in early winter snowfalls.

Glacier front fluctuations

(T. J. Chinn, G. Bishop, DSIR GEO)
A proposal has been submitted to continue work on monitoring the frontal positions of four glaciers, the Dart, Franz Josef, Fox and Ivory Glaciers. The recent advances of most New Zealand glaciers which commenced around 1983 appear to have halted. This resurgence is best displayed by the Franz Josef Glacier which gained some 550 m over the period.

Antarctica, Dry Valleys region: glacier front fluctuations

(T. J. Chinn, DSIR GEO)
Measurements of frontal positions of ice-cliffed glaciers from permanent benchmarks is being continued on an opportunistic basis with the cooperation of various field parties. Results are consistent with the low activity of these cold glaciers and changes are over an order of magnitude less than on comparable temperate glaciers. Of some ten glaciers measured over the past ten years, five have advanced and five have receded. The highest rate of advance measured was 0.6 m per year.

Hydrometric studies

(J. A. McConchie, Victoria University of Wellington)
Measurements commenced in 1988 are continuing at the Miers and Adams Glaciers. Runoff, climatological parameters and glacier ablation and fluctuations are measured over the summer season at each glacier, and a third flow-measuring station lies downstream of the confluence of the two glacier streams.

Submitted by T. J. Chinn

SWEDEN

Mass balance of Storglaciären, Swedish Lappland

(Per Holmlund and Axel Bodin, Department of Physical Geography, Stockholm University)

Detailed mass-balance studies of Storglaciären have existed since 1945–46. During these years net ablation has dominated, but recently the trend has changed. For example, only eight of the first 35 mass-balance years (1945–46 to 1979–80) had positive net balance while the net balance during the 1980s alone was positive for six years. The last two years have had the largest specific winter balances on record. During 1989–90 mean net balance was +0.59 m w.eq. (b_w = 2.26 m, b_s = 1.67 m).

These last ten years high precipitation has led to an increase in thickness (almost 10 m) in the upper part of Storglaciären, according to photogrammetric maps from 1980 and 1990. On the other hand, frontal recession has continued but with decreased speed.

Other mass balance and recession studies in Swedish Lappland

(Per Holmlund, Axel Bodin, Håkan Grudd, Gunhild Rosqvist and Mart Nyman, Department of Physical Geography, Stockholm University)

Besides those on Storglaciären, mass-balance studies were carried out on five other glaciers (though with less detail). These glaciers all have similar specific summer balances, but winter balances vary a lot.

Glacier	*Area*	*Elevation*	*Aspect*	*Mass balance (m w.eq.)*			*ELA*
	km²	m a.s.l.		b_w	b_s	b_n	m a.s.l.
Tarfalaglac.	0.9	1390–1720	E	3.1	–1.9	1.21	< 1390
Storglaciären	3.0	1140–1720	E	2.3	–1.7	0.59	1495
Kårsaglac.	1.2	940–1460	E	2.1	–1.8	0.35	1100
Riukojietna	4.6	1100–1456	E	1.4	–1.2	0.21	1300
Rabots Glac.	3.7	1090–1925	W	1.7	–1.8	–0.04	1378
Mårmaglac.	3.6	1500–1740	E	1.4	–1.5	–0.12	1660

Ice recession is studied at about 20 glaciers. For the larger (5–25 km²) ones, all of which have long and flat snouts, ice recession has been very similar and the results show a decrease from 14 m a^{-1} (1977–85) to 11 m a^{-1} (1985–90).

Studies of the till layer at the bed of Storglaciären, Swedish Lappland

(Neal Iversen and Roger LeB Hooke, Department of Geology and Geophysics, University of Minnesota, U.S.A.)

Fieldwork during previous summers has indicated that a portion of Storglaciären may be underlain by a thin layer of water-saturated till. The potential influence of the till layer on the dynamics of the glacier motivated an effort during July 1990 to sample the till at a number of locations, investigate its thickness and observe the till in situ with a borehole video camera.

A total of nine boreholes were drilled to the bed with a hot-water drill. Till samples were collected from every borehole, suggesting that till may underlie a large fraction of the glacier. The grain-size distribution of the till indicates that it is a typical lodgement till, enriched in fine sand and coarse silt derived from subglacial abrasion and crushing. The grain-size distribution is very similar to that of samples from the proglacial area. While hammering the sampler into the bed, the progressive depth of sampler penetration into the till was measured. The results seem to indicate that the till layer is relatively thin (a few dm). The remote-controlled video camera that was lowered down the boreholes succeeded in obtaining images of the bed in two of them (in the others turbid water obscured the bed). The images revealed unconsolidated, poorly sorted sediments in both cases. In one of the holes the rate of glacier sliding over the upper surface of the till was measured by letting the camera hang slightly above the bed for 20 hours.

A six-year velocity record on Storglaciären, Swedish Lappland

(Peter Jansson, Department of Geology and Geophysics, University of Minnesota, U.S.A.)

A six-year continuous velocity record for a point fixed in space on Storglaciären has been assembled from two separate data sets. The data suggest a change in the dynamics of the glacier during the winter of 1984–85. The change is reflected in the emergence velocity record and is primarily caused by the vertical velocity pattern. The cause of this change must be found in the response of the glacier to the variations in net balance of the glacier, because of its long-term nature, although the relationship is not clear.

Geomorphological effects and recent climatic response of snowpatches and glaciers in the western Abisko Mountains, Swedish Lappland

(Rolf Nyberg, Anders Rapp and Lars Lindh, Department of Physical Geography, University of Lund)

Between 1985 and 1990, long-lasting snowpatches studied in the area west of Abisko have shown yearly size variations ranging from complete meltout during warm summers to only 40% reduction (of initial size at the start of ablation season) during cold summers. A clear correlation exists between size and mean summer temperature, although winter snow depth also affects the size variations. During summer, snow densities increase from *c.* 350 kg m^{-3} to more than 700 kg m^{-3} in the snowpatches. Nivation (geomorphic effects) at the snowpatch sites is dominated by transport processes.

Nordic Renland Glacier Project, East Greenland

(Margareta Hansson, Department of Meteorology, Stockholm University)

The analytical chemistry part of the Danish–Icelandic–Swedish "Nordic Renland Glacier Project" has proceeded in the laboratories of the University of Copenhagen. The deepest part (25 m long) of the 325 m-long ice core from the Renland Ice Cap in East Greenland has been analysed continuously for major anions and cations. This section of the ice core is concluded to cover the entire last glacial (including the transition from the Eem interglacial and the transition to the Holocene). The Holocene part has only been analysed spotwise.

All samples have been analysed in collaboration with Dr Eric Saltzman, University of Miami, for methane sulphonic acid (MSA), a tracer substance of biogenic DMS production in the sea.

New cold room laboratory at MISU, Stockholm

(Jost Heintzenberg and Michel Martin, Department of Meteorology, Stockholm University (MISU))

Recently, a new cold room laboratory has been established at MISU. The facilities include a storage room for ice cores, a cold and a warm laboratory. In the cold laboratory temperature and relative humidity can be varied. Furthermore, an overpressure of particle-free air can be maintained. In the adjacent warm laboratory class 100 conditions are maintained in clean benches while the room is pressurized with particle-free air. De-ionized particle-free water is available for cleaning and calibration purposes. In this blank water no particles are detectable in the working range (>0.1 µm radius) of the available optical and microscopical instrumentation.

In the cold laboratory a 4-axis robot is deployed for core processing and melting. The meltwater is analysed on line in the warm clean room by an optical particle counter for microparticles in the radius range 0.1–4 µm before it is sampled by a fraction collector for subsequent filtration and chemical analyses of bulk samples. The maximum volumetric resolution of this system is 17µl of meltwater.

At present, the facilities described above are used to address three different questions of interest to chemical glaciology:

1. Can the Younger Dryas event be elucidated in Antarctic ice cores by analysing submicrometer particles? In collaboration with the Laboratoire de Glaciologie et Géophysique (LGGE) in Grenoble, high resolution samples from several French Antarctic cores are analysed by Coulter counter (LGGE) and optical particle counter (MISU).
2. Can we detect soot and other anthropogenic substances from the plume of the European industrialised region on the glaciers of Elbrus, Caucasus? In collaboration with the Geographical Institute of the Soviet Academy of Sciences two short cores taken on Elbrus at about 4000 m altitude are being investigated to study the feasibility of investigating the development of European industrialisation through its effect on the deposited impurities in high altitude glaciers downwind of the source region.
3. How deep does airborne particulate matter penetrate into the snow? This question has been addressed with on site field experiments on Renland (East Greenland) and on Spitsbergen where the existence of airborne sub-micrometer particles has been shown down to about 20 cm below the surface.

Surface accumulation and oxygen isotopes in western Dronning Maud Land, Antarctica

(Elisabeth Isaksson and Wibjörn Karlén, Department of Physical Geography, Stockholm University)

A surface snow accumulation record is obtained from the $\delta^{18}O$ stratigraphy in 10 m firn cores. The mean annual accumulation for the period 1976–88 is 0.4 m w.eq. for the Riiser-Larsen Ice Shelf and 0.3 m w.eq. for Ritscherflya. One core from Amundsenisen, 300 m a.s.l., suggests a mean annual accumulation of 0.1 m for 1954–88. This time scale is based on β-activity measurements.

The spatial and temporal variations are large, but all records from the Riiser-Larsen Ice Shelf and Ritscherflya show a decreasing accumulation trend during 1976–88. One likely explanation could be the decreasing winter temperature which has been recorded at Halley during this period.

The $\delta^{18}O$ records from the Riiser-Larsen Ice Shelf and Ritscherflya show a high variability and little correspondence to the temperature record from Halley. However, the $\delta^{18}O$ variations from the core from Amundenisen are more closely related to the temperature record. This could reflect less variability in moisture source and transportation history for precipitation at higher elevations than for precipitation in coastal areas.

Ice-flow and ice-depth measurements in western Dronning Maud Land, Antarctica

(Per Holmlund and Jens-Ove Näslund, Department of Physical Geography, Stockholm University, Veijo Pohjola, Department of Physical Geography, Uppsala University)

During its second year this project was continued with radio-echo sounding of ice-depths along several stake profiles in the Vestfjella region as well as detailed velocity measurements on two small ice streams. The latter measurements were carried out using Geotronics 440 and 114. One ice stream (Plogbreen) flows between the two northernmost nunataks in Vestfjella, the other flows between Sivorgfjella and Tottanfjella in Heimefrontfjella.

Blue-ice studies in Scharffenbergbotnen, western Dronning Maud Land, Antarctica

(Stig Jonsson and Arjen Stroeven, Department of Physical Geography, Stockholm University)

The blue-ice project was continued for the third continuous summer season. The existing stake net (34 stakes) was used to determine mass balance and ice movement. Two automatic weather stations (10 km apart) recorded weather parameters in the blue-ice area and outside it. Net ablation in the blue-ice area during 1989/90 was only half as large as during 1988/89, when a maximum evaporation of 20 cm was measured. The main reason for this difference seems to be the much higher accumulation during 1989/90, as blue-ice areas are very sensitive to accumulation.

Oxygen-isotope measurements of a 10 m long ice core taken 5 km from the edge of the blue-ice area were used to determine normal accumulation in the area. Stake measurements from the same area for the last three summers show that accumulation in 1988/89 was around 50% lower than normal and that it was more than 50% larger than normal during 1989/90.

Regional climate in western Dronning Maud Land, Antarctica

(Stig Jonsson, Department of Physical Geography, Stockholm University)

More or less continuous weather data exist for an automatic weather station that was in operation between 16 January 1988 to 5 June 1989 on the downstream side of Heimefrontfjella. The weather station was located in the bottom of a blue-ice area (Scharffenbergbotnen) inside a large cirque and recorded weather data every 3 h.

When weekly running means are calculated for air pressure, air temperature, wind speed and relative humidity, a monthly periodicity becomes very clear between March and September 1988, and this periodicity reappears in March the following year, although weaker. This monthly periodicity, which was so apparent in Scharffenbergbotnen during the Antarctic winter 1988, can also be found in weather data from the British station Halley, but there it is less regular and the amplitude is smaller. This suggests that the periodic variation was a regional feature, which somehow was amplified by the topography in Scharffenbergbotnen.

Submitted by Stig Jonsson

International Glaciological Society

JOURNAL OF GLACIOLOGY

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

J F NYE
The topology of ice-sheet centres.

S C COLBECK AND G C WARREN
The thermal response of downhill skis.

R S WILLIAMS, D K HALL AND C S BENSON
Analysis of glacier facies using satellite techniques.

T S CLARKE
Glacier dynamics in the Susitma River basin, Alaska.

M E R WALFORD AND J F NYE
Measuring the dihedral angle of water at a grain boundary in ice by an optical diffraction method.

M LEHMAN AND U SIEGENTHALER
Equilibrium oxygen- and hydrogen-isotope fractionation between ice and water.

G KC C CLARKE AND E W BLAKE
Geometric and thermal evolution of a surge-type glacier in its quiescent state: Trapridge Glacier, Yukon Territory, Canada, 1969–89.

P W THORP
Surface profiles and basal shear stresses of outlet glaciers from a Late-glacial mountain ice field in western Scotland.

J SCHWEIZER AND A IKEN
The role of bed separation and sliding over an undeformable bed.

F HERMANN AND K HUTTER
Laboratory experiments on the dynamics of powder-snow avalanches in the run-out zone.

M O JEFFRIES, H V SERSON, K R KROUSE AND W M SACKINGER
Ice physical properties, structural characteristics and sratigraphy in Hobson's Choice Ice Island and implications for the growth history of East Ward Hunt Ice Shelf, Canadian High Arctic.

K ECHELMEYER, T S CLARK AND W D HARRISON
Surficial glaciology of Jakobshavns Isbræ, West Greenland: Part I. Surface morphology.

Y WEI, S J DEFRANCO AND J P DEMPSEY
Crack-fabrication techniques and their effects on the fracture toughness and CTOD for fresh-water columnar ice.

R R FORSTER, C H DAVIS, T W RAND AND R K MOORE
Snow-stratification investigation on an Antarctic ice stream with an X-band radar system.

J B JOHNSON
Simple method of shock-wave attenuation in snow.

R L BROWN AND M Q EDENS
On the relationship between neck length and bond radius during compression of snow.

E M SHOEMAKER
Subglacial floods and the origin of low-relief ice-sheet lobes.

ANNALS OF GLACIOLOGY

The following papers are published in Volume 15, Proceedings of the Symposium on Ice–Ocean Dynamics and Mechanics, held at Dartmouth College, Hanover, USA, 27–31 August 1990.

R B ALLEY
Sedimentary processes may cause fluctuations of tidewater glaciers.

W F BUDD, I SIMMONDS AND W XINGREN
The physical basis for a dynamic Antarctic sea-ice model for use with an atmospheric GCM.

G CASASSA, K C JEZEK, J TURNER AND I WHILLANS
Relict flow stripes on the Ross Ice Shelf.

S J DeFRANCO, Y WEI AND J P DEMPSEY
Notch-acuity effects on the fracture toughness of saline ice.

J P DEMPSEY AND Z G ZHAO
Transient sub-surface uplift of a floating ice sheet.

H EICKEN AND M A LANGE
Image analysis of sea-ice thin sections: a step towards automated texture classification.

B ERLINGSSON
The propagation of characteristics in sea-ice deformation fields.

G M FLATO AND W D HIBLER III
An initial numerical investigation of the extent of sea-ice ridging.

C FOX AND V A SQUIRE
Coupling between the ocean and an ice shelf.

R E GAGNON AND J MØLGAARD
Evidence for pressure melting and heat generation by viscous flow of liquid in indentation and impact experiments on ice.

H HOEBER
Sea-ice dynamics in the Weddell Sea in winter.
M A HOPKINS AND W D HIBLER III
Numerical simulations of a compact convergent system of ice floes.
M A HOPKINS AND W D HIBLER III
On the ridging of a thin sheet of lead ice.
K HUTTER
Ice–ocean dynamics and mechanics: a summary of the papers.
M IKEDA
Mesoscale eddy formation and evolution in the ice-covered ocean.
C F IP, W D HIBLER III AND G M FLATO
On the effect of rheology on seasonal sea-ice simulations.
T H JACKA AND R THWAITES
An Antarctic field study of the rheology and movement of a sea-ice flow aggregate.
M O JEFFRIES
Massive, ancient sea-ice strata and preserved physical–structural characteristics in the Ward Hunt Ice Shelf.
D E JONES, F E KENNEDY AND E M SCHULSON
The kinetic friction of saline ice against itself at low sliding velocities.
P KALIFA, S J JONES AND T D SLADE
Microcrack nucleation in granular ice under uniaxial compression: effect of grain-size and temperature.
M A LANGE AND H EICKEN
Textural characteristics of sea ice and the major mechanisms of ice growth in the Weddell Sea.
M G McPHEE
A quasi-analytical model for the under-ice boundary layer.
R D MUENCH, C H PEASE AND S A SALO
Oceanographic and meteorological effects on autumn sea-ice distribution in the western Arctic.
W A NIXON AND L J WEBER
Fatigue-crack growth in fresh-water ice: preliminary results.
M S PELTO AND C R WARREN
Relationship between tidewater glacier calving velocity and water depth at the calving front.
S J PRINSENBERG, I K PETERSON AND G A FOWLER
Estimates of ice-edge melt rates off Labrador and eastern Newfoundland, Canada.
R S PRITCHARD
Sea-ice mechanical energy balance: nearshore Chukchi Sea, 1982.
P H RANELLI AND W D HIBLER III
Seasonal Arctic sea-ice simulations with a prognostic ice–ocean model.
J E RIES AND W D HIBLER III
Interannual characteristics of an 80 km resolution diagnostic Arctic ice–ocean model.
M SAYED AND R M W FREDERKING
Ridge-sail statistics at the shear edge of Lancaster Sound, March 1984.
H H SHEN AND S F ACKLEY
A one-dimensional model for wave-induced ice-flow collisions.
E M SCHULSON, D E JONES AND G A KUEHN
The effect of confinement on the brittle compressive fracture of ice.
D S SODHI
Energy exchanges during indentation tests in fresh-water ice.
V A SQUIRE AND C FOX
The role of incoming waves in ice-edge dynamics.
K STEFFEN
Energy flux density estimation over sea ice based on satellite passive microwave measurements.
A STÖSSEL
Application of an atmospheric boundary layer model to a large-scale coupled sea-ice–oceanic mixed-layer model for the Southern Ocean.
W B TUCKER III, D K PEROVICH, M A HOPKINS AND W D HIBLER III
On the relationship between local stresses and strains in Arctic pack ice.
A WARN-VARNAS, R ALLARD AND S PIACSEK
Synoptic and seasonal variations of the ice–ocean circulation in the Arctic: a numerical study.
A P WORBY AND I ALLISON
Ocean–atmosphere energy exchange over thin, variable concentration Antarctic pack ice.
J ZHANG AND W D HIBLER III
On the role of ocean circulation in seasonal and interannual ice-edge variations in the Bering Sea.

INTERNATIONAL SYMPOSIUM ON SNOW AND SNOW-RELATED PROBLEMS

Nagaoka, Japan 14–18 September 1992

The Second Circular is now available from The Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, England.

Glaciological Diary

** IGS Symposia
* Co-sponsored by IGS

1991

23-27 September
SCAR International Conference on Antarctic Science — Global Concerns, Bremen, Germany (Dr G. Hempel, Convenor, Antarctic Science – Global Concerns, Alfred-Wegener-Institut, P.O. Box 120161, D-2850 Bremerhaven, Germany)

24-28 September
POAC '91. 11th International Conference on Port and Ocean Engineering Under Arctic Conditions, St. John's, Newfoundland (Hanny Muggeridge, Ocean Engineering Research

Centre, Memorial University of Newfoundland, St. John's, Newfoundland, Canada A1B 3X5)

26-28 September
* VIth Italian Glaciological Meeting, Gressoney St. Jean/La Trinité, Valle d'Aosta, Italy. Glacier: scientific and economic resource. (Comitato Glaciologico Italiano, via Maria Vittoria 25, I-10123 Torino, Italy)

9-13 December
AGU Fall Meeting, San Francisco, California, U.S.A. (1991 Fall Meeting, American Geophysical Union, 2000 Florida Avenue, N.W., Washington, DC 20009, U.S.A.)

12-15 December
2nd meeting on Environmental Change in Iceland, München, Germany (Johann Stötter, Institut für Geographie der Universität München, Luisenstr. 37, 8000 München 2, Germany)

1992

2-4 February
Seventh International Symposium on Okhotsk Sea and Sea Ice, Mombetsu, Hokkaido, Japan (The Secretariat, The Okhotsk Sea & Cold Ocean Research Association, c/o Department of Planning & Adjustment, Mombetsu Municipal Office, Saiwai-2, Mombetsu, Hokkaido 094, Japan)

23-27 March
AGU Chapman Conference on Climate, Volcanism, and Global Change, Hilo, Hawaii. (Stephen Self, Department of Geology and Geophysics, The University of Hawaii at Manoa, Honolulu, Hawaii 96822, U.S.A.)

6-10 April
XVII General Assembly of the European Geophysical Society, Edinburgh, Scotland (EGS Office, Postfach 49, 3411 Katlenburg-Lindau, Germany)

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

7-11 June
OMAE 1992. 11th International Conference on Offshore Mechanics and Arctic Engineering, Calgary, Canada. (N.K. Sinha, Institute for Mechanical Engineering, National Research Council of Canada, Ottawa, Ontario, Canada K1A0R6)

15-19 June
IAHR 11th International Ice Symposium, Banff, Alberta, Canada (Conference Secretariate, IAHR Ice Symposium, c/o Mrs Yolande Matsusaki, Manager Conference Centre, 4 Lister Hall, University of Alberta, Edmonton, ALTA, Canada T6G 2H6)

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

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

1993

18-23 April
** Symposium on Applied Ice and Snow Research, Rovaniemi, Finland. Co-sponsored by Ministry of Education, Finland, Arctic Centre, University of Lappland, City of Rovaniemi (Secretary General, IGS, Lensfield Road, Cambridge CB2 1ER, U.K.)

26 June-1 July
4th Canadian Marine Geotechnical Conference, St John's, Newfoundland, Canada (C-CORE, Memorial University of Newfoundland, St John's, NF, Canada A1B 3X5)

5-9 July
6th International Conference on Permafrost, Beijing, China (Cheng Guodong, Lanzhou Institute of Glaciology and Geocryology, Academia Sinica, Lanzhou, 730000, China)

News

AWARDS

Professor emeritus Carl Benson has been elected a Fellow of the American Association for the Advancement of Science in recognition of his distinguished career in glaciology — development of a glacier facies concept, studies of glacier–volcano interactions, and research low-temperature air pollution. His work includes seasonal snow cover, low temperature air pollution problems, freezing of small turbulent streams, glacier mass balance problems on McCall Glacier, and glacier–volcano interactions in the Wrangell Mountains and on the west side of Cook Inlet. He taught in the department of Geology and Geophysics of the Geophysical Institute, University of Alaska, which he joined in 1960, and where he is still active in research. He was department chair from 1969 to 1973.

Richard C. Hubley Crystal

Mark F. Meier reports that at the 1990 meeting of Northwest Glaciologists in Seattle, Washington, USA, an award was made to **Austin Post** in recognition of his work over many years:

Northwest Glaciologists, a unique and effective non-organization, has served the science of glaciology for nearly 20 years. I am happy to note that at this 1990 meeting there are glaciologists attending from such outposts of the Northwest as Nagoya, Japan; Fairbanks, Alaska; Pasadena, California; Oslo, Norway; and Innsbruck, Austria. The Seattle–Tacoma–Vancouver (B.C.) area, which spawned Northwest Glaciologists, has been a leading center of glaciological research since the early 1950s. The one person most responsible for developing this interest at that time was Dr Richard C. Hubley.

Dick Hubley's short but productive career included such achievements as: beginning long-term studies of the mass balance of Blue Glacier; pioneering work on the energy balance of melting snow and ice surfaces; initiating aerial reconnaissance studies of glacier regimes; managing development and execution of glacier observation programs in the U.S. during International Geophysical Year 1957–59; and initiating the McCall Glacier project in northern Alaska. Tragically, Dick Hubley's life was lost on McCall Glacier near the end of IGY. Northwest Glaciologists has created an award to honor special contributions to glaciology, and to be named after, and thus also to honor, Dick Hubley. this is the Richard C. Hubley Crystal.

I take great pleasure, on behalf of Northwest Glaciologists, to present the Hubley Crystal to **Austin Post**. Austin Post's seminal contributions to glaciology have had world-wide impacts on the field, although in many cases he is not well known as the original source. Some of these significant contributions are:

Glacier surges: This is currently a subject of great interest. A scientific milestone in the recognition and understanding of these interesting ice masses was the classic paper by Post in 1960 on the Muldrow, Black Rapids and Susitna Glaciers, that defined, quantified and described the glacier surge cycle, and showed how surging glaciers could be identified even when quiescent. The name, in fact, comes from a paper by Post. He also discussed the enigmatic distribution of surging glaciers, a problem that has not been solved. Post wrote a perceptive manuscript on the mechanism for rapid surge flow which was submitted to but rejected by *Science* about 20 years ago. Recent detailed studies on Variegated and other glaciers, however, showed that his concept was right on target.

Earthquake Advance Hypothesis: Tarr and Martin proposed in the early 20th century that large earthquakes, by shaking down masses of snow, caused the anomalous glacier advances we now call surges. This theory was repeated in textbooks, until Austin Post collected and published his observations following the great Alaska earthquake of 1964. His work thoroughly demolished the concept and provided a correct explanation.

Aerial and air photo reconnaissance: This new technique is the only way to cope with the study of glacier phenomena over huge areas. Post pioneered this methodology, which allows the quick detection of abnormal events such as lake outbursts, surges, debris flows, volcanic phenomena, and led to the quantifying of mass balance indices through the invention and use of such concepts as equilibrium line altitude (ELA) and accumulation area ratio (AAR) which are now dear to the hearts of Quaternary scientists seeking to reconstruct past glaciers.

Stability of tidewater glaciers: The reason for the asynchronous behavior of iceberg-calving glaciers in Alaska was first deduced by Austin Post. This led to a major study of Columbia Glacier that elucidated the general principles that are critical to understanding the cyclic behavior of glaciers that end in the sea. These principles have been taken up in studies of present and past glaciers in the Arctic and Antarctic, and are used in modelling experiments to predict future glacier behavior.

Photography: The Post photograph collection is unique in many ways. It is a scientific data set of great value because it covers a very large area of diverse glaciologic and geomorphologic phenomena, because it was repeated on a regular basis, and because Post has an uncanny ability to spot an interesting or unusual happening and then to alter his schedule to investigate and document the feature. His photo collection also extols the beauty of mountains, as seen with a sensitive eye (and a large-format camera), a fact that has been recognized in many books, *Audubon* magazine, and countless requests.

It is not necessary to mention all of Austin Post's contributions to glaciology, but I do wish to make additional note of his eagerness to help others — especially young scientists. Often Austin will get an inquiry from a young investigator asking if he has photographs or knowledge of some phenomenon in some place. By the time a meeting has been arranged, the investigator will find, more likely than not, a large set of printed photographs taken through the years waiting for him, complete with Austin's analysis of what has happened and why it has happened.

For these reasons, and many others, it gives me great pleasure to present to Austin Post, on behalf of Northwest Glaciologists, the Richard C. Hubley Crystal, in recognition of major contributions that have had lasting impact on the field of glaciology.

Mark R. Drinkwater, research associate at the Jet Propulsion Laboratory and member of the polar oceanography group, received a prize paper award from the IEEE Geoscience and Remote Sensing Society in Helsinki, Finland, in June 1991. This annual award was presented for his 1990 paper entitled 'Synthetic aperture radar polarimetry of sea ice' with a citation 'for exceptional achievements for the benefit of the geoscience and remote sensing community'. Dr Drinkwater's recent work has focussed on investigations of ice sheet and sea ice geophysics using microwave radar polarimetry.

MEETING REPORT: NORTH-WEST GLACIOLOGISTS

The annual meeting of Northwest glaciologists was hosted in 1990 by Charlie Raymond at the University of Washington, and although no records are kept, a new attendance record must have been set with over 77 participants.

Topics ranged the spectrum of glaciological topics including tidewater and alpine glaciers, Arctic ice caps, Antarctic ice streams, snow studies, ice physics, radars, and cores, blue ice runways, glacial geology, and periglacial processes. There were 52 oral presentations, including a report on a surging glacier that is 1 km long, and another on the predicted reappearance of glaciers in Hawaii.

Charlie Raymond hosted a very enjoyable reception at his home located in a wooded glade of residential Seattle. Despite the attendance of practically everyone at the meeting, the stilts that elevate the house above the forest slopes stoutly bore the weight, much to Charlie's relief.

MEETING REPORT: GLACIER MASS BALANCE WORKSHOP

The North American Committee on Climate and Glaciers held a Mass Balance Workshop on November 28 and 29, 1990 at the University of Washington, Seattle, USA. The committee was formed earlier at the Northern Hydrology Symposium, held in July 1990, in Sakatoon, Canada to coordinate mass balance programs and approaches between Canada and the USA. The purpose of the Mass Balance Workshop was to outline the standards and priorities for evaluating the mass balance of glaciers in North America. Results of this meeting (in preparation) are divided into four topics: (1) the relevance of mass balance measurements; (2) mass balance methodologies; (3) data collection and reporting standards; (4) expansion of the network of benchmark glaciers. For those interested in the results, and who are not already on the mailing list, please contact Dr Simon Ommanney, National Hydrology Research Institute, 11 Innovation Blvd., Sakatoon, Saskatchewan S7N 3H5, Canada.

INTERNATIONAL EXPERIMENTAL INVESTIGATIONS AT THE GLACIOLOGICAL FIELD BASE 'ABRAMOV GLACIER'

V. G. Konovalov reports that a programme of experimental investigations at the Abramov Glacier has been created together with various agencies of the USA, Canada, Austria, Switzerland, and India, China, Nepal and others. The motto is 'ICEX 91–99'. Individual projects are:

(1) regeneration of mountain glaciation,
(2) radiosonding of glaciers and estimation of their volumes,
(3) microflora at the glaciers and snow cover surfaces,
(4) physical and mechanical processes inside the glaciers,
(5) measurements of evaporation from glaciers and snow cover surfaces.

Since 1968 a set of stationary hydrometeorological and specific observations has been made in the Abramov Glacier basin in accordance with the international (IHD, IHP) and all-Union projects and programmes. The main task of the stationary works in the Abramov Glacier basin during all these years was to study regularities of spatial and time variability of the components of the income and expenditure parts of the heat and water–ice balance equations.

1. At present the estimates are available and the process is described related to accumulation and transformation of solid atmospheric precipitation in the 55.5 km^2 Abramov Glacier basin. The following results are the major ones here:

1.1 Relationships between monthly sums of precipitation in the outer glacial part of a basin and elevation;

1.2 Maps of distribution and relationships between snow depth, snow water equivalent and elevation compiled for the surface of Abramov Glacier;

1.3 Estimates of avalanche nourishment and snow drifting contributions into total value of accumulation on the glaciers;

1.4 Methods for separation and dating of annual layers of firn and ice depth for compuation of annual volumes of infiltrational ice formation;

1.5 Methodical recommendations on network optimization of the snow-cover measuring points at the Abramov Glacier;

1.6 Conclusions on spatial variability of infiltrational ice formation and on the values of accumulation at the Abramov Glacier surface.

2. The main scientific results obtained in studies of the elements of the expenditure part of water–ice balance at the Abramov Glacier include the following:

2.1 Maps of distribution at the Abramov Glacier of the monthly and annual values of snow and ice melting and the dependence of the same elements on altitude;

2.2 Empirical methods of computation of snow and ice melting intensity;

2.3 Qualitative estimates of modelling the process of total glacier melting;

2.4 Description of process of water yield from snow in ablation period and experimental study of water movement in the firn depth;

2.5 Absolute and relative characteristics of the components of heat balance of the glacier surface based on the data of gradient and direct measurements by means of heat-flow meter and evaporimeters installed at the experimental site;

2.6 Detailed description and a model of river flow computation with snow–glacial feeding.

3. The results discussed above were used as the basis for plotting a map of distribution of annual mass balance in the Abramov Glacier; a relationship is defined between annual mass balance and elevation; a correlation is obtained between annual mass balance and maximum elevation of snow line at the glacier which is of important scientific and applied value; a 50 years long series of annual mass balance of Abramov Glacier is reconstructed by the data of measurements and computations. Such a series is required for study of long-term variability of water

resources of glaciation. The materials of measurements at Abramov Glacier were used to compile the following maps planned in the programme on development of the *Atlas of World Snow and Ice Resources*: surface relief, albedo and natural surface contamination, glacier movement and variations of its level.

4. The range of scientific results obtained from studies in the Abramov Glacier basin includes the following:

4.1 Development and improvement of the methods and equipment for thermal boring of a glacier without sampling the ice core within it.

4.2 Development of a data base of meteorological and glaciological observations at Abramov Glacier, development of computer programmes on processing of geodetical, hydrometric and the major part of meteorological and actinometric observations.

4.3 Characteristics of variations of Abramov Glacier sizes made from the data of aerial photo-surveys and geodetical observations.

Description of the glaciological field base 'Abramov Glacier'

Accommodation and working conditions are housed in a complex at the main base of the GEFB situated in the middle of Abramov Glacier on an ancient moraine, 3837 m a.s.l., which rises more than 100 m above the glacier. It includes:

- the main building with a transreceiver room, film-projector room, battery department, kitchen, ward-room and four living rooms each to accommodate two people;
- living quarters — 'an hotel' with five double rooms and a vegetable storage cellar;
- four separate living quarters for one or two people;
- station laboratory for the complex background monitoring, with two living rooms for two people;
- cold laboratory with refrigerating chamber to store and process the cores;
- two storehouses, one for instruments and equipment, the other for foodstuffs;
- a garage for scooters;
- a diesel-electric power station (DES);
- a bath-house with a shower, sauna, washing and laundry room;
- a site of the station for complex background monitoring to take air samples;
- a meteorological site.

There are three branches of the main complex: I- (SP-1) - snow measuring site situated within the glacier terminus at 3850 m a.s.l.; II - in the Koksu river flood plain 1.5 km distant from the terminus end (hydrological site), and III - is in the glacier firn zone ('Firn') at 4440 m. All three branches consist of rooms, autonomous 1–2 kW electricity supply, and gas stoves. There is a television installation in the base receiving two broadcasts, a film-projector with a set of 150 films, a library, a billiard-table, a tennis-table, sets of chess, draughts, dominoes and cards. 25–30 people can live in the base at the same time; if there are more it is necessary to pitch tents.

DES supplies the main base and its branches over the glacier tongue with electricity. It has three autonomous diesel-electric units of 8–12 kW. DES supplies lighting, instruments and equipment as well as an electric stove for baking bread and heating the sauna with electric current. Besides the diesel-electric unit there are petrol units of 1–8 kW.

Central heating is used in the main building, hot water after cooling the diesels being used for this purpose. Other buildings are heated by electric radiators. The annual reserve of gas in containers is delivered to the kitchen by helicopters.

Means of transport include two tractors, one of them used only in the vicinity of the base, the other on the glacier tongue, and scooters, which in summer operate only on the body of the glacier, though in winter over the whole basin.

Further information may be obtained from Dr V. G. Konovalov, Central Asian Regional Research Hydrometeorological Institute, 72, Observatorskaya str., Tashkent, USSR 700052.

JAPANESE SOCIETY OF SNOW AND ICE

Issue No. 9 of the *Bulletin of Glacier Research* has been published recently. BGR is a journal written in English and published by the Data Center for Glacier Research of the Japanese Society of Snow and Ice. the DCGR was established in 1973 for the members of JSSI to promote and organize glaciological research on snow patches, glaciers and ice sheets inside and out of Japan. BGR has been published almost annually for the last five years, containing various original papers and reports of glacier-related studies. Non-members of JSSI are also encouraged to contribute to this journal.

The contents of BGR No. 9 are:

Spitsbergen, by T. Kawamura, T. Kameda and K. Izumi.
Accumulation rate at Site J and Dye 2, Greenland, by H. Shoji, H. B. Clausen and T. Kameda.

Anyone who wishes to obtain this journal and/or 'Information for Contributors' should write to: Data Center for Glacier Research, Japanese Society of Snow and Ice, Komori Bldg., 3-12 Kouji-machi, Chiyoda-ku, Tokyo 102, Japan.

The price of the journal is ¥2000 for personal use. Back numbers and any other information are also available from the above address.

OBITUARIES

William Launcelot Scott Fleming, Director of the Scott Polar Research Institute 1947–49, died on 30 July 1990. He was born in Edinburgh in 1906 and educated at Rugby School and Cambridge University. He specialised in geology and in 1929 won a Commonwealth Fellowship to Yale, where he worked on Long Island, publishing a monograph on its geology for which he was awarded an M.S. Returning to Cambridge, he entered a theological college. In the vacations he joined expeditions to Iceland, Spitsbergen, and then Graham Land, where his friends gave him the title "The Bishop", with a formal parish covering the whole of Antarctic territory claimed by the British. Like all other members of the British Graham Land Expedition he was awarded the Polar Medal on return.

In Cambridge he was appointed Dean of his college, Trinity Hall, and led a full life, writing up research results from the expedition and coaching college crews on the River Cam in addition to his college responsibilities. During the Second World War he served as a naval chaplain, and then returned to Trinity Hall. Soon his load of work increased, when he became part-time Director of the Scott Polar Research Institute upon the retirement of the founding Director, Frank Debenham. He appointed Terence Armstrong and Brian Roberts, who became key figures in the move to involve the Institute in the new, international age of polar affairs.

In 1949 he was appointed Bishop of Portsmouth, an appropriate naval diocese, and stayed there until 1959, when he was appointed Bishop of Norwich. In 1971, at the age of 65, he became Dean of Windsor and Domestic Chaplain to Her Majesty the Queen.

Throughout this period, Launcelot kept in touch with his Cambridge friends and colleagues. He had been a member of the British Glaciological Society and spoke at its 25th anniversary dinner in 1961. He is remembered for his warm friendliness, wisdom, tolerance and unorthodox reverence.

Brian Sagar, Associate Professor of Geography at Simon Fraser University, Burnaby, British Columbia, Canada, died of cancer on 12 January 1990. He was born in Lancashire in 1927, and was educated at the University of Hull. He was recruited to work with the United Africa Company and served in northern Nigeria for four years. Then he returned to Lancashire, to teach geography and chemistry at Manchester Grammar School.

A chance encounter in a pub with a Canadian colleague from the days in Nigeria led Brian in 1958 to join an expedition to northern Ellesmere Island, "Operation Hazen". He served as glaciologist and climatologist each summer until 1966. He took his M.Sc. from McGill University in 1959, for his thesis on cold climates and glacier mass balance. From 1961 to 1966 he worked for the Geographical Branch in Ottawa, and then in July 1966 was appointed Assistant Professor of Geography at Simon Fraser University. He was able to teach on the Arctic and on Africa. He gave unstintingly of his time and abilities in public service and professional development, and was a loyal and devoted friend and companion.

New members

Neil Arnold, Department of Geography, University of Cambridge, Downing Place, Cambridge CB2 3EN, U.K.
Nancy E. Brown, c/o Oles, Morrison & Rinker, 3300 Columbia Center, Seattle, WA 98104, U.S.A.
Wayne Davidson, P.O. Box 120, Resolute Bay, NWT X0A 0V0, Canada.
Hajo Eicken, Alfred-Wegener-Institut für Polar- und Meeresforschung, Postfach 120161, Columbusstrasse, D-2850 Bremerhaven, Germany.
Michael R. Gorman, Scott Polar Research Institute, University of Cambridge, Lensfield Road, Cambridge CB2 1ER, U.K.
Ken Koizumi, Institute of Low Temperature Science, Hokkaido University, Sapporo 060, Japan.
Peter W. Nienow, Department of Geography, University of Cambridge, Downing Place, Cambridge CB2 3EN, U.K.
Toshihiro Ozeki, Institute of Low Temperature Science, Hokkaido University, Sapporo 060, Japan.
Winfield H. Peterson, Project Olive Harvest, Box 64, APO New York, NY 09289, U.S.A.
Allan V. Robinson, British Antarctic Survey, High Cross, Madingley Road, Cambridge CB3 0ET, U.K.
Takayuki Shiraiwa, Institute of Low Temperature Science, Hokkaido University, Sapporo 060, Japan.

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ICE

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

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