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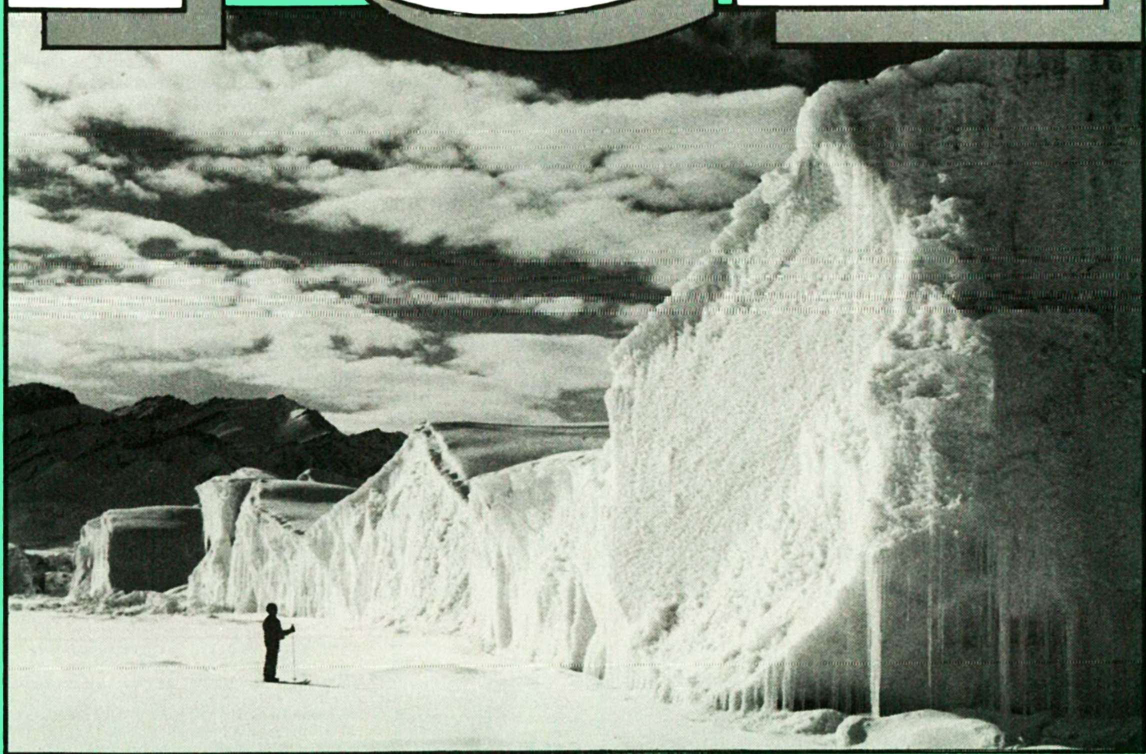

NEWS BULLETIN OF THE INTERNATIONAL GLACIOLOGICAL SOCIETY

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COVER PICTURE: Ice front in spring, unidentified picture from IGS files.

Scanning electron micrograph of the ice crystal used in headings by kind permission of William P. Wergin, Agricultural Research Service, U.S. Department of Agriculture

RECENT WORK

DENMARK

(For abbreviations used see page 22)

Mapping glacial deposits

(S.A. Schack Pedersen, K.S. Petersen, GEUS)
Geological mapping of the Djursland region, in central Denmark, has been concluded. This region is dominated by glaciodynamic features related to the NE and SE ice advances, respectively, in the Late Weichselian. The map (DGU Map 51, 1:50,000) shows the distribution of glaciogeological deposits. Three geological cross sections are displayed as well as two key maps which show the regional stratigraphic divisions of Quaternary deposits and the geology of the pre-Quaternary surface.

The glaciodynamics of the region will be described in a book, the Geology of Djursland, which will give an introduction to the glaciodynamic concept applied in mapping glacial deposits in Denmark, the main glacio-geological stratigraphy and the glaciogeological history of the landscapes in this central region of Denmark.

Glaciotectonic studies

(S.A. Schack Pedersen, K.E.S. Klint, P.R. Jakobsen, GEUS)
Three major contributions to glaciotectonic studies have been concluded in the last 3 years. The application of balanced cross sections in the structural analysis has been very successful in describing glaciodynamic development. Sequential phases of deformation, fracturing, folding and faulting, are distinguished and combined in understanding the glaciotectonic framework. The sequential deformations are related to two different regimes: a) proglacial deformation, and b) subglacial deformation. Studies of subglacial deformation have been integrated with the studies of tills, and till fracture patterns are an important branch of the investigations which are applied in understanding geotechnical and hydrogeological problems.

A regional study of the density of glaciotectonic deformation, based on water-well information has been concluded. This investigation gives an interesting picture of glaciotectonic deformation in a glaciated terrain subjected to major glacial advances during the ice ages.

DENMARK-GREENLAND

Minturn circles, glacial deposits from NW Greenland

(P.W.U. Appel, GEUS)
In Inglefield Land, NW Greenland, circular features up to 80 m across consisting of one rock type only, angular to slightly rounded blocks of syenite up to 0.7 m, heavily covered by lichen, have been studied on flat permafrost-bound boulder fields and on flat outcrops of Cambrian sediments. So far about 300 circles have been found partly as rings and partly as filled circles. The rings mostly consist of one layer of syenite blocks, but circles up to 3 m high circles with a diameter of well over 50 m have been encountered. These have been named Minturn circles from the turbulent Minturn elf traversing central Inglefield Land. The first stage in formation of Minturn circles took place under cold ice by a process of melting–refreezing. In step two, numerous blocks of syenite were transported by the Inland Ice across Inglefield Land, and concentrated in meandering rivers on the surface of the ice. Finally, the circles were deposited gently during melting of the ice.

Late Pleistocene ice distributions and climate change in East Greenland

(S. Funder, L. Hansen, GM/UCop; A. Geirsdóttir, UR; J.B. Jensen; GEUS)
In continuation of the PONAM project, fieldwork was carried out in Jameson Land to clarify the Greenland ice sheet's response to climate change during the last inter-glacial–glacial cycle. Results indicate the Early Weichselian Aucellaelv glacier advance was characterised by growth of both local ice caps and the Inland Ice, while the Late Weichselian glacial maximum only comprised an advance of a large fjord glacier; preceded by a phase of large glacier-dammed lakes on land.

Sea ice in the Greenland Sea

(L. Toudal, B.B. Thomsen, DCRS/TUD; P. Wadhams, D. Low, SPRI; H. Valeur, K.Q. Hansen, DMI)
Under the framework of the European Subpolar Ocean Project (ESOP), DCRS did an extensive study of the development of the sea-ice conditions in the Greenland Sea during 1996. Available satellite data from NOAA-AVHRR, ERS-1/2 SAR and the SSM/I microwave radiometer have been used to map ice conditions.

Passive- and active-microwave data for mapping the Greenland ice sheet

(N. Krupis, KUTL; P. Gudmandsen, RSC formerly TUD)
Passive-microwave radiometer and active-scatterometer satellite data at almost at the same frequency and polarisation have been combined in studies of the snow surface to take advantage of any symbiosis that may be present. The two frequencies are 6.6 GHz and 5.3 GHz, respectively, at horizontal polarisation, but the two data-

sets were acquired at an interval of six years. Knowing the stability of the central part of the ice sheet, this was considered of little importance, and was confirmed by investigation of radiometer data over a 9 year period which showed a drop over time to 0.9 in correlation of brightness temperature in the area. To avoid seasonal variations only March and April were considered.

The combination of the two datasets was made without any knowledge of the distribution of brightness temperature and backscatter properties over the ice sheet. Only the accumulation zone (above 1500 m altitude) was considered to avoid the influence of summer melt. Characteristic zones were delineated on the basis of a 2-D scatterplot of data from spatially coinciding areas. They were found largely to correspond to ground data acquired over a period of more than 30 years and to other satellite observations based on only one dataset. The map elements are about 150 x 150 km corresponding to the coarsest spatial resolution of the passive-microwave data. Still, interesting details that have not been reported before, including the percolation and ablation zones, are obtained from the mapping which was made without any adjustment of data or reference to previous work.

Application of SAR interferometry to Greenland glaciers

(S.N. Madsen, J. Mohr, N. Reeh, DCRS/TUD)

The primary study area is Storstrømmen Glacier in NE Greenland, a large outlet glacier from the ice sheet, which surged between 1978 and 1984. Satellite (ERS-1/2) as well as airborne SAR are used for the studies.

The ERS-1/2 satellite interferometry study was initiated in 1994. Five descending ERS tandem pairs and two ascending pairs have been processed, confirming that winter data are generally more reliable for interferometric applications, as data do not de-correlate due to surface changes caused by melting. Two descending and two ascending orbit pairs had sufficient correlation to be phase unwrapped reliably, allowing decomposition of the interferometric phase in a topography and a displacement term. Combining the displacement terms from the descending and ascending orbits and assuming surface parallel flow, the full 3-D surface flow pattern of Storstrømmen was estimated. The radar observations are in good agreement with available GPS reference data.

In collaboration with the DPC and AWI, airborne experiments were carried out on Storstrømmen with the multi-frequency, polarimetric, and interferometric EMISAR developed at DCRS. Four corner reflectors were deployed in a 10 km (N–S) by 30 km (E–W) test area on Storstrømmen. They serve as reference points for the multi-baseline repeat-track interferometry data. Airborne interferograms from 1994 and 1995 showed very low phase noise and were easily unwrapped. Although the uncertainties on the baseline estimates were reduced to the centimetre level, they were still not sufficiently accurate to be used for an extraction of glacier velocity, which in the 20 km wide test area is known to be on the order of a few metres per year only. The major unknown is probably a very low frequency drift of the inertial navigation unit which is presently being studied.

Both the ERS-1/2 and EMISAR studies will be extended to Nioghalvfjerdsfjord Gletscher in North-East Greenland and Daugaard-Jensen Gletscher in central East Greenland.

North GRIP deep drilling in Greenland and EPICA

(C.U. Hammer, NBI/UCop)

This new deep drilling in central Greenland (75.1° N, 42.32° W) some 315 km north-northwest of the Summit drill sites was initiated in 1995 with strong support from the Danish Ministry of Research's Polar Programme via the Danish Natural Science Research Council (SNF). North GRIP is a international project with participants from 9 countries: Denmark, Belgium, France, Germany, Iceland, Japan, Sweden, Switzerland and USA.

The first goal of the drilling was to obtain an ice core to bedrock at a site where optimal conditions were believed to exist for obtaining the oldest undisturbed ice layers. The main goal is to analyse Eemian ice, which is believed to be represented in a continuous sequence undisturbed by the ice flow.

The site was chosen after intensive radio-echo soundings and surface traverses from 1993 to 1995. In 1996, the camp was constructed and the drilling started. Part of this field season was used to test the Antarctic EPICA deep ice-core drill. At the end of 1996 the drilling had reached 351.5 m after a successful first phase test of the EPICA drill.

Further testing of the EPICA drill is planned for Greenland in 1997. The group is participating in EPICA, which consists of two phases; first a deep drilling at Dome C and later in Dronning Maud Land.

North GRIP is steered and co-ordinated scientifically by one or two meetings in Copenhagen every year. The centralised steering, and experience obtained from the GRIP operation (1989–1992), are important reasons why project costs will be some 25 percent lower those of GRIP.

Hans Tausen Ice Cap drilling

(C.U. Hammer, NBI/UCop)

The Hans Tausen Ice Cap, in north Greenland (82.50° N, 37.47° W) was the target of an interdisciplinary Nordic project from 1993 to 1997. Preparations for drilling were made in 1993–1994, e.g. surface elevation and bottom topography were investigated. In June 1995, a drilling through a suitable dome of the ice cap was performed and a 344.9 m long ice core to bedrock was obtained. Isotopic sampling was made in the field as well as ECM measurements. The core is being analysed chemically.

Glacier basin investigations on Hans Tausen Ice Cap, north Greenland

(H.H. Thomsen, O.B. Olesen, GEUS; N. Reeh, DCRS/TUD; P. Johnson, LUT; J.Y. Landvik, UNIS)

Mass-balance, ice-dynamics and stable-oxygen isotope studies were made in a glacier basin in the northeastern part of the Hans Tausen Ice Cap. The stable oxygen-isotope sampling programme of surface ice indicated that ice from the last ice age was not present at the margin of the ice cap, a conclusion supported by ice core drilling. Glacial-geological studies to the north of the ice cap, and earlier investigations south and west of the ice cap, show that areas adjacent to the present ice cap margin became ice-free after the last ice age, about 6000– 7000 years ago. It is thus likely, that any earlier ice cap became extinct some time after 6000 BP, and that the present Hans Tausen Ice Cap started building-up in mid-Holocene. The results from the mass-balance and englacial-temperature studies indicate the existence of an efficient warming mechanism probably due to development and refreezing of extensive slush fields.

Nioghalvfjerdsfjord glacier project

(N. Reeh, DCRS/TUD; H.H. Thomsen, O.B. Olesen, C.E. Bøggild, A. Weidick, A.K. Higgins, GEUS; W. Starzer, DPC)

Glaciological research was initiated in 1996 on the floating glacier tongue filling Nioghalvfjerdsfjorden in NE Greenland. Collection of mass-balance and energy-balance data has been started to map and model the surface mass balance. In addition, other observational programmes were carried out to estimate the mass balance at the bottom of the glacier, i.e. hot-water drilling through the glacier, establishment and measurement of strain-rate and surface mass balance in a net around the drilling sites by GPS, and establishment and measurement by GPS of a line of poles for surface mass balance and velocity observations along the centre-line of the glacier. A corner-reflector for an airborne SAR campaign was mounted on bedrock beside the glacier.

Photogrammetric mapping has been done using vertical air photos from 1963 and 1978. The surface topography for each year was plotted together with information about the intensely developed meltwater drainage patterns on the surface. Comparison of recognisable surface-drainage features, such as stream and lake shapes, is in progress to map mean surface velocities over the 15 year period. Landsat, ERS-1 and NOAA data are being examined to document the sea ice and glacier margin stability conditions. Organic samples for dating were collected along the lateral margin of the floating glacier. Data indicate the entire c. 60 km presently floating part of the glacier had disappeared 7–8 ka ^{14}C years ago.

Preliminary rough mass-conservation modelling indicates a negative mass balance at the bottom of the glacier with bottom melt rates of 4–5 m based on ice velocities from field measurements and ice-thickness values from photogrammetric surface-elevation mapping assuming hydrostatic equilibrium of the floating ice tongue.

Ablation rates of Wisconsin ice

(C.E. Bøggild, T. Tukiainen, GEUS; H. Oerter, AWI)

In NE Greenland it has been observed that the surface of Wisconsin (ice age) ice is significant darker than that of the younger Holocene ice. From deep ice cores it is also documented that ice-age ice contains orders of magnitude more microparticles, which could explain the dark appearance of Wisconsin ice. Spectral reflectance measurements with a SE590 spectrometer show the Wisconsin–Holocene transition to be most detectable in the shortest wavelengths around 350 mn, which corresponds to channel 1 and 2 of Landsat TM. Mapping the lower albedo Wisconsin ice has been performed along 50 km of the ice-sheet margin, to analyse general albedo contrasts.

From energy-balance calculations using this data, it is shown that ablation rates are 10 to 70% less in Holocene ice compared to the less reflectant Wisconsin ice. This has paleoclimatic implications since, at a period after the termination of the Wisconsin ice age, the entire surface of the ablation zone of all the Northern Hemisphere ice consisted of this "dark" and dirty ice. Enhanced ablation, following the increased solar absorption, may have advanced the disintegration of the former ice sheets and enhanced the transition from glacial to interglacial conditions.

Spatial variations of energy balance, melt rates and snow accumulation, Storstrømmen North-East Greenland

(C. E. Bøggild, GEUS)

Mass-balance observations from North-East Greenland show ablation vs. elevation to be an inconsistent and "noisy" decline of melt rates with altitude, caused by the commonly occurring gravity-driven katabatic winds. The winds increase in strength on inclined slopes and provide excess turbulent energy for surface melting in summertime, and redistribute accumulated snow in wintertime.

A spatially distributed energy-balance model has been developed which can simulate the distribution of turbulent heat fluxes, based on the katabatic wind field and the spatially distributed radiation budget, and provide the energy-balance field for melt-rate estimation over the entire glacier surface in gridpoints.

For simulations on the Storstrømmen glacier, input data are from 8 automatic weather stations (AWS) recording in the summer of 1995. The background albedo field was derived from Landsat TM data and ground truth for calibration.

Generally the model can reproduce the observed "noisy" ablation profile, as well as the general ablation gradient of the glacier, although some discrepancies between observations and modelling results occur near sea level and at the very ice margin. Results show the sensible-heat fluxes, caused by the katabatic wind field, to be the predominant reason for the "noisy" melt pattern. Simulation of the katabatic wind field uses inversion strength and angle of inclination as the main driving forces. However, from observations it is clear that dense cold air develops on the plateau above the ablation zone, and reaches over half way to the terminus of the glacier, i.e. the ablation distribution is controlled by radiation conditions in the accumulation zone above.

AWS transect from the ice margin in NE Greenland to the summit

(C. E. Bøggild, GEUS; K. Steffen, CIRES)

A transect of automatic weather stations (AWS) will be installed from the ice margin in North-East Greenland to the summit at the North GRIP deep drilling site. The AWS profile will improve boundary conditions for modelling the mass-balance–climate relation at the ice sheet margin.

At North GRIP two AWS will be installed. One from the GEUS project and one from the American PARCA (Program for Arctic Regional Climate Assessment) project. Intercalibration of the two types of stations will provide a link between the PARCA GC-NET and the GEUS/AWI stations. The PARCA GC-NET consists of a network of stations along the 2000 m contour (accumulation zone) of the ice sheet, whereas the GEUS/AWI stations are mainly located in the ablation zone of the northern part of the ice sheet. By linking the two station networks we will obtain good spatial coverage of the surface climate, which in turn is relevant for estimating the climate sensitivity of the ice sheet.

DENMARK–RUSSIA

Late Pleistocene ice distributions and climate change in northern Russia

(I. Demidov, RAS; S. Funder, GM/UCop; A. Lyså, UT; E. Larsen, NGU)

The Norwegian–Russian–Danish "Arkhangelsk Project" has conducted fieldwork along the Severnaya Dvina and Vaga rivers of northern Russia. The results show there were (at least) two major glaciations where the Scandinavian ice sheet grew and melted over northern Russia. The first advance, during the Karelian cold period, caused a considerable isostatic reaction, while this is not seen to have followed after the Last Glacial Maximum. Preliminary luminescence dates have surprisingly given very young ages of 10–14 ka for this maximum phase.

Submitted by Henrik Højmark Thomsen

NEW ZEALAND

Cape Roberts Project, update for 1997

(P.J. Barrett, Project Science Coordinator, VUW; International Steering Committee: M. Bianca Cita, UM; F. Davey, IGNS; F. Tessensohn, BGR; M. Thomson, BAS; P.-N. Webb, OSU; K. Woolfe, JCU)

The Cape Roberts Project is a co-operative venture between Antarctic scientists, administrators and support personnel from 6 countries — Australia, Britain, Germany, Italy, New Zealand and the USA — to obtain cores that record tectonic and climatic history of the region from around 30 to 100 million years ago by offshore drilling.

In 1986 CIROS-1 was drilled 700 m beneath the floor of western McMurdo Sound, coring strata from 22 to 36 million years old. These strata contained indications of ice on land beyond 34 million years, the time when most scientists now agree that Antarctica cooled to form the first large ice sheets due to shifting ocean circulation after the northward drift of Australasia. These and older strata were subsequently traced north to Cape Roberts, where seismic and magnetic surveys show a gently tilted sequence of strata more than 1500 m thick exposed at the sea floor. We have planned a series of holes to obtain continuous cores into the oldest strata, with 2 holes 400 m deep in the first season and one 700 m deep in the second season.

A new system has been developed for supporting the drill string in water up to 500 m deep, along with 50 tonnes of drilling equipment on sea ice 1.5 m thick. The project has acted as a stimulus for a range of activities enhancing knowledge of the geological history of the region, including a review of biostratigraphic correlation for the Antarctic–Australia–New Zealand region, and a review of procedures for core description and interpretation of glacial and related sediments.

First drilling was scheduled for October 1996, but plans were frustrated in early July last year by the break-out of fast sea-ice off Cape Roberts. A stable frozen sea surface had not formed by the end of July, and drilling was postponed. Sea-ice development will be monitored daily by satellite through the winter.

Glacier-monitoring programme

(T. J. Chinn; AAPC)

A programme to estimate the mass-balance changes of some 48 selected glaciers of New Zealand's Southern Alps has been continued using the end of summer position of the snow line (ELA) as a surrogate for annual mass balance. The ELAs were obtained from oblique aerial photographs taken from a hand-held camera in a small fixed-wing aircraft. The flights, timed for the elusive last day of fine weather before the first snowfall of winter, have often encountered cloud before the survey was completed. 1996 was the third year in succession when all the index glaciers were covered. Results of the 1996 survey indicate the trend to highly positive balances of recent years may be reversing with five of the 48 glaciers showing negative balances.

GPR profiles and lake surveys at Southern Alps glaciers

(I. Owends, D. Nobes, W. Lawson, UCan)

Ground penetrating radar (GPR) profiles on four glaciers in the Southern Alps (Tasman, Hooker, Franz Josef (upper) and Mueller Glaciers) elucidated their depth and internal structure at the profile locations, as well as some features of GPR for research on temperate valley glaciers. Depth data indicated glaciers on the leeward side of the major north–south divide continue to respond to changes in climate by decreasing in thickness. Internal reflectors and diffractors observed at all profiles are interpreted as large-scale structural and/or hydrological features. In particular, it seems likely that large diffractors observed in profiles of the lower Tasman Glacier are englacial channels of the order of 1–2 m in diameter, that are probably approximately bed-parallel. During this work, GPR was used successfully on heavily debris-covered ice (debris layer approximately 0.5–1.0 m thick) in the lower ablation areas of the Tasman and Hooker Glaciers. Control experiments in the upper accumulation area of the Franz Josef Glacier suggest the orientation of buried (sub-snow) crevasses with respect to the antennae affects the nature of the signal, and that for the best basal reflection, antennae should be located perpendicular to crevasse orientation. Surveying (with GPS) of proglacial lakes at the Hooker and Tasman Glaciers indicates these lakes are expanding rapidly. The lake at the Hooker Glacier, for example, doubled in surface area between 1986 and 1996.

Sub- and proglacial glaciotectonic processes beside dry-based glaciers in south Victoria Land, Antarctica

(S. Fitzsimons, UO; R. Lorrain , FUB)

Observations of the structure and sedimentology of landforms at the margins of dry-based glaciers in the Wright and Taylor valleys have demonstrated that deformation of ice-marginal sediments produces thrust-block moraines. This project is concerned with understanding the relationship between glacier dynamics, structural glaciology and the formation of these thrust-block moraines. It involves analysis of the composition and structure of basal-ice facies and measurements of basal-ice deformation. In 1996, a 24 m tunnel was excavated at the base of the Suess Glacier and a series of experiments on basal ice and substrate deformation are being conducted over winter. High debris concentrations in ice within 2 m of the bed, together with blocks of sediment derived from the bed, contrast strongly with previous descriptions of basal conditions in dry-based glaciers. The structure of the basal ice suggests that proglacial glaciotectonic structures are an extension of subglacial deformation and that significant erosion of the frozen sediment bed has occurred. Preliminary results from isotopic and chemical analysis of basal ice suggest liquid water may have been present when some basal ice formed.

Evolution of the Ross Ice Shelf calving front over the last 150 years

(H.J.R. Keys, DOC; S.S. Jacobs, LDEO; L. Brigham, NPS)

The last major calving event along the Ross Ice Shelf front occurred a decade ago. This 'B-9' event took away at least 85 years of advance, but it changed the ice shelf area by only 1%. Since 1987 most of the area lost during that event has been regained due to ongoing advance elsewhere along the ice front. The western front is now well north of any position recorded during the last 150 years, and has not experienced major calving for at least 90 years. Apparent velocity increases, changes in flow direction and counterclockwise rotation of an east–west ice peninsula have occurred recently from 173°E–180°. Ice-front heights generally decrease from east to west, but variability is high, partly due to local irregularities. Elevations are relatively low from 171°–178°W, the location of 'warm' Modified Circumpolar Deep Water circulation beneath the outer ice shelf. Modern heights are considerably higher than historic heights between 179°W and 178°E and lower west of 174°E, probably due to recent dynamic changes. The general advance of the ice shelf and the several decades to a century or more that elapse between its major calving events are also characteristic of the Ronne-Filchner Ice Shelf but in contrast the Larsen and several smaller ice shelves along the Antarctic Peninsula and in the Ross Sea have retreated by large amounts during the past few decades.

Mixed avalanches induced by 1995–96 eruption of Ruapehu Volcano

(H.J.R. Keys, DOC)

Mixed avalanches composed of volcanic material, snow and ice appear to be a poorly documented form of natural hazard. Well-known hazards due to eruptions included lahars, ballistic blocks and ashfall. These induce slab and wet-snow avalanches (up to class 3), as well as secondary lahars (which have been reasonably documented in the literature). Volcanic mixed avalanches and secondary lahars (n=120) were noted over a 15 month period from 29 June 1995. They occurred within seconds (due to block impacts) to months (due to tephra layer destabilisation) after individual eruptions. Most started within 3 km of the active crater, although two avalanches induced by ash layers in the snowpack occurred 11 km away on a separate volcanic peak. This research is documenting volcanic mixed avalanches as hazards to people on Ruapehu and qualifying initiation processes. Similar work on secondary lahars (including debris and hyperconcentrated flows) may occur together with the Institute of Geological and Nuclear Sciences.

Snow accumulation and climate change on Mount Ruapehu

(H.J.R. Keys, DOC)

This work aims at understanding and modelling the effects of climate change on snow distribution on Ruapehu

(2797 m), the largest single venue for downhill skiing in New Zealand. Potential effects of climate warming causes substantial debate during planning for ski area expansion currently constrained at a maximum elevation of 2300 m by national park management. A preliminary multivariate model suggests that average snow depths at 2000 m are not very sensitive to climate change scenarios because increased precipitation offsets warming. At elevations below about 1800 m the positive and negative phases of the Southern Oscillation appear to have considerable influence on snow accumulation and duration.

Interaction of waves and shore-fast ice

(V.A. Squire, UO; C. Fox, L. Wilkins, UA; T. Haskell, IRL; S. Franskenstein)

A field experiment was conducted during November/ December 1996 on the land-fast ice of McMurdo Sound to investigate the directional coherence properties of waves travelling beneath the ice, and to measure how the waves changed as they passed through features such as ridges and cracks. Sixteen strain-gauge rosettes, each with three instruments were deployed accurately by means of GPS near the ice edge, with all instruments telemetering data back to a central receiving station. The strain gauges were built at low cost to be disposable should the sea ice break up during the experiment. They performed well and some very good data were collected, though wave activity was limited to relatively short periods. The data will also be used to validate theoretical models that describe how waves travel through sea-ice plates, and how sea ice breaks up. Data from a parallel and concurrent New Zealand study on the fatigue of sea ice will be used to develop the theme further.

Nuclear magnetic resonance (NMR) studies of sea ice

(P. Callaghan, C. Eccles, MAU; J. Seymour)

Nuclear magnetic resonance should be a useful tool for measuring the unfrozen brine content of sea ice, given that such techniques are sensitive to the liquid-water content within a sample. Indeed relatively routine measurements in the laboratory yielded the brine content of small samples of artificial sea ice, as well as the rotational and translational mobility of this water in the porous ice. The real challenge has been to develop instrumentation suitable for use in Antarctica. This instrument utilises the Earthþs magnetic field instead of the larger fields which are usually generated in the laboratory. Because the Earthþs field is very weak, the intrinsic sensitivity is very low, requiring signal averaging, which in turn requires considerable signal stability.

In 1994 and 1995 the Earthþs Field Nuclear Magnetic Resonance system was used successfully in Antarctica. Attention has been focused on making good quality measurements of liquid-brine signal amplitude and spin-spin relaxation times in core samples removed from the ice. Strong and repeatable correlation has now been found between the NMR estimates of brine-volume profiles through the sea-ice sheet and those found in the conventional way from salinity and temperature profiles. Anisotropic restricted diffusion effects are apparent in Pulsed Gradient Spin Echo experiments. Such measurements can be used to model brine-pocket morphology. The eventual aim is to measure brine content within sea ice without removing cores, thereby avoiding the brine drainage which plagues conventional techniques.

Thermal conductivity of sea ice

(J. Trodahl, M. McGuinness, K.A. Collins, VUW; T. Haskell, IRL)

Calculation of heat flux in climate models requires knowledge of the thermal conductivity of sea ice. In general the standard source used by modellers for the value of the thermal conductivity is a prediction, rather than a measurement. Drawing upon experience gained in measuring the optical and ultraviolet properties of sea ice, this group has been determining the thermal conductivity of sea ice in situ, by recording temperatures throughout the ice thickness from the time when the ice is first safe for foot traffic until break-up is imminent. This provides information on the thermal conductivity as a function of depth in the ice sheet, as well as producing a record of the changes in the conductivity as the sea ice thickens. One interesting result is that often the measured thermal conductivity is approximately 20% greater than the thermal conductivity of fresh-water ice. Since the impurity in sea ice should reduce the conductivity, this result reopens discussion on the role played by convection within the sea ice in the sculpting of the physical properties of a sea-ice sheet. This conundrum is still under investigation.

Cyclic loading, low-cycle fatigue, and acoustic-emission measurements

(T. Haskell, IRL; P. Langhorne, UO)

Fatigue behaviour of sea ice is being determined by subjecting beams of sea ice to repeated bending with zero mean stress. These *in situ* cantilever beams are nominally 10 x 1 x 2 m. Despite the considerable effort over a number of years there is still some way to go before this dataset can be considered complete, mainly because of the inherently statistical nature of fatigue measurements and because of the natural variability in sea-ice properties. Our initial estimates suggest that the endurance limit lies in the range 35–60% of the flexural strength.

In order to assess the damage caused to sea ice by the cyclic loading, acoustic-emission measurements are being made concurrently. It appears that microcracking can take place long before failure of the ice sheet and is not necessarily associated with cyclic softening, which is observed only in the last few cycles before failure. Such defects, once initiated, appear to grow in discrete steps.

Submitted by Pat Langhorne

SWEDEN

ALPINE GLACIERS

Folding in an advancing polythermal terminus, Storglaciären

(P. Holmlund, P. Jansson, J.-O. Näslund, R. Pettersson, C. Rickardsson, NGSU)

The terminus of Storglaciären is approaching an advancing stage after approximately 80 years of retreat. Detailed surface-velocity and strain-rate measurements and radar tomography of the ice thickness and thermal layering of the terminus indicates that the glacier is overriding a stagnant ice-wedge. The processes involved are to be followed during the coming year.

Accuracy of mass-balance measurements, Storglaciären

(Peter Jansson, NGSU)

The available data for Storglaciären provide an excellent opportunity for investigating the accuracy of mass-balance measurements. Winter balance has been measured in a regularly spaced, globally identical, network for the past 30 years whereas summer balance has been determined from an ablation stake net of continually changing distribution. The effects of this and varying evaluation procedures through time can now be checked.

Short-term variations in ice dynamics and hydrology of Storglaciären

(P. Jansson, O. Fredin, NGSU)

The relationship between subglacial water pressure and flow of the glacier is studied by measuring water pressure and short-term ice velocity. In the past, both well-correlated records and records with a 6 hr phase shift have been obtained. This indicates that the relationship between the development of the drainage system through a particular season and the recorded velocity variations is complex.

Model study of Storglaciären

(A.P. Stroeven, NGSU)

Almost half a century of continuous investigations has resulted in an impressive database against which to test a numerical time-dependent flow model of Storglaciären. The model is one-dimensional, and describes the glacier geometry along a 5 km long central flowline at 100 m intervals. The objectives are threefold. First, to investigate whether realistic longitudinal glacier profiles can be generated given physical (ice hardness, flow velocities), geometric and mass-balance input. Second, to simulate the historic variations of Storglaciären (retreat since its Little Ice Age maximum at 1910) and to derive information concerning past climate change in northern Sweden for comparison with other evidence. This part of the study also derives climatic constraints on Holocene maximum glacier extent in the northern Swedish mountains prior to 1910. The third objective, once the model is optimized, is to predict the future behaviour of Storglaciären for varying climate scenarios.

ANTARCTIC GLACIERS

Snow accumulation in western Dronning Maud Land, East Antarctica

(C. Richardson, P. Holmlund, NGSU)

Spatial variations in snow accumulation are being studied with a ground-based snow radar. Continuous radar profiles have been recorded along transects from the coastline to the polar plateau at 3500 m a.s.l. in western Dronning Maud Land. For selected characteristic regions, the average accumulation rate and the spatial variability will be analysed in relation to physical parameters such as altitude, surface slope and distance from the coastline. The data will also be used to obtain detailed 3-D maps of the snow layering at coring sites. The accumulation variability is interpreted from high-resolution radar profiles of stratigraphy in the uppermost 12 m of the snowpack. The radar soundings are calibrated with firn-core data.

Ice flow and depths in Maudheimvidda, Dronning Maud Land, East Antarctica

(P. Holmlund, J.-O. Näslund, NGSU)

For a balanced flow study in the Maudheimvidda basin, measurements of ice flow and ice depth have been carried out for a 25,000 km^2 large portion of the East Antarctic ice sheet. Between 1988–89 and 1993–94 ice movement at the several inlets and two outlets of the study area was surveyed by optical instruments at ranges up to 20 km and by high-precision differential GPS measurements at longer distances. For the major outlet, the Veststraumen Ice Stream, between the Mannefallknausane nunataks and southern Vestfjella, a maximum ice velocity of 200 m a^{-1} was determined. For the second outlet, the smaller Plogbreen Ice Stream, the maximum velocity was 90 m a^{-1}. During the same period, continuous ice-depth profiles were retrieved by radio-echo soundings at 60, 155 and 345 MHZ, conducted from helicopter, terrain-carrier and skidoo. The mass-gain of the basin, comprising the ice flux into the area and its snow accumulation (from stake, radar and firn-core measurements), will be compared with the basinþs ice-flux mass-loss in the balanced flow calculation.

Ice-sheet–climate–landscape interaction, Dronning Maud Land, East Antarctica

(J.-O. Näslund, Per Holmlund, NGSU)

Interactions between the East Antarctic ice sheet, climate and landscape evolution are poorly known. Therefore a study on the subglacial landscape and long-term glacial history of western Dronning Maud Land was started in 1988–89. Mapping of subglacial bedrock morphology in the Heimefrontfjella and Vestfjella area was conducted by radio-echo soundings at 60 and 155 MHZ. The derived morphological data supply information on the climate prevailing at the time of landform formation and on the erosive capability of the present-day ice sheet. Mapped subglacial cirques and glacial valleys close to nunataks indicate that a warm-based, probably alpine, glaciation occurred before the formation of the present mainly cold-based ice sheet, possibly as early as in the pre-Quaternary. The origin and morphological characteristics of valley systems and mountain massifs beneath local ice divides at the inland Amundsenisen plateau and the coastal Högisen ice dome are also being studied.

Glacial erosion, Vestfjella–Heimefront-fjella region, Dronning Maud Land, constrained by cosmogenic dating

(J.-O. Näslund, A. Stroeven, NGSU; M. Kurz, MCGWH)

The isotopic composition of bedrock surface layers can provide information on how long the surfaces have been exposed to cosmic rays. During the austral summer 1993–94 outcropping striated bedrock samples were collected from five nunatak peaks in the Vestfjella, Mannefallknausane and Heimefrontfjella mountains, western Dronning Maud Land, East Antarctica. The samples, from sites ranging in altitude from 500 to 2250 m a.s.l., were retrieved 50 to 300 m above the present ice surface. By assuming the glacial erosion that striated the pavements removed all of the previously isotopically altered bedrock, we infer that a cosmogenic date on such a surface will yield a minimum age, at an order of magnitude scale, for wet-based glaciation. The purpose is to test a suggested Late Weichselian age for ice-sheet overriding and erosion. It also allows construction of a dated glacial chronology for western Dronning Maud Land.

Ice flux through Heimefrontfjella Range, Dronning Maud Land

(V. Pohjola, IGUU; C. Merry, BPRC; SWEDARP members)

The surface velocity distribution from the outlet glacier Kibergbreen has been constructed by: a) tracing the motion of objects (crevasses) from SPOT images (taken 1987 and 1995); and b) using surface-triangulation measurements on aluminium markers during 1989–90. Ice depths are given from several radio-echo measurements by SWEDARP expeditions. Using a simple ice-deformation model the ice flux through the tributary glacier Bonnevie–Svendsenbreen was calculated. The calculated annual ice flux was of the same magnitude as the annual accumulation estimated from the relatively small catchment for this tributary (55 km^2). We are making use of the force-budget technique to get a better estimate of the ice flux through this ice system, which eventually will give us better information on the state of balance of this East Antarctic outlet glacier.

GLACIER HYDROLOGY

The firn aquifer on Storglaciären

(T. Schneider, NGSU)

Meltwater and precipitation infiltrate into firn in the accumulation area of temperate glaciers and percolate until the firn becomes impermeable. An aquifer is built up and a large amount of water can be stored inside the glacier. Continuous water-level measurements in the firn area of Storglaciären reveal maximum storage in the beginning of September about one week before the end of the ablation season. Preliminary recession analyses show that the firn aquifer can be drained within ~6 weeks. Thus, no water is stored over the winter and the minimum water level represents the level where firn becomes impermeable. This firn–ice transition was found on Storglaciären at a depth of about 20 m below the snow surface in spring. New field measurements are focused on the extent of the firn aquifer over the whole accumulation area of Storglaciären.

Proglacial suspended-sediment transport

(T. Schneider, P. Jansson, NGSU)

Proglacial suspended-sediment concentration and water discharge, surface velocity of the glacier and meteorological data will be used to establish a model for simulating suspended sediment transport. Previous investigations shows that suspended-sediment transport cannot be simulated solely by water-discharge data. It was found that during years of high suspended-sediment transport extremely high precipitation events occurred. However, the correlation with precipitation and discharge did not improve the model adequately. A new approach is to include glacier dynamics in modelling of suspended-sediment transport in glacierized basins.

Hydrological modelling in a glacierized drainage basin

(T. Schneider, K. Jonson, NGSU; B. Holst, H. Sanner, SMHI)

Previous applications of the HBV model, a semi-distributed precipitation–runoff model with a melt routine based on a simple degree-day method, showed it was not possible to adequately simulate the water balance in a glacierized drainage basin together with the mass balance of the glacier. A new version of the HBV model was used to simulate the water balance in the Tarfala valley and the mass balance of Storglaciären. The new version of the HBV model includes changes in the snow distribution and the melt routines. In addition the model became more distributed, which means that the conditions for melting of snow and ice on, and the routing of water through, the glacier can be taken into account.

PALAEOGLACIOLOGY

Innuitian ice sheet records, Queen Elizabeth Islands, N.W.T., Canada

(C. Hättestrand, A.P. Stroeven, NGSU; A.S. Dyke, GSC)

Ice-flow directions inferred from striated bedrock outcrops on two small islands in the inter-island channels of the Queen Elizabeth Islands, N.W.T., Canada, refute a local source of ice for this glacial erosion. Numerous striated bedrock outcrops were discovered on Baillie-Hamilton Island, off the west coast of northern Devon Island. Four ice-flow directions were recognized by extremely well-developed rat-tails, crescentic fractures, and microscale stoss-lee features. The consistency of obtained ice-flow directions indicates that the overriding ice was not topographically deflected by the 200 m high island. We therefore conclude that a thick, wet-based, ice flowed obliquely across the more than 300 m deep strait surrounding Baillie-Hamilton Island, and cut these surfaces. A similar conclusion was derived from four striated bedrock outcrops on the northeast coast of North Kent Island, positioned between Devon and Ellesmere Islands. Ice flowing from northwesterly directions obliquely across Baillie-Hamilton and North Kent Islands could not have emanated from local ice domes covering the larger islands. Instead, these results are consistent with a hypothesized larger ice sheet covering the Queen Elizabeth Islands originating in the Norwegian Bay region, the Innuitian ice sheet.

Pliocene Antarctic ice sheet

(A.P. Stroeven, NGSU; M.L. Prentice, H.W. Borns, QSUM)

Two semi-consolidated glacial till patches on Mt. Fleming, south Victoria Land, Antarctica, have been investigated. Similar types of semi-consolidated tills elsewhere in the Transantarctic Mountains (TAM) have been interpreted primarily as deposits of a wet-based East Antarctic ice overriding the highest summits of TAM in late Pliocene time. The timing of this event comes from marine diatom assemblages enclosed in some of these glacial deposits. These diatoms are inferred to originate from marine sediments deposited in basins on the Antarctic craton west of TAM during deglacial periods, basins that today are filled with East Antarctic ice. However, lithostratigraphic analyses on samples from eight pits dug in the Mt. Fleming tills indicate that both deposits are lodgement tills deposited underneath ice emanating from local, alpine, sources. If true, these results have profound implications for the age and climate of deposition, landscape evolution, and the significance of diatom occurrences in the till matrix.

SEA ICE

Baltic Sea ice response to seasonal, inter-annual forcing & climate change

(A. Omstedt, L. Nyberg, SMHI)

The objectives of this study are to formulate and explore a coupled sea-ice–ocean model and to examine the sensitivity of ice in the Baltic Sea to climate change. The model treats the Baltic Sea as 13 sub-basins with vertical resolution, horizontally coupled by estuarine circulation and vertically coupled to a sea-ice model which includes both dynamic and thermodynamic processes. The reducing effect on the barotropic exchange due to sea ice in the entrance area is also included. The model was first verified with data from three test periods representing one mild, one normal and one severe winter. The maximum seasonal ice extent was then examined on the basis of simulated and observed data for 1980–1993. After that some climate scenarios (both warm and cold) were examined. The seasonal, regional and inter-annual variations of sea ice are well described by the model, and the thermal response in the Baltic Sea can be realistically simulated applying data from rather few stations. The Baltic Sea system is highly sensitive to climate change, particularly during the winter season. Warming may drastically decrease the number of winters classified as severe, forcing the climate towards more oceanic conditions. On the other hand, cooling will increase the number of severe winters, forcing the climate towards more sub-Arctic conditions.

SNOW AND ICE CLIMATOLOGY

Glacio-meteorology of Storglaciären

(B. Holmgren, MIUU; R. Hock, GGEZ)

Two comprehensive glacio-meteorological experiments were conducted on Storglaciären: one from 1975–1979 and the other from 1993–1994. Automatic weather stations were operated on the glacier collecting data on air temperature, wind speed and humidity at various levels, data on surface and sub-surface radiative fluxes as well as ice and snow and temperatures. In addition, data on ice and snow evaporation, ablation and glacial discharge were obtained. Results of both projects are being analyzed with respect to the spatial and temporal variation of various climatic elements on the glacier. The data are also being used to derive parameterizations for glacier melt and eventually for simulating short-term glacier ablation.

Climate in empty glacier cirques located just below the glaciation limit

(P. Jansson, S. Jonsson, NGSU)

The local climate is being recorded by an automatic weather station in the Rassepautasj Massif, northern Sweden. The massif contains cirques with different aspects, all located just below the glaciation limit. The climate data will be used to model the conditions favorable for glacier growth in these cirques. The information obtained will be compared with established climate records to produce a synthetic record of cirque glacierization. This is important in order to evaluate how much erosion may be produced by small cirque glaciers during the time they are active. An alternative hypothesis is that cirques may be subglacially developed or at least enlarged underneath an ice sheet. This study should provide information on the probability of such theories.

GLACIERS AND CLIMATE

Coupling between Scandinavian glaciers and atmospheric circulation

(V. Pohjola, IGUU; J. Rogers, BPRC; B. Holmgren, MIUU)

Glaciers in the Scandinavian mountain range are currently advancing while most of the monitored mountain glaciers of the world are retreating. We have examined atmospheric circulation variability and compared changes in air pressure indices to changes in the mass balance of glaciers in the northeastern part of the Atlantic Ocean. The mass balance of Scandinavian glaciers is well correlated with the strength of maritime flow in both winter and summer, the presence of high pressure over the Barents Sea being a critical factor in summer. The increased positive mass-balance of Scandinavian glaciers is partly due to persistent strong westerly winds over the northeastern Atlantic during post-1980 winters and to cold summertime flow which together have helped to maintain positive glacier net balance by decreasing ablation since 1980. Daily–weekly ablation and accumulation measurements on one glacier will be used to investigate how well pressure indices reflect actual snow accumulation/melting in a glacier basin.

Recent climatic variations from shallow Greenland ice cores

(V. Pohjola, IGUU; J. Bolzan, J. Rogers, BPRC)

The stable oxygen-isotope record measured in ice cores contains temperature and other climatic signals, but the interpretation of the temperature signal is complicated by diffusional processes. One effect is to change the amplitude between the summer and winter isotopic extremes, a process which depends on the seasonal accumulation rate (layer thickness) and the firn temperature. We have use a simplified version of a diffusion model to calculate the effects of isotopic diffusion in nine shallow ice cores, retrieved in 1987 as a part of a deep-drilling site-selection survey in central Greenland. We then compare the reconstructed isotopic seasonal signals with temperature data from coastal stations, short records from automatic weather stations from the ice core sites and from satellite microwave brightness records in order to tune the diffusion model. The reconstructed isotopic signals have a meaningful correlation with temperature records and would be a useful tool in reconstructing past atmospheric circulation patterns over the region.

TARFALA RESEARCH STATION

Measurements made as part of the Tarfala Research Station routine program involve measurements both in the Tarfala Valley and the Swedish mountains as a whole. They are carried out by the glaciology group at the Department of Physical Geography, Stockholm University (Currently: P. Holmlund, P. Jansson, T. Schneider, P. Klingbjer, J.-O. Näslund, C. Richardson, M. Stenberg).

The routine program at Tarfala

The 51 year long mass-balance record of Storglaciären forms the basis for glacio-climatic studies in Sweden. Measurement of the mass balance of Storglaciären is carried out by the staff of Tarfala Research Station, situated only a kilometer from the glacier. In order to maintain a high standard of the measurements, a stake net on the glacier is surveyed every week or every second week throughout the melt season.

Climatic data have been collected continuously at Tarfala Research Station since 1965; the automatic weather station was computerized in 1989. In 1995 Tarfala became an official meteorological station with introduction of a automated synoptic weather station. The hydrological regime is surveyed every year using stream gauges at 3–4 sites in the valley. The main aim with this study is to establish a hydrological balance for Storglaciären.

The station is also used for student courses at different levels, and to host small conferences. Results and general information about the station are published every year in an annual report available through NGSU.

Glaciers as climate change indicators

The regional representativity of Storglaciären is studied using other glaciers. These are usually visited twice a year, once at the end of the accumulation period and once at the end of the ablation period. The total number of glaciers in the mass-balance program varies. Currently the program involves five glaciers: Mårmaglaciären, Rabots glaciär, Riukojietna, Stour Räitaglaciären and Storglaciären. These glaciers have been chosen with respect to the east–west climatic gradient in the area, in which the western glaciers are influenced by a much more maritime climate compared to the eastern ones. In addition to the mass balance program, 20 glaciers are observed with respect to changes in frontal position. This program has been run in full since 1965 and it includes, besides surveys of glacier front positions, photogrammetric surveys and radio-echo soundings in order to improve the time resolution. Automatic computerized weather stations have been placed at glaciers situated remote from the climate stations used by SMHI.

Submitted by Peter Janssen

SWITZERLAND

GLACIERS AND ICE SHEETS

Glacier variations in the Swiss Alps

(M. Hoelzle, D.Vonder Mühll, VAW and GK/SANW)
Annual surveys of glacier fluctuations in the Swiss Alps are sponsored by the new Glaciology Commission of the Swiss Academy of Natural Sciences (GK/SANW) and by the Laboratory of Hydraulics, Hydrology and Glaciology (VAW) at the Federal Institute of Technology in Zürich. The measurements are continuous since 1880 and the monitoring strategy is being reviewed according to the corresponding international programmes (World Glacier Monitoring Service, Global Climate Observing System).

The 115th to 117th surveys can be summarized as follows: The decreasing number of advancing glaciers and the prevailing number of retreating ones make it obvious that the generally recessive trend in glacier length over the last 150 years has continued if not accelerated. In single cases, where rather small glaciers increased in length, this was due either to particular mechanisms of glacier movement or to perennial snow deposited by avalanches on glacier snouts. Mass balances have been predominantly negative.

1850 glacier advance and 21st century glacier-retreat scenarios

(M. Maisch, B. Denneler, A. Wipf, GIUZ)
An inventory-like documentation of the 1850 glacier advance in the Swiss Alps has been completed. The dataset records nearly 50 parameters of approximately 2000 glaciers. Losses in area, length and volume as well as changes in equilibrium-line altitudes (ELA), based on an assumed accumulation area ratio of 0.67, were compared with the present situation (Swiss Glacier Inventory of 1973). The datasets were interpreted and described with respect to regional patterns of topography, climate and hydrogeography. Today a total of 1300 km^2 (area) and 74 km^3 (volume) is estimated to remain in the Swiss Alps. The ice loss of 500 km^2 equals 27.2% of the formerly glacierized area in 1850 (1800 km^2). The absolute amount of ice loss in general is directly correlated with former glacier size. The percentage of glacier retreat depends inversely on the vertical extension of the accumulation area. The overall ELA rise since the end of the Little Ice Age is about +90 m, showing slightly higher values in the southern parts of the Swiss Alps, a trend which can be interpreted as an effect of regionally decreasing precipitation. More than 70% of the present glacier tongues and forefield areas are supposed to lie within the belt of probable permafrost conditions, thus causing complex interactions between ice melting and slope instabilities within morainic deposits.

The datasets were finally used to estimate the amount of future ice retreat caused by anticipated global and regional warming in the next century. Assuming different ELA-rise scenarios (ELA +100 m, +200 m, +300 m etc.), the models produce regionally different ice-decay curves. In general, they reveal very clearly that the present glaciers, mainly the large set of smaller ice patches, will shrink and disappear very quickly. Applying ELA scenarios between +100 m to +300 m (as an impact of a temperature rise of the order of +1° to +2°C), between 20% to 75% of the presently existing glaciers in the Swiss Alps will melt completely. This scenario could be expected to take place already between the middle and the end of the next century.

The clearly visible and measurable ice retreat since 1850 outlines the importance of glaciers as climatic indicators and as useful instruments to predict and visualize the possible glaciological consequences of future atmospheric warming. The datasets will also be used as a reference for future inventory projects.

Mapping and modelling of high-altitude firn temperatures in the Alps

(S. Suter, M. Hoelzle, VAW and GIUZ; W. Haeberli, GIUZ)
In 1994, englacial temperatures were measured in deep holes (down to 120 m), shallow holes (down to 15 m) and with surface soundings (2–3 m depth) in the Monte Rosa area, southern Alps (Switzerland). On upper Grenzgletscher and in the saddle of Colle Gnifetti (3900–4450 m a.s.l.) cold firn and ice temperatures were measured. A 120 m profile at a core drilling site at 4200 m a.s.l. showed a prominent heat anomaly at about 30 m depth. However, the advection of cold ice from Colle Gnifetti comes out clearly in the deeper part. The 15 m temperatures vary quite strongly and range between –3 and –14°C depending on aspect and the topographic conditions. The 2–3 m temperatures on upper Grenzgletscher, measured in May 1994, correlate remarkably well with the calculated potential direct solar radiation. A multiple linear regression model of firn temperatures from the Alps of the last 40 years including altitude (as a proxy for the mean annual air temperature) and aspect (as a proxy for the radiation) yields aspect depending lower boundaries for the occurrence of cold firn. The distribution according to this model shows a wide aspect-depending variability. While on northerly slopes cold firn already is probable above 3400 m a.s.l., this boundary rises to 4150 m a.s.l. on southerly slopes. By applying the model to glacier-inventory data from the Alps, 120 glaciers with cold-firn areas were revealed. Further investigations on the spatial occurrence of cold firn areas and the physical processes leading to their formation are planned using a number of temperature, ground-penetration radar and energy-balance measurements and by modelling.

Hydrological control on basal flow dynamics of Alpine glaciers

(U.H. Fischer, VAW; with University of Wales, University of Alberta and University of Cambridge)

Enhanced motion of a glacier at the bed occurs due to reductions in basal drag associated with increased sliding and reductions in sediment strength associated with increased deformation of subglacial sediments. However, sliding and bed deformation are frequently interdependent and the relative contribution to the total basal motion may be sensitively dictated by variations in subglacial water pressure at both the ice–bed interface and within the sediments. Research at Haut Glacier d'Arolla reveals systematic variations in patterns of subglacial water pressure at two distinct temporal scales. Firstly, channelised drainage replaces a pre-existing distributed drainage system over large regions of the glacier bed during the summer. This causes seasonal reductions in subglacial water pressure over the parts of the bed affected by the channel. Secondly, hourly variations in channel discharge (driven by diurnal melt cycles or rainstorms) drive water-pressure waves laterally across the glacier bed through the adjacent remaining distributed system. The aim of this project is to examine (a) how the seasonal evolution of the subglacial drainage system from a distributed to a more channelized configuration influences patterns of subglacial water pressures, basal drag, and its partitioning between sliding and bed deformation; and (b) how short-term laterally-propagating water-pressure fluctuations between major subglacial channels and surrounding areas of the bed influence lateral variations in sliding, subglacial sediment strength and bed deformation at a time scale of hours. The study will be undertaken at a sub-glacier-wide scale using arrays of water-pressure transducers, drag spools, ploughmeters and tiltmeters.

Ice flow over basal irregularities

(G.H. Gudmundsson, VAW)

A linear-perturbation theory has been used to calculate 3-D transient-flow disturbances caused by bedrock undulations and spatial variations in resistance to basal sliding. The theory is currently being used to study the time-dependent surface response to sudden temporal changes in the mean basal-sliding velocity. If sliding velocities are high enough, flow over bedrock bumps having widths comparable to the mean ice thickness generates linear surface undulations which are strikingly similar to the observed flow stripes on ice streams. The group velocity of surface undulations is always less than the well-known kinematic-phase velocity. For length scales comparable to the mean ice thickness, the group velocity is even smaller than the surface velocity of the ice.

Flood protection at Gruben, Valais

(D.Vonder Mühll, VAW; A. Kääb, W. Haeberli, GIUZ; E.Klingelé, IGP)

In connection with flood and debris-flow hazards at Grubengletscher (Saastal, Valais), resulting from the formation and growth of several lakes at the glacier margin and within the surrounding permafrost, the evolution of the polythermal glacier, of the creeping permafrost within a large rock glacier at its orographic right side and of the various periglacial lakes was monitored by regular field visits and documented for the last 25 years by photogrammetric analysis of annually flown high-resolution aerial photographs. Since 1985, especially fast and dangerous changes were recognized in two cases: growth of Lake No. 3. was caused by the accelerated retreat of the glacier margin, and progressive enlargement of periglacial Lake No. 5 on the back of the active rock glacier resulted from a self-reinforcing thermokarst process in massive ice buried on top of the rock-glacier permafrost. Moreover, the level of proglacial Lake No. 1 started to remain at remarkably lower levels during the last few years, indicating that changes in the hydraulic system or in the permeability of the damming moraine complex may have taken place.

Geophysical investigations combining refraction seismics, D.C. resistivity soundings and gravimetry were performed to determine the structure and stability of the moraine dam at proglacial Lake No. 1. In combination with the seismically determined geometry of the moraine complex, the results of the gravimetric survey indicated an astonishingly low porosity of only about 10 to 15 vol%. However, zones with extreme porosity are located near the surface, while evidence for water-saturated zones are weak and limited to layers in immediate proximity to the moraine–bedrock interface. Signs of presently existing permafrost could not be found but the observed extreme porosities are likely to have resulted from thaw of subglacial and periglacial permafrost after the retreat of the partially cold glacier tongue.

In 1995 to 1998, Lakes No. 3 and 5 were artficially drained. At the same time, the safety and retention capacity of proglacial Lake 1 was enhanced by deepening and reinforcing the outlet structure on top of the moraine complex.

Slope stability related to glacier shrinkage and permafrost degradation

(W. Haeberli, A. Kääb, GIUZ; M. Wegmann· D.Vonder Mühll, VAW)

Glacier shrinkage in the Alps has been pronounced since the middle of the 19th century and could continue beyond the limits of Holocene variability in the near future. Changes in Alpine permafrost are less well documented but are likely to take place at various time and depth scales. This development leads to a variety of slope stability problems in bedrock and non-consolidated sediments (moraines and scree slopes). A brief overview and review of recent literature was prepared with respect to characteristic situations and interactions as illustrated by recent events observed in the Alps. In the chain of processes linking slope stability via preparatory factors to marginal stability and from there via triggering factors to instability with controlling factors, the evolution of ice above and below the ground surface usually represents a preparatory factor, whereas water commonly acts as a triggering factor. The resulting instabilities relate to the interactions between (a) permafrost and bedrock; (b) hanging glaciers, permafrost and bedrock; (c) glacier tongues, permafrost and bedrock; (d) glacier tongues and bedrock; (e) glacier tongues and loose sediments (moraines); and (f) permafrost and loose sediments (scree, rock-glacier fronts). Photogrammetric monitoring has started of a large and reactivated slope instability at the orographic right side of the Great Aletsch glacier tongue.

Glacier-hazard mapping

(W. Haeberli, A.Kääb, R. Frauenfelder, D. Bieri, C. Huggel, K. Itten, GIUZ; G. Leysinger, P. Oberholzer, F. Salami, H.H. Utelli, GGEZ; J. Schneider, R. Wyss, IGZ)

Various efforts are being made to develop adequate techniques for systematic mapping of potential glacier hazards in the Swiss Alps. Estimates of ice-avalanche run-out distances in the Grindelwald area proved to be quite successful as demonstrated by events from Gutzgletscher in 1995. The federal guidelines for natural-hazard mapping were evaluated with respect to special conditions in glacierized areas by field studies at Gruben- and Rossbodengletscher. Remote-sensing techniques (air photos, high-resolution satellite imagery, maps) are being tested for inventorying dangerous lakes above timberline and the applicability of geographical information systems for automated delimitation of potentially critical cases. The general goal is to develop a long-term hazard monitoring system.

Temperature and deformation rates in Greenland ice sheet near Jakobshavn Isbræ in boreholes to the bed

(M. Funk, A. Iken and M. Lüthi, VAW)

Flow and temperature modelling indicate the existence of a considerable layer of temperate ice at the base of the Jakobshavn Isbrae as well as at the base of the adjacent ice sheet. The high deformation rate of this basal "warm" ice may be a major contribution to the high surface velocities of the ice stream.

This project will provide information on flow properties and internal temperature distribution over the whole depth of the ice sheet beside the ice stream. In summer 1995 the following measurements were performed: a) englacial temperature, with particular regard to the detection of the depth of the transition surface to the temperate basal layer. b) electrical conductivity between electrodes lowered into pairs of adjacent boreholes. Hence, the depth and a kind of electrical conductivity of different conductive layers could be pointed out. By identifying patterns of conductivity in the ice stream with those in the adjacent ice sheet, information was obtained on differences in total vertical strain. c) borehole tilting, recorded from tilt sensors frozen in the ice. Two holes have been equipped with 9 pairs of tilt sensors and 9 temperature probes at different depths from the glacier bed to the surface. With a specially developed transmitting system, only a two-conductor cable is required for transmitting the output of the tilt and temperature sensors to the data logger at the glacier surface. d) airborne radio-echo soundings along a profile over the drill site to detect internal layers of the ice as well as total ice depth. These measurements were performed by NASA and the University of Kansas (R. Thomas and P. Gogineni). e) surface strain rates and velocities by GPS in a area of 10 km^2 around the ice sheet experimental site.

Borehole experiments were performed in boreholes thermally drilled to the bottom of the ice sheet (860 m depth) and in 900 m deep boreholes in the ice stream. The experimental site on the ice stream was some 50 km behind the calving front, and the ice sheet site 10 km north of the ice stream site.

SNOW AND AVALANCHES

Snow-cover modelling

(C. Fierz, P. Weilenmann, SFISAR)

The formation of weak layers in the snowpack is of prime importance for operational avalanche warning. Although many snow-cover models have been developed (including DAISY at SFISAR), very few reproduce the formation of weak layers.

Together with the Centre d'Études de la Neige in Grenoble, we have started an intercomparison of both qualitative and quantitative model outputs, accompanied by intensive fieldwork, to follow the seasonal evolution of the snowpack with special emphasis on both the formation of weak layers and the temporal evolution of north- and south-facing snowpacks. This should lead to improvements in the reliability of snow-cover models for monitoring the evolution of a seasonal snowpack.

Coupled to a suitable model for the input parameters, the long-term goal is an efficient operational snow-cover model for avalanche forecasting.

Snow-permafrost interactions, Murtèl-Corvatsch, eastern Swiss Alps

(L. Bernhard, F. Sutter, W. Haeberli, R. Weibel, GIUZ; F. Keller, MTS; H.U. Gubler, ALPUG)

A research project combining field observations with high-resolution digital terrain information and a Geographical Information System (GIS) is being conducted with respect to winter snow conditions and their effects on mountain permafrost at the active rock glacier Murtèl– Corvatsch (Upper Engadin, eastern Swiss Alps).

Time and amount of early snowfalls in autumn greatly influence the intensity of ground cooling by affecting radiative fluxes and heat conduction through the cooling surface. Later, in early winter, a system of vertical funnels (holes) develops within the still thin snow cover. Systematic mapping reveals that such snow funnels are regularly distributed along topographic depressions, especially in furrows of ogive-like flow patterns, probably following cold-air drainage patterns. This results in the development of an air circulation system which directly couples the cold winter atmosphere via the snow funnels with the air-chamber system in the coarse blocks of the active layer underneath the snowpack. The thermal insulation effect of thick snowpacks accumulating in furrows from snow redistribution by wind can, thus, be essentially overcome. With increasing snow depth later in wintertime, the funnel system first starts migrating towards the steep slopes of more wind-exposed ridges and then disappears.

Interpolation of repeated snow-depth point measurements on the basis of topographic parameters integrated within a multiple regression model reflecting relief effects on snow-depth distribution clearly shows that the patterns of thick snow in furrows and thin snow on ridges persists throughout the cold season. Time sequences of spring snowmelt were modelled using data about initial snow depths, number of melting days, mean incoming solar radiation, albedo, coefficient of cloud cover, specific melt heat and mean snow density. Modelling results were compared with spatial information about snow disappearance collected by an automatic camera and clearly confirmed that snow stays much longer in furrows than on ridges.

In topographic depressions, effects from late melting of thick snow causing delayed surface warming during spring and early summer appear to be combined with effects from enhanced high winter cooling. The resulting colder ground temperatures and shorter thawing seasons explain the pronounced decrease of active-layer thickness in deep furrows as documented by earlier seismic refraction soundings.

Dynamics of powder-snow avalanches

(D. Issler, SFISAR; F. Hermann, S. Keller, VAW)
In order to improve hazard mapping for powder-snow avalanches (PSAs), guidelines for practitioners and computational tools are being developed on the basis of model experiments in a large water tank and of field observations after natural PSA events. The latter provided semi-quantitative data on snow entrainment and deposition in the avalanche track and run-out zone. They also corroborated the existence of an intermediate layer between the dense-flow avalanche and the suspension cloud of the PSA, termed saltation layer for its similarity with the corresponding phenomenon in snow drift. The laboratory experiments use fine quartz particles or glass beads whose local speeds and concentrations are recorded with an ultrasonic Doppler apparatus. They serve for validating the numerical model under development in a setting where similar physical processes take place. A series of experiments with unchanneled track and runout at high spatial and temporal resolution were complemented by sedimentation and turbulence measurements.

The mathematical model of the suspension layer is based on the turbulence-averaged Navier–Stokes equations for the ice–air mixture, with the k–þ scheme used to achieve closure. The boundary conditions at the bottom are formulated in terms of mass and momentum exchange rates with the saltation layer that depend on concentration and velocity differences between the layers. Depth-average mass and momentum balances are solved for the saltation layer. The model ties erosion and sedimentation rates to the local variables of the saltation layer; order-of-magnitude estimates can be given for the various parameters despite the very limited experimental information on this topic. The model is being implemented in two versions: A fully 3-D code based on a commercial finite-volume flow solver is intended for use by experts in difficult consulting situations (complex topography, interaction with structures, etc.); a depth-average one-dimensional finite-volume code is limted to relatively simple situations but will be made available to practitioners later in conjunction with guidelines on the assessment of PSA hazard.

Experimental avalanche dynamics

(The late T. Castelle, EPFL-GEOLEP; R. Bolognesi and collaborators, SFISAR; V. Chritin, EPFL-LEMA; in collaboration with CEMAGREF; LIME, Grenoble; AIATR Innsbruck; Graz TU-INW; CSVDI Arabba; Univ. di Torino)
The SFISAR avalanche measurements with Doppler and frequency-modulated radar at Val Medel were terminated in 1994 after a last successful campaign. Flow speeds, flow heights and one slope-perpendicular flow-speed profile of relatively small artificially released dense-flow avalanches were obtained. Data analysis revealed a different type of behavior from earlier measurements.

The old project is being succeeded by an international effort in the 4th Framework Programme of the European Union, including virtually all European institutes active in avalanche research. One part of the new project concerns simultaneous field measurements of all the parameters that are relevant in the dynamics of dense-flow and powder-snow avalanches. These include released mass, entrained or deposited mass, flow velocities along the track, densities, texture, flow heights and flow velocity profiles as well as the pressures exerted on various large obstacles. The data are to be used in the validation of dynamic models used in avalanche-hazard mapping. In parallel, various detector systems will be tested for use in avalanche alarm systems; the goal is to develop a common European standard for such systems.

The measurement techniques to be used comprise aerial photogrammetry or laser distance measurements for determining mass balance, tracer methods to detect mixing effects, radar from 6 to 36 GHz for measuring velocities, flow depths and velocity profiles, polyvinyl-difluoride pressure sensors on various types of obstacles, image-analysis techniques, seismic and acoustic recordings as well as manual investigations of the deposits.

During the winter 1994–95, naturally and artificially triggered avalanche activity in the Vallée de la Sionne (Valais) was monitored for site selection. The winter 1995–96 served as a test period for instrumentation and logistics. Additional instrumentation will be installed as soon as it has been developed and tested.

Numerical simulation of snowdrifting

(P. Gauer, D. Issler, SFISAR)
Snowdrifting is a key factor in avalanche formation because it significantly increases the release probability, size and runout distance of avalanches from lee-side slopes. The goal of this project is to develop and test a numerical model of snowdrift that allows simulation of the snow distribution in a complex topography, the deposition of snow behind snow fences, etc. The envisaged

spatial and temporal resolution is of the order of 1–10 m and several 10 minutes, respectively. The boundary conditions may be supplied by field measurements or by a mesoscale meteorological model. The key problem is to adequately describe the physical processes in the saltation layer, similar to the situation encountered in powder snow avalanches. Accordingly, the theoretical framework and numerical methods will closely parallel those used in powder-snow avalanche modelling. The validation of the model is based on existing field measurements as well as wind-tunnel studies. This project involves institutes in France, Italy, Spain, Norway, Iceland and Switzerland.

Weak layers and snowpack stability

(P. Föhn, C. Camponovo, G. Krüsi, SFISAR)
Thin weak layers are inspected in the field and the snow structure of these layers and the neighbouring layers are analysed by special photography and serial cuts of sample blocks in the laboratory. A new shear frame with acceleration measuring box was constructed to measure controlled mechanical shear strength in the field. Thus the strain rate of measurements can also be considered.

Skier influence on snow-cover stability

(J. Schweizer, C. Camponovo, C. Fierz, SFISAR)
To gain insight into the release of snow-slab avalanches triggered by skiers, the skier impact on the snow cover is measured in situ with load cells at different depths within the snow cover, for various snow conditions. Different cases of dynamic loading, similar to both the Rutschblock procedure and skiing are studied. Correlations between measured forces and corresponding snow-cover layering, test area and loading methods are investigated.

Results are compared to forces induced on the snow cover calculated by the finite-element method and to stability measurements in the field.

Economics of avalanche prevention

(C. Wilhelm, SFISAR)
Effectiveness of avalanche prevention is ascertained quantitatively with an appropriate concept of risk, including the avalanche danger area and use of the area. Building on the principle of loss costs, the suitability of supply- and demand-oriented assessment methods in avalanche prevention is being considered. Discussion of safety targets from the economic viewpoint is taking place against a background of technical options, in close connection with development of the macroeconomic scale of avalanche prevention (e.g. expenditure, damage, risks).

Finally, avalanche-prevention projects in various risk categories have been the subject of case studies, which were analysed in the light of absolute and relative economic efficiency. Efficiency target scales such as marginal costs, benefit-cost ratios and amortisation periods, suitable for use as investment-oriented decision criteria, emerged from the cost-effectiveness analysis and cost-benefit analysis.

FROZEN GROUND

Permafrost monitoring, Swiss Alps

(D. Vonder Mühll, VAW; M. Hoelzle, VAW and GIUZ; A. Kääb, W. Haeberli, GIUZ; B. Krummenacher, K. Budmiger, GGUB; M. Monbaron, GGUF)
Efforts have continued on installing and maintaining a measurement network for monitoring the long-term evolution of permafrost in the Swiss Alps with regard to ongoing and potential future warming trends. Methods applied include aerial photogrammetry of creeping permafrost within selected rock glaciers, temperature and deformation measurements in boreholes, data archiving from geophysical surface soundings and analysis of specially flown small-scale infrared photography. Borehole measurements are now available from the Upper Engadin (Murtèl, Pontresina–Schafberg), high-precision photogrammetry of rock-glacier flow and thickness change at Gruben (Valais), Muragl, Murtèl, Pontresina–Schafberg (Grisons) and infrared-airphoto flights from Simplon, Saas, Goms (Valais) and Poschiavo, Val di Campo, Upper Engadin (Grisons). The monitoring strategy is being reviewed with a view to a combined glacier and permafrost monitoring network of the new Glaciology Commission within the Swiss Academy of Sciences and in accordance with corresponding international programmes (Global Geocryological Database, Global Climate Observing System).

Temperature evolution in permafrost

(D. Vonder Mühll, VAW; T. Stucki, SFISAR; W. Haeberli, GIUZ)
The 60 m deep borehole through the active rock glacier Murtèl–Corvatsch (Upper Engadin) performed in 1987 enabled a 10 year long series of temperature measurements to be started within creeping mountain permafrost. Two additional permafrost drillings at Pontresina–Schafberg (Upper Engadin, established in 1990) allow assessment of the evolution of permafrost temperatures at a regional scale: the comparison of the temperature records from the two drill sites at about 3 m depth, i.e. immediately underneath the permafrost table, show a synchronous behavior. Between 1987 and 1994, the uppermost 25 m at Murtèl–Corvatsch rapidly warmed up by more than 1°C in 7 years at 11.6 m depth. The surface temperature is estimated to have increased from −3.3°C (1988) to −2.3°C (1994), thereby probably exceeding previous peak temperatures during the 20th century. After 1994, within only two years, the temperatures cooled down reaching again values similar to those in 1987. The variability of the observed permafrost temperatures is caused by: (a) long-lasting zero-curtains in autumn occurring with early snowfalls and reducing the period of negative temperatures within the active layer; (b) global radiation and air temperature influencing temperatures mainly in summertime; (c) snow-cover thickness during wintertime affecting mean annual permafrost temperatures. Snowcover thickness in November/December is highly correlated with mean winter and annual permafrost temperature near the permafrost table. The strong cooling in 1994–96 is because the Upper Engadin got very little snow and,

consequently, the insulating snow cover was thin, enabling intensive cooling of the ground.

Permafrost map of the Swiss Alps

(F. Keller, ILU)
Computer programmes have been developed within Geographical Information Systems (GIS) for automated mapping of mountain permafrost in combination with digital terrain information. One of these programmes, PERMAKART, based on empirical knowledge of topographic factors affecting the distribution pattern of discontinuous permafrost in the Alps, was used to compile a permafrost-map of Switzerland (altitudes above 2,000 m.a.s.l.) at a grid resolution (mesh width) of 100 m. The reliability of this map was tested statistically by comparison with a sample of 800 BTS measurements (bottom temperature of winter snow as an indicator for permafrost presence/absence). About 3.6 % of the surface of Switzerland is estimated to be covered by mountain permafrost. Including the 2.5% transitional zone at the lower permafrost boundary, this surface area is somewhat more than the present glacierized area. Examples are given of the use of such computer applications for automated permafrost mapping in mountain areas with respect to engineering problems and protection against natural hazards such as landslides, rock falls and debris flows.

Verification of BTS method for mapping mountain permafrost

(M. Hoelzle, M. Wegmann, VAW; B. Krummenacher, GGUB)
Measurement of bottom temperatures of the winter snow cover (BTS) is a well-developed technique for mapping permafrost distribution. A method for continuous measurement of BTS with miniature data loggers was used with a new logger case. The tool is specially designed for field conditions. It was tested in two case studies on and around rock glaciers in Switzerland. In the Murtèl–Corvatsch area (Upper Engadin) and the Furggentälti area (Bernese Alps). The continuous measurements verified the assumptions of the conventional BTS method. Important boundary conditions for BTS measurements are a sufficiently thick, undisturbed snow cover and adequate measurement time. In autumn, before the snow cover is well-developed, air circulation is still possible in the coarse active layer of the rock glacier and heat conduction through the thin snow cover is facilitated. At the end of the winter, meltwater percolation disturbs the equilibrium BTS. At the base of an artificially compacted snow cover the temperatures were influenced throughout the whole winter by atmospheric variations.

Movement and deformation within rock glaciers, Upper Engadin

(M. Hoelzle, A. Kääb, D. Vonder Mühll, VAW; S. Wagner, ADASYS)
In 1987, the first borehole through an active rock glacier was drilled on Murtèl rock glacier (Upper Engadin). Three years later, two additional boreholes were drilled into rock-glacier permafrost on the nearby Pontresina Schafberg. Deformation of all three boreholes was monitored with slope indicators (horizontal deformation) and magnetic rings (vertical deformation). The three rock glaciers differ in ice and debris content, in the temperature of the perennially frozen ground, as well as in surface and bedrock topography. In order to analyze the flow behavior of these rock glaciers and to compare the results with those from other borehole-deformation measurements in ice and soil, a constitutive law was applied to each of the three datasets. The flow behaviour of these ice–rock mixtures, in the considered low-stress range, depends less on shear stress than assumed before. Comparing the viscosity of ice–rock mixtures and glacier ice shows that ice will beccme softer with a low debris content and harder, when the debris content exceeds 30%. This confirms earlier laboratory measurements.

At Murtèl–Corvatsch, 75% of the annual surface velocity (6 cm a^{-1}) takes place within a shear horizon at a depth of 28 to 30 m. At Pontresina-Schafberg, the deformation rates are smaller. The surface velocity measured in borehole 1 is around 4 cm a^{-1} and in borehole 2 around 1 cm a^{-1}. In addition to the yearly measurements of horizontal and vertical deformation, photogrammetric investigations were performed at Murtèl and Pontresina Schafberg. Surface velocities could be determined between 1971 and 1991 with an analytical plotter. The measured surface movements can only be interpreted qualitatively, because the mean error range is around 40 to 60 cm or 2–3 cm a^{-1} and the results are marginally significant. However, a comparison between the photogrammetric results and the measurements in the boreholes shows quite good agreement.

Ice in rock-glacier permafrost

(W. Haeberli, GIUZ; D. Vonder Mühll, VAW)
Viscous flow patterns characteristic of rock glaciers are caused by the long-term (i.e. Holocene) existence of a thick and continuous perennially frozen layer supersaturated with ice. The variability over several orders of magnitude of the electrical DC resistivity indicates that the corresponding ground ice may have multiple origins. Taking into consideration combined effects from climatically controlled ground thermal conditions and from flow-induced thinning/thickening in areas of longitudinal extension/compression helps to explain the observed systematic decrease of DC resistivity along surface-flow trajectories. This change in DC resistivity probably reflects (a) the warming of permafrost through creep movements from colder to warmer areas, and (b) the replacement of high-resistivity surface and supra-permafrost ice by low-resistivity sub-permafrost ice through dynamic thinning of the active layer and permafrost in areas of longitudinal extension. The understanding of the underlying processes must be further improved by studying the physical and chemical characteristics of the ice and by numerically modelling the flow of rock glaciers by coupling thermal and mechanical states as well as the input of debris and the formation/disappearance of ice.

Analysis of moss from the active rock glacier Murtèl–Corvatsch, Engadin

(W. Haeberli, A. Kääb, GIUZ; D. Vonder Mühll, S. Wagner, VAW; P. Geissler, JBVG; J. N. Haas, BUB; in collaboration with Institute of Environmental Physics, University of Heidelberg, Germany)

Sub-fossil stem remains of seven different bryophyte species were found 6 m below the surface and about 3 m below the permafrost-table massive ice of the active rock glacier Murtèl–Corvatsch. The moss species point to the former growth of the recovered mosses around the drill site. 127 pollen and spores captured by the mosses and representing 23 taxa were determined. The local vegetation during deposition must have been a moss-rich Alpine grassland meadow rich in *Cyperaceae, Poaceae, Chenopodiaceae* and *Asteraceae*, comparable to today's flora present around the study site. For ^{14}C analysis, accelerator mass spectrometry (AMS) had to be used due to the small sample mass (about 0.5 mg Carbon content). The mean conventional ^{14}C age of 2250 ± 100 years (1 þ variability) corresponds to ranges in the calibrated calendar age of 470 BC to 170 BC and 800 BC to AD 0 at statistical probabilities of 68 and 95%, respectively. This result is compared with the present-day flow field as determined by high-precision photogrammetry and with information about the thickness, vertical structure and flow of the permafrost from borehole measurements. Total age of the rock glacier as a landform is on the order of 10^4 years; the rock glacier most probably developed around the onset of the Holocene, when the area it now occupies definitely became deglaciated. The bulk of the ice–rock mixture within the creeping permafrost must be several thousand years old. Characteristic average values are estimated for: (a) surface velocities through time (cm a^{-1}); (b) long-term ice and sediment accretion rates (mm a^{-1}) on the debris cone from which the rock glacier develops; (c) retreat rates (1 to 2 mm a^{-1}) of the cliff which provides the debris to the debris cone and rock glacier; and (d) ice content of the creeping ice–rock mixture (50 to 90% by volume). The pronounced supersaturation of the permafrost explains the steady-state creep mode of the rock glacier.

25 years of creep monitoring, Gruben rock glacier

(A. Kääb, W. Haeberli, GIUZ; G.H. Gudmundsson, VAW)

Aerophotogrammetric monitoring of Gruben rock glacier from 1970 to 1995 provides a unique time series documenting 3-D surface kinematics of creeping mountain permafrost, in places affected by historical fluctuations of the polythermal Gruben glacier. Changes in elevation and surface velocities were measured over five 5 year periods using a regular grid with a mesh width of 25 m and with an accuracy of a few cm a^{-1} using an advanced monoplotting technique of multi-temporal stereo models. Although surface lifting occurred in places and within individual time intervals, surface subsidence predominated at an average rate of a few cm a^{-1} in the periglacial part of the rock glacier and of a few dm a^{-1} in the glacier-affected part which still contains some dead ice in permafrost. Fluctuations of horizontal surface velocities seem to correlate with temporal changes in surface elevation. Analyzing flow along principal trajectories and interpreting the advance rate of the front indicate an age of the rock glacier, which is measured in millennia. Dynamic effects of 3-D straining within the creeping permafrost as computed from the measured velocity field at the surface are estimated to contribute to surface heave or subsidence in the same order of magnitude as the observed vertical changes. Temporal variations of surface altitudes at Gruben rock glacier show distinct similarities with mass-balance and surface-altitude variations determined on nearby glaciers, but at a greatly reduced amplitude. This similarity may indicate that the same climatic forcing (summer temperatures?) could have a predominant influence on permafrost aggradation/degradation as well as on glacier mass balance in mountain areas.

Distribution of permafrost in the western calcareous Swiss Alps

(E. Reynard, M. Phillips, IGUL)

The distribution pattern of discontinuous permafrost was studied in the western Swiss Alps, between the Morcels and the Wildstrubel massifs, based on field observations (geomorphological mapping) and measurements (ground temperatures beneath the winter snow cover [BTS] and spring temperatures), including the use of models of the potential distribution of permafrost. Results of 1995 field work seem to indicate the lower limit of discontinuous permafrost in the western calcareous Swiss Alps is lower than in the more continental eastern Swiss Alps. This could be due to both climatological and morphological factors. An inventory of rock glaciers is being established and several rock glaciers are currently the object of more detailed investigations. The effects of snow cover and karst on the distribution of permafrost are being studied. Fieldwork in the Penninic Alps should provide useful data for comparison.

Permafrost and rock-wall stability

(M. Wegmann, H. Gudmundsson, VAW; W. Haeberli GIUZ; H.R. Keusen, GEOTEST; C. Schindler, IGZ)

Detailed semi-quantitative observations and measurements in the Jungfraujoch area form the basis of a study on the effects of permafrost dynamics and glacier recession on the geotechnical properties of strongly jointed rock walls. In different boreholes, equipped with highly precise thermistors, extensiometers and inclinometers, temperature-related deformations are measured. The observations are supplemented by geological, geomorphological and glaciological field investigations. To compute redistribution of stresses, changes in thermal conditions as well as temperature and frost-related deformations 2-D models are applied to rock walls of deeply-cut glacier troughs and steep mountain ridges. The resulting description of thermal and geotechnical characteristics of periglacial rock walls is expected to lead to new insights into frost-shattering processes and rock-wall stability in cold mountain areas.

ICE CORES

Methane and tetrafluorocarbon in an ice core from Colle Gnifetti

(H.W. Gäggeler, IAC; T. Blunier, B. Stauffer, KUP; A. Döscher, U. Schotterer, PSI; in collaboration with Max Planck Institut für Aeronometrie, Katlenburg-Lindau, Germany)

In an ice core drilled in 1982 at Colle Gnifetti, measurements were performed between the surface and a depth of 52 m w.eq. This corresponds to about two centuries. The anthropogenic increase of methane concentration, well-documented in Greenland ice cores, was well-preserved in this high-Alpine ice core. However, it was found that gas closure already occurs surprisingly close to the surface, i.e. at 13.5 m w.eq., corresponding to a density of only 0.7 g cm^{-3}. It has to be assumed that the occurrence of frequent ice layers strongly reduces gas exchange with the atmosphere.

In addition, for the first time the pre-industrial atmospheric background concentration of CF_4 was determined from this ice core. It was found that this concentration was 53% of the present level. Possible sources of this background CF_4 could be volcanic fumes, biomass burning, degassing from minerals or releases from the Earth's surface after impaction of large bolides.

Cosmogenic isotopes in the GRIP core

(S. Baumgartner, J. Beer, P. Kubik, H.A. Synal, M. Suter, EAWAG)

The European GRIP and the American GISP II ice cores provide the most detailed records of environmental parameters over the last 200,000 years of all the ice cores drilled so far. AMS measurements of cosmogenic isotopes are extremely useful for reconstructing the history of precipitation rates as well as modulation of the cosmic ray flux by solar wind and the geomagnetic field. Calculation of the ^{36}Cl flux shows rather constant values except for 37 ka BP when the flux increased by about a factor two and a decrease in the lowest part of the GRIP core most likely due to decay (T1/2 = 300 ka).

During the last 120 ka, the concentrations of both ^{10}Be and ^{36}Cl are highly correlated with þ^{18}O, which is used as an estimate of paleotemperatures. This correlation is interpreted in terms of a changing precipitation rate. Assuming radioisotope fluxes to be independent of þ^{18}O, the correlation of the ^{10}Be and ^{36}Cl concentrations with þ^{18}O is used to estimate the dependence of the precipitation rate on þ^{18}O. The agreement with precipitation rates determined by annual-layer counting and ice-flow modelling shows the usefulness of this approach.

The fluxes of ^{10}Be and ^{36}Cl are modulated by the geomagnetic field and the solar activity. Therefore a production model was used to estimate the contribution of the geomagnetic field, as reconstructed from sediment cores, to the production rate of ^{10}Be and ^{36}Cl. Results indicate that a large part of the long-term variability in the fluxes of ^{10}Be and ^{36}Cl can be explained by geomagnetic field variations.

Ice-core drillings in Antarctica

(T. Stocker, B. Stauffer, J. Schwander, KUP)

The Division for Climate and Environmental Physics is participating in the "European Project for Ice Coring in Antarctica" (EPICA), an international project of the European Science Foundation involving 10 nations. The goal is to get information about climatic changes over the past 500,000 years and about their mechanisms and links to Northern Hemisphere changes through two core drillings in East Antarctica. KUP manufactured the drill heads for the new drill, constructed mainly in Grenoble, and is providing the EPICA drill tower. It is developing a more efficient Continuous Flow Analysis (CFA) system and a device to measure DC conductivity with an increased resolution and a better signal-to-noise ratio for core analyses in the field.

Atmospheric composition, GRIP and Byrd ice cores

(T. Blunier, J. Tschumi, J. Schwander, B. Stauffer, KUP)

Further CO_2 and CH_4 measurements on air extracted from ice samples from the GRIP and the Byrd ice cores have been measured. The GRIP measurements are done in close collaboration with the Laboratoire de Glaciologie et Géophysique de l'Environnement in Grenoble. Comparison of methane records from Greenland and Antarctica allows determination of inter-hemispheric concentration differences for the Holocene epoch. These differences allow the major source areas of methane in the past to be identified. Methane shows distinct variations during most of the last glacial epoch with high concentrations during the so-called Dansgaard–Oeschger events. These global and fast variations can, despite some inter-hemispheric differences, be used to synchronise age scales of polar ice cores from both hemispheres. A synchronisation of the age scales of enclosed gases between the GRIP and the Byrd ice cores for the late-glacial period and the transition between glacial and post-glacial epochs also allows comparison of CO_2 concentrations measured on Byrd samples with fast climatic variations observed in the GRIP ice core.

Stable isotopes in cold ice

(M. Leuenberger, C. Lang, A. Fuchs, KUP)

Besides isotopic measurements of þ^{13}C on CO_2, þ^{15}N and þ^{18}O on N_2 and O_2, we have focused on the elemental ratio of O_2/N_2 in order to reconstruct the expected atmospheric O_2 decrease corresponding to the well-documented CO_2 increase during the industrialization period. We experienced problems with the extraction method (milling system) in that the Ar/N_2 ratio varied unexpectedly. However, the Ar/N_2 ratio was very well correlated with the O_2/N_2 ratios for ice samples which are a few hundred years old. This could point to a fractionation during the milling process (e.g. diffusional process). Measurements covering the last 250 years were corrected according to this correlation. This gave us a best estimate of O_2 concentration decrease of 1.3 permil during the last 250 years. The isotopic composition of atmospheric oxygen (d_a), as measured on GISP2 ice, was used to model the temporal variations of parameters influencing the Dole effect (e.g. difference between d_a and d_o, the seawater þ^{18}O). Our results support the recent findings that fractionation associated with biological activities on land and in the ocean decreased during colder periods. This is somewhat unexpected since generally lower temperatures lead to higher fractionations. Furthermore our results indicate variations of the sea-surface water (d_o) due to melting events of polar ice sheets (e.g. Heinrich events).

Transfer of H_2O_2 and HCHO from the atmosphere into snow and ice

(M. Hutterli, R. Röthlisberger, S. Sommer, B. Stauffer, KUP)

Investigations of the transfer of H_2O_2 and HCHO from the atmosphere into snow and ice continued in 1995 and 1996 at Summit in central Greenland. The field measurements performed in collaboration with the University of Arizona included H_2O_2 and HCHO gas-phase measurements, measurements of the H_2O_2 concentration gradient from the snow surface up to 3 m above the snow surface, and measurements of the concentration of both components in firn samples and in air samples extracted from different depths of the firn. Additionally the short-term propagation of HCHO was investigated by exposing the snow surface to a high HCHO concentration for a limited time. H_2O_2 and HCHO show appreciable concentration changes in the snow after deposition. The concentrations of H_2O_2, HCHO, NH_4^+ and Ca^{++} have also been measured along selected firn cores from North Greenland collected during German traverses of the North GRIP project. CFA (Continuous Flow Analyses) measurements have been performed in the laboratory. While the Ca^{++} concentration was not at all affected by storage and transportation of the core, we observed slight changes of the H_2O_2 and NH_4^+ concentrations in the upper 30 m of the firn and of the HCHO concentration in the entire firn core. The results give interesting information about the deposition pattern of ammonium on the Greenland ice sheet and allow reconstruction of the history of annual accumulation over the past 500 years.

Air mixing in firn

(J. Schwander, KUP; with the LGGE and PSU)

At the depth where firn transforms into ice and where air gets isolated in bubbles there is a difference between the age of the ice (depending on accumulation rate and temperature) and that of the air (diffusive mixing in the firn). At Summit, central Greenland, the age difference between the air and the ice is roughly 210 years under present climatic conditions. This difference was not constant during the past. Based on temperature and accumulation-rate estimates from stable-isotope data we have calculated the age difference for the past 100,000 years for the GRIP and GISP2 ice cores. We used a dynamic firn-densification model to calculate the firn– ice transition depth and the age of the ice at this depth, and an air-diffusion model to determine the age of the air at the transition. During the Holocene, the age difference stayed rather stable around 200 years, while it varied between 250 and 1500 years during the last glaciation. The model results for the age difference are verified by matching corresponding climate events in the methane and þ$^{18}O_{ice}$ records. This study corroborates the large temperature change from glacial to Holocene climate recently found by evaluating borehole temperature profiles. The past firn–ice transitions depths are compared with independent results obtained from þ^{15}N of N_2 measurements. This technique is based on the gravitational enrichment of ^{15}N compared to the lighter ^{14}N.

SNOW/ICE CLIMATOLOGY AND HYDROLOGY

Melt and discharge models of glaciers

(R. Hock, C. Noetzli, H. Lang, GGEZ; with Glaciological Commission of the Bavarian Academy of Sciences)

A grid-based glacier-melt and discharge model has been applied to Storglaciären, a small valley glacier (3 km^2) in northern Sweden for the melt seasons of 1993 and 1994. The energy available for melt was estimated from a surface energy-balance model using meteorological data collected by automatic weather stations on the glacier. Net radiation and the turbulent heat fluxes were calculated hourly for every gridpoint of a 30 m resolution digital terrain model. Discharge of Storglaciären was then simulated from calculated meltwater production and precipitation by three parallel linear reservoirs corresponding to the different storage properties of firn, snow and ice. The performance of the model was validated by comparing simulations of meltwater production and discharge to measurements of ablation and discharge, respectively. The model will also be tested on Vernagtferner, Austria.

GLACIAL GEOLOGY / PALAEOGLACIOLOGY

Alpine glacier fluctuations and dendrochronological investigations

(H. Holzhauser, GIUZ)

Palaeosols and fossil woods have been dated in an attempt to reconstruct, without gaps, the amplitude of Holocene fluctuations of various Alpine glaciers situated in the Valaisian and Bernese Alps (Rhone, Grosser Aletsch, Gorner and lower Grindelwald glaciers). At present, the last 3200 years have been reconstructed. Special attention is paid to minimum glacial extensions.

With the aid of dendrochronological investigations of larch trees from the upper timberline in the Alps, it is hoped to construct a long absolute dendro standard curve. This curve could be used as an aid to absolute dating of fossil woods and as an indicator of past short- and long-term climate changes. The standard curve has now been extended from AD 623 to 1995 by this work. The results concerning the last 700 years (late Middle Ages and modern times) will be combined with those of C. Pfister (documentary sources) and H.J. Zumbühl (historical pictorial records) from the University of Bern.

Quaternary system of Rhône Glacier

(E. Reynard, IGUL)

A working group has been created to re-examine the Late Glacial Maximum, late-glacial and Holocene Quaternary history of the Rhone Glacier system, with special emphasis on the Lake of Geneva basin. It includes researchers from: Geographical Institute and Geological Institute, University of Lausanne; Botanical Museum of Lausanne; Institute F.A. Forel; Geological Institute, University of Geneva; Geographical and Geological Laboratories, University of Chambéry (France).

The Rhone Glacier region is where the glacial theory originated in the early 19th century. Despite or because of this very long scientific interest, its Quaternary chronology is very confused: persistence of old concepts, lack of evidence for some traditional chronological attributions, different interpretations on the French and Swiss sides, unreliable datings, incoherent correlations, etc. The aim of the working group is to review all the literature on the subject, to establish the history of the different concepts and interpretation schemes, to point out the reliable facts and those which have to be rejected, and to propose a new scientific base for interpretation and future research. The work will consider both the Swiss and the French parts of the system together and include results of recent work.

Rutor Glacier in the middle Holocene

(C. A. Burga, GIUZ; with Istituto di Geologia, Milano)

In 1991, C.A. Burga and G. Orombelli sampled new material from a fresh section of Alpine peat bog sediments, covered formerly by the Rutor Glacier (2510 m a.s.l., Aosta Valley, Italy). A detailed sediment profile was made, 20 additional radiocarbon dates obtained and a second series of pollen analyses completed.

Shear behaviour of lodgement tills

(B.U. Müller, QUAB)

This project is part of a larger-scale one to develop a model to explain and understand the mechanisms at the glacier base which ultimately lead to the typical erosional and depositional patterns found in the Alps and in the Alpine foreland. One key to this understanding may be found in the (soft-rock) lithology of the glacier beds, and its influence on the formation of lodgement tills. One of the most important parameters concerning the basal-deformation behaviour of glaciers may be the shear strength of glaciogenic sediments. Although some investigations on the shear behaviour of tills have been made in the past, until now there has been no direct relationship identified between the flow dynamics of an ice body over its bed and the shear strength of the sediments on the glacier bed. We have choosen a strongly geotechnical approach for which we will obtain profiles that clearly show soft-sediment deformation by shearing in a well-defined "lodgement till environment". Selected sediment samples from such profiles will be sheared in a "ring-shear machine" and an effort made to compare these results with the physical properties and the clay mineralogy of the samples.

Pleistocene paleogroundwater archives

(U. Beyerle, W. Aeschbach-Hertig, R. Kipfer, D. Imboden, EAWAG; R. Purtschert, KUP)

Several water samples from a confined gravel aquifer in the upper Glatt Valley, southeast of Zürich, were collected to reconstruct past environmental changes. Noble gases, ^{14}C, þ^{13}C, þ^{2}H, þ^{18}O, freons, tritium, major ion chemistry, pH, alkalinity, temperature, conductivity and oxygen were measured. The calculated ^{14}C ages increase with distance from the recharge area up to 25,000 years BP. A gap in calculated ^{14}C ages between at least 16 and 20 ka BP indicates that during the Last Glacial Maximum local ground-water recharge was interrupted by overlying glaciers. The measured noble-gas concentrations in ground water, which allow the water temperature at the time of infiltration to be calculated, imply that the climate prior to the Last Glacial Maximum was at least 5°C colder than today. Investigations will continue on further paleo-ground-water systems which were influenced by the ice cover during the last ice age. For a better interpretation of the data these investigations have to be combined with studies on young ground water beneath glacier-covered areas.

Late-glacial permafrost–glacier relation, Col di Val Bighera (Italy)

(R. Gehrig, C. Burga, W. Haeberli, GIUZ)

At the orographic right side of the Val di Varadega near Col di Val Bighera, a relic rock glacier was found which has penetrated a lateral moraine, probably dating from early late-glacial time. The reconstructed glacier equilibrium line and the topographic position of the rock-glacier front (2100 m a.s.l., eastern exposure) indicate a depression of the mean annual air temperature of about 5° to 8°C and annual precipitation of less than half today's values. These findings confirm the pronounced continentality of the late-glacial climate in the Alps.

Ice flow analysis of the late-Würm Rhein Glacier

(C. Benz, W. Haeberli, O. Keller, R. Weibel GIUZ; G.H. Gudmundsson, VAW)

An initial digital registration, modelling and analysis of the Würmian Rhein Glacier during its maximum extent has been done with a geographical information system (GIS). Existing data in analogue form (maps of reconstructed ice margins, ice surfaces or ground surfaces with/without Holocene sediments) have been compiled from various sources. The information was digitally registered, using the GIS ArcInfo and an intermediate resolution digital terrain model (DTM). Existing algorithms and models for estimating surface boundary conditions are tested with the 3-D model of the Würmian Rhein Glacier.

Submitted by Wilfried Haeberli

ABBREVIATIONS USED IN REPORTS:

ADASYS	ADASYS (consultants), Ebnat Kappel, Switzerland
ALPUG	ALPUG (consultants), Davos, Switzerland
APPC	Alpine and Polar Processes Consultancy, 36 Grandview Cres., Dunedin, New Zealand
AWI	Alfred-Wegener-Institut für Polar- und Meeresforschung, Bremerhaven, Germany
BAS	British Antarctic Survey, Cambridge, UK
BGR	Bundesanstalt für Geowissenschaften und Rohstoffe, Germany
BPRC	Byrd Polar Research Center, Ohio State Univ., Columbus, Ohio, USA
BUB	Botanical Inst., Univ. of Basel, Switzerland
CIRES	Cooperative Inst. for Research in Environmental Sciences, Univ. of Colorado, USA
DCRS	Danish Center for Remote Sensing, TUD
DMI	Danish Meteorological Inst.
DOC	Dept. of Conservation, Private Bag, Turangi, New Zealand
DPC	Danish Polar Center
EAWAG	Swiss Federal Inst. for Environmental Science and Technology
EPFL	École Polytechnique Fédérale de Lausanne, Switzerland
ETHZ	Eidgenössische Technische Hochschule-Zürich, Switzerland
FUB	Université Libre de Bruxelles, B-1050 Brussels, Belgium
GEOTEST	Geotest (consultants), Zollikofen, Switzerland
GEUS	Geological Survey of Denmark and Greenland, Copenhagen, Denmark
GGEZ	Inst. of Geography, ETHZ
GGUB	Geomorphology Group, Inst. of Geography, UB
GGUF	Inst. of Geography, Univ. of Fribourg, Switzerland
GIUZ	Inst. of Geography, Univ. of Zürich, Switzerland
GK/SANW	Glaciological Commission, Swiss Academy of Sciences
GM	Geological Museum, UCop
GSC	Geological Survey of Canada, Ottawa, Ontario, Canada
IAC	Inst. of Inorganic Chemistry, UB
IGNS	Inst. Geological & Nuclear Sciences, New Zealand
IGP	Inst. of Geodesy & Photogrammetry, ETHZ
IGUL	Inst. of Geography, Univ. of Lausanne, Switzerland
IGUU	Inst. för Geovetenskap, Uppsala Univ., Uppsala, Sweden
IGZ	Inst. of Geology (Eng. Geology), ETHZ
ILU	ILU alpin (consultants), Samedan, Switzerland
IRL	Industrial Research Ltd, PO Box 31-310, Lower Hutt, New Zealand
JBVG	Conservatoire et Jardin Botaniques de la Ville de Genève, Chambésy
JCU	James Cook Univ., Australia
KUP	Physics Inst. (Climate and Environment Project), UB
KUTL	Kaunas Univ. of Technology, Lithuania
LDEO	Lamont-Doherty Earth Observ., Columbia Univ., Palisades, NY 10964, USA
LGGE	Lab. de Glaciologie et Géophysique de l'Environnement, Grenoble, France
LUT	Lund Univ. of Technology, Sweden
MAU	Massey Univ., Palmerston North, New Zealand
MCGWH	Dept. of Marine Chemistry and Geochemistry, Woods Hole Oceanographic Institution, Woods Hole, MA, USA.
MIUU	Meteorologiska Inst., Uppsala Univ., Uppsala, Sweden
NBI	Niels Bohr Inst. for Astronomy, Physics and Geophysics, UCop
NGSU	Naturgeografiska Inst., Stockholms Univ., S-106 91 Stockholm, Sweden
NGU	Geological Survey of Norway
NPS	Naval Postgraduate School, Monterey, CA 93943, USA
OSU	Ohio State Univ., Columbus, Ohio, USA
PSI	Paul Scherrer Inst., Villigen, Switzerland
PSU	ESSC/Geoscience, Penn State Univ., University Park, PA 16802, USA
QSUM	Inst. for Quaternary Studies, Univ. of Maine, Orono, ME 04469, USA
QUAB	Geological Inst. (Quaternary Geology), UB
RAS	Russian Academy of Sciences, Petrozavodsk, Russia
RSC	RS-Consult ApS, Denmark
SFISAR	Swiss Federal Inst. for Snow & Avalanche Research, Davos-Dorf, Switzerland
SMHI	Sveriges Meteorologiska och Hydrologiska Inst., S-601 76 Norrköping, Sweden
SPRI	Scott Polar Research Inst., Cambridge, UK
SWEDARP	Swedish Antarctic Research Project, Swedish Polar Research Secretariat, Royal Academy of Sciences, S-104 05 Stockholm
TUD	Technical Univ. of Denmark, DK-2800 Lyngby, Denmark
UA	Univ. of Auckland, Private Bag, Auckland, New Zealand
UB	Univ. of Bern, Switzerland
UCan	Univ. of Canterbury, Private Bag 4800, Christchurch, New Zealand
UCop	Univ. Copenhagen, Denmark
UM	Univ. degli Studi di Milano, Italy
UNIS	Univ. Courses of Svalbard, Norway
UO	Univ. of Otago, PO Box 56, Dunedin, New Zealand
UR	Univ. of Reykjavík, Iceland
UT	Univ. of Tromsø, Norway
VAW	Laboratory of Hydraulics, Hydrology and Glaciology, ETHZ
VUW	Victoria Univ. of Wellington, Wellington, New Zealand

INTERNATIONAL GLACIOLOGICAL SOCIETY

ANNUAL GENERAL MEETING 1997

MINUTES OF THE ANNUAL GENERAL MEETING OF THE INTERNATIONAL GLACIOLOGICAL SOCIETY

16 July 1997 in the Wrest Point Convention Centre, Hobart, Tasmania, Australia

The President, Dr Norikazu Maeno, was in the Chair. 45 members from 12 countries were present.

1. The Minutes of the last Annual General Meeting, published in ICE, 1996, Nos 111/12, p.13–15, were approved on a motion by W.F. Budd, seconded by R.A. Bindschadler and signed by the President.

2. The President gave the following report for 1996–97:

This is my first report to you as President of the International Glaciological Society. I was very sorry not to have been able to be present at the last AGM in Victoria and would like to thank you again for conferring this honour on me. I repeat my promise made to you through Bjørn Wold to do my best to serve the Society.

Last year, we reported Council had accepted recommendations from the Publications Committee for changes to the style of the *Journal* and *Annals*. This was conditional on a review of the use of vertical justification in other journals. Until this was completed, papers that had already been set were held back for reformatting into the new style. Our new font brought to light incompatibilities between software versions being used in Cambridge and by our printers. These problems created delays in production, so the first issue of the *Journal* was printed late and our two Annals volumes have been delayed about three months. The issue was dealt with by your Council in Chamonix in May. Another computer has been purchased and we have upgraded to a Windows-based version of 3B2 which will also be used by the printers. The backlog is being cleared and we expect to be caught up shortly. The final issue of Volume 42 (No. 142) has been published, as well as the first issue (No. 143) for 1997. Most of the second issue of the *Journal* is now with the printer, but we don't have enough copy to make our target of 200 pages, even including papers accepted as late as March 1997. Ninety-nine papers were submitted to the *Journal* in 1996. Of these, 48 have been accepted, 22 rejected and 29 are still with authors for revision. So far in 1997, 70 papers have been submitted, compared to 57 at the same time last year. Of these, 19 have been accepted, 4 rejected, and 47 are either under review or are with authors for revision. For *Annals* 24, all papers are now with the printer and we expect pagination to be completed this month and the volume to be printed in August. Even though there will be an additional 20 papers, the style changes and page limit should mean the number of pages will be about the same as the EISMINT volume. For *Annals* 25, all papers have now been set and are doing the rounds between the copy editors and authors, before being sent to the printer for layout. We are hoping this volume will be ready for printing in September.

The style changes also affected the production of *ICE*. The second and third issues (111 and 112) were combined and published last year, with the Minutes of the 1996 AGM. Although we had sufficient material for a double issue to start 1997, priority was placed on reformatting the *Journal* and *Annals* papers, thus delaying *ICE*. It is being put together as I speak to you and should be published by the end of the month. It will contain long reports from the US, Canada and the UK. Enough material remains for the final issue of the year, as soon as the Minutes from the AGM have been prepared. However, we are always looking for material. If you feel a summary of your activities is overdue, contact your National Correspondent to find out when the next report will be prepared and submitted.

There have been changes in the Scott Polar Research Institute (SPRI) during the past year that have affected the Society. The Institute obtained support for an extension to be known as the Shackleton Memorial Library. This affects the principal storage areas used for stock and historical files, as well as our office space. Some 15,000 books, reports and reprints, belonging to the Society, have been catalogued and portions will be incorporated into the SPRI library. All historical files and old accounts were retained for later review. The Secretary General will now share his office with two people previously occupying the Polar Record office. The bibliographic information that has been obtained will be shared with the Institute and used to update the SPRILIB electronic catalogue, as part of a continuing collaboration between our two organizations, which has been so mutually beneficial. On your behalf, I would like to thank the Director of the Institute, Dr. John Heap, who is here today, for helping to ensure that this relationship continues.

On a separate note, I should mention that the Society's application for registration under the Data Protection Act, a legal requirement if you store any personal information on an individual in a computer, such as membership details, was approved earlier this year.

Much of the Secretary General's time earlier this year was taken up working with the local organizers and the editorial board of our International Symposium on Snow and Avalanches, held in Chamonix Mont Blanc, France, at the end of May. We established a full editorial team, selected abstracts, published the 3rd circular and programme, and ran what some veteran conference goers described as the best meeting ever. By early July, many of the final papers were already in hand and most were on their way; copy editing of the first 12 papers had already started. On behalf of you all I would like to thank the editorial board, headed by Dave McClung, and the local organizing committee, headed by François Sivardière, and the Secretary General and his wife Margaret for helping to make that meeting such an outstanding success.

Although we have had somewhat less involvement with the meeting here on Antarctica and Global Change, our office in Cambridge helped the local committee where possible, passing on experiences from other meetings. During this week the Secretary General has worked with the Editorial Board to identify potential production problems and information that might be required by our copy editors. I would like to thank Jo Jacka, Bill Budd and their committee members for their wonderful collaboration, Antarctic CRC for inviting us to publish papers from this meeting in the *Annals of Glaciology*, and Beth Pocock and the staff of Mures Convention Management for their excellent organization and for making us feel so welcome and comfortable.

Next year, we will be organizing the International Symposium on Glaciers and the Glaciated Landscape in Kiruna, Sweden, 17–21 August 1998 and publishing papers from that meeting in an *Annals* volume to be edited by Johan Kleman; copies of the first circular are available here. The following month we will be working with our Chinese colleagues and Professor Qin Dahe on papers from the Sixth International Symposium on Antarctic Glaciology (ISAG-6), which will be held in Lanzhou, from September 5–9. Again copies of the first circular should be available here. In May, your Council accepted an offer from the Austrian Institute for Avalanche and Torrent Research for a meeting on Snow and Avalanches to be held in the year 2000 in Innsbruck. Other meeting topics and venues are under active consideration and will be reviewed by our new Council this evening. These include meetings on: the Verification of Cryospheric Models; Sea Ice and its Interactions with the Ocean, Atmosphere and Biosphere; Remote Sensing in Glaciology; and Ice Cores and Climate.

We are most fortunate to have our Treasurer here with us today. He will be presenting the accounts and reporting on the state of our finances. He will be proposing to Council this evening a modest increase in dues to take account of inflation since our last increase.

The use of the credit-card option for IGS payments is increasing. Many members believe this implied automatic renewals until further notice. On Monday, Council approved this option. So, those of you who choose to do so can authorize us to make annual deductions.

Last year, in Victoria, we introduced a new IGS pin. We have a small supply here, so any member who did not attend one of our last two meetings and does not have a pin, and wants one, should see Simon or Margaret Ommanney.

Some of you may have hoped, as we did, that this might have been an occasion for the presentation of the Seligman Crystal to Dr Sigfús J. Johnsen; an award announced last year. Unfortunately, his field programme has not allowed him to attend either of our meetings this year, so the presentation will have to be postponed to another day.

One of the real pleasures for a President of this Society is the opportunity to announce awards. This year, I am delighted to be able to tell you that Council unanimously accepted the recommendation of the Awards Committee that Dr Claude Lorius should receive the Seligman Crystal.

Claude Lorius's contribution to Antarctic glaciology spans a long period of productive activity and has culminated with wide recognition for his role in the analysis of deep ice cores for paleo-records of global change. Claude's work during the IGY at Charcot is still a landmark of valuable data through the year at an isolated interior site. Claude was influential with his colleagues in establishing the French CNRS Laboratoire de Glaciologie et de Géophysique de lþEnvironnement at Grenoble, in conjunction with Prof. Louis Lliboutry and his colleagues at the University. As director of the CNRS laboratory, Claude Lorius presided over its development and growth into one of the most prominent glaciology centres in the world. The study of ice cores for paleo-climate and paleo-environmental records became the leading speciality of the centre and established the group as world leaders in many aspects.

Through the 1970s and early 1980s, Claude Lorius was an active member of the planning group for the IAGP (International Antarctic Glaciological Project). This resulted in a wide range of studies, including aerial sounding, oversnow traverses and deep core drilling. Traverses were carried out inland from Dumont d'Urville, Casey and Mirny and deep core drilling was undertaken at Dome C, Vostok and Law Dome. One of the most successful products was the collaboration organised by Claude Lorius between the Russian (Soviet) deep core drilling at Vostok and French– Russian analysis of the ice cores. The detailed and sophisticated French measurements on the Vostok ice cores added immense value to the Soviet core drilling program. Claude Lorius translated the spatial oxygen-isotope record from Antarctica into a relative temperature proxy, thus providing the key to Vostok and the important carbon-dioxide–temperature relationship that is now so famous. He helped demonstrate that atmospheric carbon dioxide, methane, and global temperature variability have been tightly linked during the past 160,000 years. The series of papers published in Nature and elsewhere have become world renowned and stand as landmarks in paleo-environmental records and research.

Considering the nature of the work being recognized, it is perhaps particularly appropriate that he should be recognized at this meeting.

It also gives me great pleasure to announce that Council unanimously accepted the recommendation from the Awards Committee of Honorary Membership for Dr Charles Swithinbank.

Charles Swithinbank has been a stalwart of the IGS since its early days as the British Glaciological Society.

A first-class scientist, administrator, linguist, pilot, mechanic, cartographer and travelling companion, he assisted the IGS immensely by being based for much of his professional life in Cambridge, the home of the IGS. The Society benefitted from his close liaison with Hilda Richardson and his international outlook, fostered through working in the Antarctic with the Russians, Americans, the Maudheim expedition and the British. A field he has made a notable personal contribution to is satellite remote sensing, or earth observation from space. He was among the first to recognise the huge potential of using satellite images for glaciological research and has forged close and productive international links, especially in the USA where he had worked for a number of years. From tracking sea-ice extent and iceberg drift in the early weather satellite pictures, to producing the first maps of Antarctica composed of high resolution Landsat images, he is always thinking of new ways of exploiting the massive amounts of information implicitly contained in the data. He has six features in the Antarctic named after him in Dronning Maud Land, the British Antarctic Territory and the Ross Dependency. He has received numerous honours and awards in recognition of his contribution to glaciology from Norway, Sweden, USA and UK — the latter including the Polar Medal and the Patron's Medal of the Royal Geographical Society.

This year sees the retirement of the Chief Editor of the *Journal of Glaciology*, Dr Douglas MacAyeal. He has been Chief Editor for seven years and took on this role and responsibility when the Society was trying to become more international in outlook and had just changed its editorial system. Doug rose magnificently to the challenge and established the necessary procedures for the effective management of the whole editorial process. During his term of office he has handled more than 650 papers. In recognition of his outstanding service to the Society, Council unanimously voted on Monday night to award Doug MacAyeal the Richardson Medal. Unfortunately he will not learn of this until later as he is currently unavailable, in a yacht racing on the Great Lakes.

We will be considering the appointment of his successor at the Council meeting this evening.

Members will be saddened to hear that Peter Kasser, a distinguished and influential Swiss glaciologist and an Honorary Member of our Society, passed away last year. An obituary will appear later this year in *ICE*.

On behalf of you all, I would like to express my thanks to our headquarters' staff: to Simon Ommanney, our Secretary General; his assistant Linda Gorman; the Production Manager, David Rootes; and those others who help maintain the quality of our publications and service to members — Ray Adie, Ken Moxham and Sylva Gethin, our copy editors, and Sally Stonehouse and Brenda Varney, who process your manuscripts. To the members of our three committees, Nominations, Publications and Awards, and to Doug MacAyeal, our Chief Scientific Editor, and the members of his editorial board, we also express our warmest thanks.

W.F. Budd proposed and I.M. Whillans seconded that the President's report be accepted. This was carried unanimously.

3. The Treasurer, J.A. Heap, presented the following report with the audited Financial Statements for the year ended 31 December 1996.

"The state of the Society's finances is best summarised by considering the changes from 31 December 1995 to 31 December 1996 in the following funds, as shown on page 14 of the accounts:

Seligman Fund: increased from £2,089 to £2164, as a consequence of interest accrual;

Contingencies Fund: maintained at the same level of £12,684;

Annals Fund: increased from £35,501 to £56,424;

Publications Fund: increased from £11,975 to £13,198, as a consequence of sales, royalties and interest accrual;

Future Volumes: increased from – £7,894 to +£12,706 reflecting principally advanced income received with respect to Annals 25;

Accumulated Fund: increased from £20,798 to £36,327 (page 7) consequent upon a profit in that account for the year of £6,982 (page 13) plus a gain of £8,547 in the value of investments due to an adjustment to market value from cost (page 15, note 15).

During the past year the Society and its auditors have been obliged to adopt a new form for the presentation of the accounts as dictated by the Charity Commissioners in their Statement of Recommended Practice (SORP). The annual movement of funds into and out of the individual Annals accounts is now incorporated within a single, annual balance sheet. In some respects this makes it harder to appreciate the true financial situation of the Society because previously an *Annals* volume was only accounted for once all the symposium and publication costs had been met. Thus in some years we may apparently have higher income because grants are received in advance, or we may have higher outgoings because that is the year the printers bills are settled.

In 1995 the Society published 646 pages in the *Journal of Glaciology* and 421 pages in the *Annals of Glaciology*. In 1996 the figures were 596 for the *Journal* and 674 for the *Annals*, there being two issues of the *Annals* in this year. As I noted in my report for 1995, the Societyþs publications are still very much dependent on the provision of page charges. I wish to register the Societyþs warmest thanks to all those authors who have been both able and ready to support the Society in this way.

May I, again make a plea to all members of the Society to do all in their power to increase the membership and to ensure that libraries in any institutions in which they have influence either maintain their subscriptions or take out a subscription."

I.M. Whillans proposed and R.A. Bindschadler seconded that the Treasurer's report be accepted. This was carried unanimously.

4. Election of auditors for the 1997 accounts. E.M. Morris proposed and I.M. Whillans seconded that Messrs Peters, Elworthy and Moore of Cambridge be elected auditors for the 1997 accounts. This was carried unanimously.

5. Election to the Council 1997–2000. After circulation to all members of the Society of the Council's suggested list of nominees, no further nominations were received, and the following people were therefore elected unanimously:

Vice-President	R.A. Bindschadler
Elective Members	H. Miller M.J. Sharp M. Sturm

Qin Dahe has been co-opted to the new Council.

The President thanked those members who had served on the previous Council and were now retiring.

JOURNAL OF GLACIOLOGY

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

V B AIZEN, E M AIZEN, J DOZIER, J M MELACK, D D SEXTON AND V N NESTEROV
Glacial regime of the highest Tien Shan mountain, Pobeda–Khan Tengry massif

D B BAHR
Width and length scaling of glaciers

A M BAZHEV, O ROTOTAEVA, J HEINTZENBERG, M STENBERG AND J F PINGLOT
Physical and chemical studies in the region of the southern slope of Mt. Elbrus, Caucasus

C R BENTLEY
Rapid sea-level rise from a West Antarctic ice-sheet collapse — a short-term perspective

C R BENTLEY, N LORD AND C LIU
Radar reflections reveal a wet bed beneath stagnant Ice Stream C and a frozen bed beneath ridge BC

C R BENTLEY AND J M WAHR
Satellite gravity and the mass balance of the Antarctic ice sheet

E W BLAKE, C P WAKE AND M D GERASIMOFF
The ECLIPSE drill: a field-portable intermediate-depth ice coring drill

C R BENTLEY AND J M WAHR
Satellite gravity and the mass balance of the Antarctic ice sheet

E W BLAKE, C P WAKE AND M D GERASIMOFF
The ECLIPSE drill: a field-portable intermediate-depth ice coring drill

R J BRAITHWAITE, T KONZELMANN, C MARTY AND O B OLESEN
Reconnaisance study of glacier energy balance in North Greenland, 1993–1994

J-B BRZOSKA, C COLÉOU AND B LESAFFRE
Thin sectioning of wet snow after flash freezing

J M CASAS, F SÀBAT, J M VILAPLANA, J M PARÈS AND D M POMEROY
A new portable ice core drilling machine: application to tephra studies

G H GUDMUNDSSON
Ice deformation at the confluence of two glaciers investigated with conceptual map-plane and flowline models

G H GUDMUNDSSON, A IKEN AND M FUNK
Measurements of ice deformation at the confluence area of Unteraargletscher, Bernese Alps, Switzerland

D M HANNAH, G R MCGREGOR
Evaluating the impact of climate on snow and ice melt dynamics in the Taillon basin, French Pyrenees

J T HARPER, N F HUMPHREY AND W T PFEFFER
Crevasse patterns and the strain-rate tensor: a high-resolution comparison

C L HULBE, I M WHILLANS
Weak bands within Ice Stream B, West Antarctica

B LEGRÉSY, F RÉMY
Using the temporal variability of satellite radar altimetric observations to map surface properties of the Antarctic ice sheet

T MURRAY, J A DOWDESWELL, D J DREWRY AND I FREARSON
Geometric evaluation and ice dynamics during a surge of Bakaninbreen, Svalbard

D PALACIOS, J DE MARCOS
Glacial retreat and its geomorphic effects on Mexico's active volcanoes from 1994–95

K C PARTINGTON
Discrimination of glacier facies using multi-temporal SAR data

B T RABUS, K A ECHELMEYER
The flow of a polythermal glacier: McCall Glacier, Alaska

J J SAPIANO, W D HARRISON AND K A ECHELMEYER
Elevation, volume and terminus changes of nine glaciers in North America

T A SCAMBOS, M A FAHNESTOCK
Improving digital elevation models over ice sheets using AVHRR-based photoclinometry

C A SHUMAN, R B ALLEY, M A FAHNESTOCK, R A BINDSCHADLER, J W C WHITE, J WINTERLE AND J R MCCONNELL
Temperature history and accumulation timing for the snow pack at GISP2, central Greenland

M J SIEGERT, J K RIDLEY
Determining basal ice sheet conditions in the Dome C region of East Antarctica using satellite radar altimetry and airborne radio-echo sounding

M VALLON, C VINCENT AND L REYNAUD
Altitudinal gradient of mass-balance sensitivity to climatic change from 18 years of observations on Argentière glacier (France)

B C WELCH, W T PFEFFER, J T HARPER AND N F HUMPHREY
Mapping subglacial surfaces of temperate valley glaciers by two-pass migration of a radio-echo sounding survey

F WILHELMS, J KIPFSTUHL, H MILLER, J FIRESTONE AND K HEINLOTH
Precise dielectric profiling of ice cores: a new device with improved guarding and its theory

ANNALS OF GLACIOLOGY

The following papers from the International Symposium on Representation of the Cryosphere in Climate and Hydrological Models held in Victoria, B.C., Canada, 12–15 August 1996 have been accepted for publication in *Annals of Glaciology* Vol. 25, edited by J.E. Walsh:

T A AGNEW, H LE AND T HIROSE
Estimation of large-scale sea-ice motion from SSM/I 85.5 GHz imagery

M R ANDERSON
Determination of a melt-onset date for Arctic sea-ice regions using passive-microwave data

T E ARBETTER, J A CURRY, M M HOLLAND AND J A MASLANIK
Response of sea-ice models to perturbations in surface heat flux

D A BAILEY, A H LYNCH AND K S HEDSTRÖM
Impact of ocean circulation on regional polar climate simulations using the Arctic Region Climate System Model

J L BAMBER, R A BINDSCHADLER
An improved elevation dataset for climate and ice-sheet modelling: validation with satellite imagery

R G BARRY
Cryospheric data for model validations: requirements and status

M BENISTON, W HAEBERLI, M HOELZLE AND A TAYLOR
On the potential use of glacier and permafrost observations for verification of climate models

A BOUDREAUX, C RAYMOND
Geometry response of glaciers to changes in spatial pattern of mass balance

R D BROWN
Historical variability in Northern Hemisphere spring snow-covered area

E BRUN, E MARTIN AND V SPIRIDONOV
Coupling a multi-layered snow model with a GCM

W F BUDD, X WU AND P A REID
Physical characteristics of the Antarctic sea-ice zone derived from modelling and observations

H DANG, C GENTHON AND E MARTIN
Numerical modeling of snow cover over polar ice sheets

C DERKSEN, K MISURAK, E LEDREW, J PIWOWAR AND B GOODISON
Relationship between snow cover and atmospheric circulation, central North America, winter 1988

D DE SÈVE, M BERNIER, J-P FORTIN AND A WALKER
Preliminary analysis of the snow microwave radiometry using the SSM/I passive-microwave data: the case of La Grande River watershed (Quebec)

H DOUVILLE
Local and global stand-alone tests of the Météo-France snow parameterization

R ESSERY
Parameterization of fluxes over heterogeneous snow cover for GCMs

R ESSERY
Seasonal snow cover and climate change in the Hadley Centre GCM

C FIERZ, C PLÜSS AND E MARTIN
Modelling the snow cover in a complex Alpine topography

G M FLATO, D RAMSDEN
Sensitivity of an atmospheric general circulation model to the parameterization of leads in sea ice

C A GEIGER, S F ACKLEY AND W D HIBLER III
Year-round pack ice in the western Weddell Sea, Antarctica: response and sensitivity to atmospheric and oceanic forcing

M B GIOVINETTO, G HOLDSWORTH, D A FISHER, N M WATERS AND H J ZWALLY
An assessment of the regional distribution of the oxygen-isotope ratio in northeastern Canada

M B GIOVINETTO, H J ZWALLY
Areal distribution of the oxygen-isotope ratio in Antarctica: an assessment based on multivariate models

H GOOSSE, J M CAMPIN, T FICHEFET AND E DELEERSNIJDER
Impact of sea-ice formation on the properties of Antarctic bottom water

M HARDER
Roughness, age and drift trajectories of sea ice in large-scale simulations and their use in model verifications

W D HIBLER III, E M SCHULSON
On modeling sea-ice fracture and flow in numerical investigations of climate

M HIGHAM, M CRAVEN, A RUDDELL AND I ALLISON
Snow-accumulation distribution in the interior of the Lambert Glacier basin, Antarctica

R C A HINDMARSH
Use of ice-sheet normal modes for initialisation and modelling small changes

K M HINES, D H BROMWICH AND R I CULLATHER
Evaluating moist physics for Antarctic mesoscale simulations

M M HOLLAND, J L SCHRAMM AND J A CURRY
Thermodynamic feedback processes in a single-column sea-ice–ocean model

P HUYBRECHTS, S T'SIOBBEL
A three-dimensional climate–ice-sheet model applied to the Last Glacial Maximum

N ISHIKAWA, Y TAKEUCHI, Y ISHII AND Y KODAMA
Characteristics of the water balance of the Moshiri experimental watershed, Japan

C S JACKSON
Sensitivity of a two-layer model atmosphere to changes in ice-sheet topography

R KATTELMANN
Rapid changes in snow cover at low elevations in the Sierra Nevada, California, U.S.A

J R KEY, Y LIU AND R S STONE
Development and evaluation of surface shortwave flux parameterizations for use in sea-ice models

M KREYSCHER, M HARDER AND P LEMKE
First results of the Sea-Ice Model Intercomparison Project (SIMIP)

G KRINNER, C GENTHON
The Antarctic surface mass balance in a stretched grid general circulation model

R KWOK, J C COMISO
The perennial ice cover of the Beaufort Sea from active- and passive-microwave observations

S LEGUTKE, E MAIER-REIMER, A STÖSSEL AND A HELLBACH
Ocean–sea-ice coupling in a global ocean general circulation model

P LEMKE, W D HIBLER, G FLATO, M HARDER AND M KREYSCHER
On the improvement of sea-ice models for climate simulations: the Sea Ice Model Intercomparison Project

R W LINDSAY, J A FRANCIS, P O G PERSSON, D A ROTHROCK AND A J SCHWEIGER
Surface turbulent fluxes over pack ice inferred from TOVS observations

A LYNCH, D MCGINNIS, W L CHAPMAN AND J S TILLEY
A multivariate comparison of two land-surface models integrated into an Arctic Regional Climate System model

J R MARKO, D B FISSEL AND D HALLER
Modelling inter-annual sea-ice variability off eastern Canada

P MARSH, J W POMEROY AND N NEUMANN
Sensible heat flux and local advection over a heterogeneous landscape at an Arctic tundra site during snowmelt

I MARSIAT, J L BAMBER
The climate of Antarctica in the UGAMP CGM: sensitivity to topography

E MARTIN, E BRUN AND Y DURAND
Snow-cover simulations in mountainous regions based on general circulation model outputs

J MASLANIK, J DUNN
On the role of sea-ice transport in modifying Arctic responses to global climate change

J MASLANIK, C FOWLER, J KEY, T SCAMBOS, T HUTCHINSON AND W EMERY
AVHRR-based Polar Pathfinder products for modeling applications

D L MCGINNIS, M D CROSS
Arctic modeling data resources: the data archives at the ARCSS Data Coordination Center and the National Snow and Ice Data Center, U.S.A.

J R MILLER, G L RUSSELL
Investigating the interactions among river flow, salinity, and sea ice using a global coupled atmosphere–ocean–ice model

L NAZARENKO, T SOU, M EBY AND G HOLLOWAY
The Arctic ocean–ice system studied by contaminant modelling

A W NOLIN, J STROEVE
The changing albedo of the Greenland ice sheet: implications for climate modeling

S P O'FARRELL, J L MCGREGOR, L D ROTSTAYN, W F BUDD, C M ZWECK AND R WARNER
Impact of transient increases in atmospheric CO_2 on the accumulation and mass balance of the Antarctic ice sheet

R J OGLESBY, S MARSHALL
Modeling polar glaciation

D K PEROVICH, W B TUCKER III
Arctic sea-ice conditions and the distribution of solar radiation during summer

I A PODGORNY
Calculation of solar-energy inputs into melt ponds

D POLLARD, S L THOMPSON
Driving a high-resolution dynamic ice-sheet model with GCM climate: ice-sheet initiation at 116 000 BP

G RAMSTEIN, A FABRE, S PINOT, C RITZ AND S JOUSSAUME
Ice-sheet mass balance during the Last Glacial Maximum

G RAMSTEIN, F FLUTEAU AND V MASSON
Existence of an ice cap during the mid-Cretaceous period (120–90 Ma): an AGCM investigation

B RANA, M NAKAWO, Y FUKUSHIMA AND Y AGETA
Application of a conceptual precipitation–runoff model (HYCYMODEL) in the debris-covered glacierized basin in the Langtang Valley, Nepal Himalaya

A RANGO
The response of areal snow cover to climate change in a snowmelt–runoff model

J A RICHTER-MENGE
Towards improving the physical basis for ice-dynamics models

D A ROBINSON
Hemispheric snow cover and surface albedo for model validation

J L SCHRAMM, M M HOLLAND AND J A CURRY
The effects of snowfall on a snow–ice-thickness distribution

M C SERREZE, J A MASLANIK
Arctic precipitation as represented in the NCEP/NCAR reanalysis

D M SMITH, C COOPER, D J WINGHAM AND S W LAXON
Evaluation of the representation of Arctic sea ice in the U.K. Hadley Centre GCM

R S STEEN, T S LEDLEY
Asynchronously coupling the cryosphere and atmosphere in an energy-balance climate model

E J STEIG
How well can we parameterize past accumulation rates in polar ice sheets?

A STÖSSEL
On the impact of sea ice in a global ocean circulation model

L TARASOV, W R PELTIER
A high-resolution model of the 100 ka ice-age cycle

S L THOMPSON, D POLLARD
Ice-sheet mass balance at the Last Glacial Maximum from the GENESIS version 2 global climate model

J S TILLEY, W L CHAPMAN AND W WU
Sensitivity tests of the Canadian Land Surface Scheme (CLASS) for Arctic tundra

L-B TREMBLAY, L A MYSAK
The possible effects of including ridge-related

roughness in air–ice drag parameterization: a sensitivity study

M A TSCHUDI, J A CURRY AND J A MASLANIK
Determination of areal surface-feature coverage in the Beaufort Sea using aircraft video data

S J VAVRUS
The effect of sea-ice parameterizations on the simulation of the Arctic ice pack

M VERBITSKY, B SALTZMAN
Modeling the Antarctic ice sheet

J W WEATHERLY, T W BETTGE AND B P BRIEGLEB
Simulation of sea ice in the NCAR Climate System Model

H J ZWALLY, M B GIOVINETTO
Areal distribution of the oxygen-isotope ratio in Greenland

BRANCH NEWS

The 1998 meeting of the British Branch of the IGS will be held at the Centre for Glaciology in Aberystwyth on 10–11 September 1998.

For further details, please contact:

Anne-Marie Nuttall
Centre for Glaciology
Institute of Geography and Earth Sciences
University of Wales, Aberystwyth,
Ceredigion SY23 3DB
Tel: 01970 622781; Fax: 01970 622659
email: a.m.nuttall@aber.ac.uk

INTERNATIONAL SYMPOSIUM ON GLACIERS AND THE GLACIATED LANDSCAPE

Kiruna, Sweden, 17–20 August 1998

CO-SPONSORED BY

Environmental and Space Research Institute, Kiruna
City of Kiruna
Department of Physical Geography, Stockholm University

SECOND CIRCULAR

The International Glaciological Society will hold an International Symposium on Glaciers and the Glaciated Landscape in 1998. The symposium will be held in Kiruna, Sweden, with registration on August 16, and sessions from August 17–20.

PARTICIPATION
This circular includes a booking form for registration, accommodation and the post-symposium tour. The forms and accompanying payments should be returned to the IGS, in accordance with instructions given, before May 15, 1998. There will be a £50 surcharge for registrations received after this date. Full refunds will not be possible for cancellations received after June 29, 1998.

Participants' registration fees cover organisation costs, copies of abstracts, icebreaker, banquet, half-day tour, and a copy of the Proceedings volume (Annals of Glaciology, Vol. 28). Accompanying persons' registration fees include organisation costs, icebreaker, banquet and half-day tour. There is an administration charge for participants who are not IGS members.

LOCAL ORGANISING COMMITTEE
Per Holmlund, Peter Jansson, Johan Kleman

SCIENTIFIC EDITOR
Johan Kleman

REGISTRATION FEES	UK£
Participant (non-member)	175 (215)
Student	80
Accompanying person aged 18 or over	50
Late registration surcharge (after May 15, 1998)	50

Refunds on registration fees will be made up to June 29, 1998. After that date a partial refund is possible until August 1, 1998, after which date no refund is given. See booking form for methods of making payment. All who register will receive a copy of the third circular and programme prior to the meeting.

TOPICS
The following topics will be open for discussion:

- Ice-covered landscapes
- Interpretation of glaciated landscapes
- Creation, reshaping and survival of subglacial forms
- Spatial and temporal variations in thermal regime
- Controls of wet base/cold base flow regimes
- Ice-substrate interaction

Sessions will be held on three full days and one half-day. A half-day excursion will be arranged during the meeting. There will be ample opportunity for poster displays, which are encouraged.

POST-SYMPOSIUM TOUR (21–23 August)
A three-day post-symposium tour by bus is planned which will cover an area from the Norwegian coast to the interior of Sweden. It is possible that the direction of the excursion will be reversed. The tour is estimated at no more than £300 (estimated maximum, cost will be adjusted downward according to the number of participants). Exact cost will be announced in the third circular.
Day 1. *Kiruna-Abisko-Narvik-Skjomen.* The landscape on the Swedish side is low relief and rich in sediments. A stop will be organized at Kärkevagge, which boasts the clearest lake in Sweden and a very rich boulder field, deposited during the last ice age. The Norwegian side is high relief (fiord landscape) and polished by ice.
Day 2. *Skjomen-Abisko-Kiruna.* Visit to the Royal Academy of Sciences Research Station at Abisko and Kaisepakte, a mountain rich in landforms.
Day 3. *Kiruna-Lainiobågen.* A tour towards the east to study the complicated network of landforms of disputable age.

PRE-SYMPOSIUM EXCURSION (16 August)
A one day pre-symposium excursion will be available for a smaller number of participants on a first come–first serve basis. The tour includes a helicopter flight around the Kebnekaise mountain, landing on Storglaciären, and a short hike down to the Tarfala Research Station (TRS) where lunch will be served. The feasibility of this excursion is higly dependent on the weather. The total cost is estimated at no more than £100, exact cost will be announced in the third circular.

TRS will also be open to visitors from August 16–26. Food and lodging is free of charge (limit 30 persons/night, also first come – first serve), access by foot (25 km).

ACCOMMODATION
The principal symposium hotels will be the Hotel Ferrum and Hotel Kiruna in the centre of Kiruna. Alternatives are also available, including cabins and hostels, all within 10 minutes of the conference hall. Details on making reservations, etc. will be sent out to those pre-registering. A full refund will be possible for cancellations received in writing by 1 July, 1998.

Accommodation details
All accommodation is located within walking distance (less than 10 minutes) of the conference hall. A city map and information on practical details will be sent with the third circular after pre-registration. Prices given here are approximate, in some cases only given as a range; exact costs are being negotiated and will be included in the third circular. The prices given here should be seen as maximum costs.

Rooms are in four categories:
Hotel Ferrum is the principal hotel in Kiruna, Rooms usually cost around £100 per person and night. Persons wishing to stay here should pay a £100 deposit. Mid-range hotels costs £30–70 per person and night. Persons using this accommodation should pay a £50 deposit.

All other hotels and hostels for this meeting cost £15–25 per person and night. Some hostels are very comfortable, all usually include TV, shower and cooking facilities. It is also possible to rent small apartments. Persons wishing to use this accommodation should pay a £50 deposit.

A camping facility is also available, as well as cabins for rent. Camping fees are usually around $10 per day and cabins (with room for four) are £50. Persons wishing to use this accommodation should pay a £20 deposit.

There are many cheap ways to stay in Kiruna. Sharing apartments or cabins or sharing rooms at hotels can substantially reduce costs. In the third circular, sent to those who pre-register, further details on the availability of such accommodation will be given.

PAPERS
Papers from the Symposium will be published by the Society in the Annals of Glaciology. Papers will be refereed and edited according to the Society's usual standards before being accepted for publication.

Submission of Papers
Participants who want to contribute to the Symposium should submit an abstract of their proposed paper in English. This abstract must contain sufficient detail to enable us to form a judgement on the scientific merit and relevance of the proposed paper. It should not exceed one page of typescript, on international size paper A4 (210 x 297 mm). References and illustrations are not required at this stage. Place the title and authors' names and addresses (preferably including E-mail address and fax number) at the top of the abstract, not on a separate sheet. Indicate at the bottom which specific topic it intends to address, and whether a poster presentation is preferred. When selecting their material, authors should bear in mind that the final version of the paper should not normally exceed 5 Annals printed pages (exceeding this limit merits mandatory page charges). Send abstracts by E-mail, fax or regular mail to the Secretary General of IGS. Last date for receipt of abstracts is 10 February 1998.

Selection of Papers
Each abstract will be assessed on its scientific quality and relevance to the topics of the Symposium. Authors whose abstracts are acceptable will be invited to present their contribution at the Symposium. First authors will be advised by April 14, 1998 of the acceptance or otherwise, other authors will not be informed separately. Authors who have not received notification by May 1 should contact the IGS office in Cambridge. Acceptance of an abstract means that the paper based on it must be submitted to the Annals of Glaciology and not to another publication. Note: Abstracts alone will not be published in the Annals of Glaciology.

Distribution of Abstracts
The accepted abstracts will be provided to all registered participants upon registration on August 17, 1998.

Submission of Final Papers and Publication
Papers presented at the Symposium will be considered for publication in the Proceedings volume (Annals of Glaciology Vol. 28). Final typescripts of these papers should be sent to the Secretary General by 16 June 1998. They should be written in English and prepared in accordance with the instructions about style that will be sent to authors with the acceptance notification. The final version of the paper should not normally exceed 5 Annals printed pages.

The papers will be refereed according to the usual standards of the Society before being accepted for publication. Speedy publication of the proceedings will depend upon strict adherence to deadlines. The deadline for revised papers is September 28, 1998.

Last date for receipt of final papers: June 16, 1998.

IMPORTANT DATES:

Abstracts due	10 February 1998	Deadline for full refund	29 June 1998
Notification of acceptance	14 April 1998	Deadline for refund	1 August 1998
Pre-registration deadline	15 May 1998	Conference starts	17 August 1998
Papers due	16 June 1998	Final revised papers due	28 September 1998

SYMPOSIUM ON GLACIERS AND THE GLACIATED LANDSCAPE

Kiruna, Sweden, 17–20 August 1998

REGISTRATION FORM

Family Name: ______________________________
First Name: ______________________________
Address: ______________________________
____

Tel: ____________ FAX: ____________ E-mail: ____________

Accompanying person(s):
Name: ______________________________ Age (if under 18)
Name: ______________________________ Age (if under 18)
Name: ______________________________ Age (if under 18)

REGISTRATION FEES		UK£	UK£
Participant (member of the IGS)		175	___
Participant (NOT member of the IGS)		215	___
Student		80	___
Accompanying person aged 18 or over		50	___
Late registration surcharge (after 1 March)		50	___
Deposits	Hotel Ferrum	100	___
	hotels/hostels	50	___
	camping/cabin	20	___
SURCHARGE (if payment made after May 15)		50	___
	Total registration fees sent	£	___

I would like to participate in the pre-symposium excursion to Tarfala [ ] (check box)

Payment may be made by cheque, in pounds sterling drawn on a UK bank, payable to

INTERNATIONAL GLACIOLOGICAL SOCIETY

By Access/Eurocard/MasterCard or VISA/Delta

Card No. [| | | | | | | | | | | | | | |] Expires [| | |]

Signature: ______________________________

Payment may also be made directly to: National Westminster Bank plc,
account no: 54770084, 56 St. Andrew's Street, Cambridge CB2 3DA, UK,
or to our Post Office GIRO account no: 240 4052 (including any Bank or Transfer charges).
Mail to: Secretary General, International Glaciological Society, Lensfield Road,Cambridge CB2 1ER, UK

IGS AWARDS

Members are invited to submit nominations for the Society's awards. Accompanying documentation should included biographical data as well as a clear rationale as to the particular contribution(s) made that warrants consideration for the award proposed. The Awards Committee will require supporting documentation from other reputable scientists as to their perception of the contribution that has been made, e.g. how it has impacted the development of the science or their own work. Proposers should approach appropriate colleagues in the strictest confidence.

The International Glaciological Society has three different ways of recognizing contributions to the science of glaciology and to its objectives. These are:

SELIGMAN CRYSTAL
"..... shall be awarded from time to time to one who has made an outstanding scientific contribution to glaciology so that the subject is now enriched."

HONORARY MEMBERSHIP
"Honorary Members shall be elected by the Council in recognition of eminent contributions to the objects of the Society, and shall not exceed twelve in number."

RICHARDSON MEDAL
"..... is awarded from time to time to one who has given outstanding service to glaciology."

Members should submit nominations in confidence to the Chairman of the Awards Committee

Dr William F. Budd, Antarctic CRC,
University of Tasmania, GPO Box 252-80,
Hobart, Tasmania 7005, Australia
(Fax: [61](3)6226 2973; w.f.budd@utas.edu.au)

with a copy to the Secretary General.

RECENT MEETINGS (of other organizations)

MIDWEST GLACIOLOGISTS

The University of Wisconsin Department of Geology and Geophysics hosted the Sixth Annual Midwest Glaciology Meeting in conjunction with the Geological Society of America North Central Section meeting. A special symposium within the GSA meeting was devoted to paleoglaciology.

There was a strong turn out for the GSA special symposium on paleoglaciology. Highlights included reconstructions of various Midwestern lobes of the Laurentide ice sheet based on the geologic record and discussions on the role of basal freeze-on in till transport. In addition, talks on the rheological properties of till were also presented.

The paleoglaciology meeting concluded with a field trip to look at glaciofluvial and drumlin deposits east of Madison. Many interesting discussions of drumlin formation were had over Wisconsin beer and fresh cheese curds.

The rest of the MGM meeting involved talks on a wide range of topics, concentrating on but not limited to work in Antarctica. Recent progress in determining sediment thicknesses from geophysical surveying in West Antarctica was discussed in several talks. Presentations based on seismic and strain-grid measurements called into question the reliability of delineating the onset of ice streams from satellite imagery. Other talks concentrated on the use of satellite and ice radar data to interpret scar features surrounding Siple Dome. In addition, a very interesting talk on the role of the Aswan dam in North Atlantic circulation was presented.

PLANETARY ICES

A Workshop on Remote Sensing of Planetary Ices: Earth and other Solid Bodies was held 11–13 June, 1997, in Flagstaff, AZ, USA: the primary goal of the workshop was to bring together the terrestrial and planetary science communities whose focus is remotely sensed surface-ice research. The workshop addressed issues such as the current problems and objectives in surface ice studies, methods and technologies currently employed, future requirements for instrumentation, field studies, supporting laboratory measurements and theoretical modelling. The workshop was intended as an initial step to foster subsequent collaboration and co-operation between the two communities for the benefit and advancement of both.

Approximately 90 people attended and benefitted from the strong interdisciplinary communication and the chance to interact with a diverse group of individuals with wide areas of expertise.

A summary of the workshop was published in EOS, Transactions of the American Geophysical Union, **78**(37), 16 September 1997, page 392, and a special section of Journal of Geophysical Research-Planets will include papers from the workshop and should appear in the summer or fall of 1998.

Some of the abstracts presented and the program are still available on line at http://wwwflag.wr.usgs.gov/USGSFlag/Space/RSIce/rsice.html.

GLACIOLOGICAL DIARY

** IGS sponsored   * IGS co-sponsored

1998

20–23 April
66th Annual Western Snow Conference, Snowbird, Utah (Randall P. Julander, c/o Snow Survey, 245 N. Jimmy Doolittle Rd, Salt Lake City, UT 84116, USA, Fax [1](801)524-5564; rjulande@utdmp.utsnow.nrcs. usda.gov

14–16 May
25 years of Snow Avalanche Research at NGI, Voss, Norway (Meeting Management AS, Niels Juelsgt. 39, N-0257 Oslo, Norway (Tel [47]22-55-50-11; Fax [47]22-56-35-10; kl@ngi.no)

3–5 June
55th Eastern Snow Conference, Jackson, NH, USA (Ross Brown, Atmospheric Environment Service, 2121 Trans Canada Highway, Dorval, Quebec, H9P 1J3, Canada, Tel [1](514) 421-4772; Fax [1](514) 421-4768; ross.brown@ec. gc.ca, http://www.tor.ec.gc.ca/CRYSYS/esc/

8–11 June
Eighth International Workshop on Atmospheric Icing of Structures (IWAIS), Reykjavik, Iceland (IWAIS '98, Skóharhlið 18, IS-101 Reykjavík, Tel [354]562-3300; Fax [354]562-3345; congrex@ itb.is; http://www.rarik.is/iwais98/)

22–26 June
Fifth Circumpolar Remote Sensing Symposium, University of Dundee, Scotland (S. Newcombe, Dundee Centre for Coastal Zones Research, University of Dundee, Dundee, DD1 4HN, Scotland, Tel [44](1382) 344-933; Fax [44]1382)345-415; s.k.newcombe@dundee. ac.uk)

23–27 June
7th International Conference on Permafrost, Yellowknife, N.W.T., Canada (J.A. Heginbottom, Terrain Sciences Division, Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario, K1A 0E8, Canada, Tel [1](613)992-7813; Fax [1](613) 992-2468; heginbottom@gsc.emr.ca)

27–31 July
14th IAHR International Symposium on Ice, Potsdam, NY, USA (H.T. Shen, Dept. Civil & Environmental Engineering, Clarkson University, Potsdam, NY 13699-5710, USA, Tel [1](315) 268-6606; Fax [1](315)268-7985; htshen@sun. soe.clarkson.edu)

17–21 August
** International Symposium on Glaciers and the Glaciated Landscape, Kiruna, Sweden (Secretary General, International Glaciological Society, Lensfield Road, Cambridge, CB2 1ER, UK)

24–28 August
* Symposium on Global Changes in the Polar Regions, Tromsø, Norway (IASC Secretariat, Postboks 5072, Majorstua, N-0301 Oslo, Norway, Tel [47]22-95-96-00; Fax [47]22-95-96-01; iasc@npolar.no)

5–9 September
* Sixth International Symposium on Antarctic Glaciology (ISAG-6), Lanzhou, China (Secretary General of ISAG-6, Lanzhou Institute of Glaciology and Geocryology, CAS, Lanzhou 730000, PR China, Fax [86](931)8885241; icecore@ns.lzb.ac.cn)

6–9 October
* Snow Hydrology, Ascutney Mountain Resort, VT, USA (Janet P. Hardy, CRREL, 72 Lyme Road, Hanover, NH 03755-1290,USA, Tel [1](603) 646-4306; Fax[1](603)646-4785; jhardy@crrel.usace.army.mil

1999

April
* EISMINT, European Geophysical Society General Assembly, The Hague, The Netherlands (Arne Richter: EGS@linax1.dnet.gwdg.de)

16–20 August
** IGS, Verification of Cryospheric Models, Zürich, Switzerland (Secretary General, International Glaciological Society, Lensfield Road, Cambridge, CB2 1ER, UK)

19–30 July
XXII IUGG General Assembly, Birmingham, UK (Http://www.wlu.ca/~wwwiahs/index.html)
Symp. 2: Interactions between the Cryosphere, Climate and Greenhouse Gases (M. Tranter, Department of Geography, University of Bristol, Bristol BS8 1SS, UK, Tel: [44](117) 928-8307; Fax: [44](117)928-7878; tranter@bris. ac.uk)
Workshop 3: Hydrology of Ice-Covered Rivers (M.G. Ferrick, CRREL, 72 Lyme Road, Hanover, NH 03755-1290, USA, Tel [1](603)646-4287; Fax [1](603)646-4785: mferrick@crrel.usace. army.mil)

27–30 July
IUTAM Symposium on Scaling Laws in Sea Ice Mechanics and Sea Ice Dynamics (J.P. Dempsey, Dept. of Civil and Environmental Engineering, Clarkson University, Potsdam, NY 13699-5710, Tel [1](315)268-6517; Fax [1](315)268-7985; john@jpdnz.cee.clarkson.edu)

2000

May
** International Symposium on Snow and Avalanches, Innsbruck, Austria (Secretary General, International Glaciological Society, Lensfield Road, Cambridge, CB2 1ER, UK)

18–23 June
** International Symposium on Sea Ice and Interactions with Ocean and Atmosphere, Fairbanks, Alaska (Secretary General, International Glaciological Society, Lensfield Road, Cambridge, CB2 1ER, UK)

2001

** Remote Sensing in Glaciology, Washington, DC (Secretary General, International Glaciological Society, Lensfield Road, Cambridge, CB2 1ER, UK)

August
** Ice Cores and Climate, Kangerlussuag, Greenland (Secretary General, International Glaciological Society, Lensfield Road, Cambridge, CB2 1ER, UK)

FUTURE MEETINGS (of other organizations)

1998 Midwest Glaciology Meeting

The Glacier Dynamics Group will host the 7th annual Midwest Glaciology Meeting at the Byrd Polar Research Center, The Ohio State University, Columbus, on Friday and Saturday, 15 and 16 May, beginning at 9 a.m. both days. The format of MGM is informal presentation and discussion. Discussion of work in progress and student presentations are encouraged. No abstracts are required and no proceedings will be published. Talks will be 10–15 minutes, depending on the number of participants. Some space will be available on walls for those wishing to display posters.

Researchers of all ice-related topics are welcome, including past and present ice sheets and glaciers, snow, permafrost, glacial geology, meteorology, climatology, etc. Scientists from both midwestern and more exotic locales are encouraged to attend. A special session, MGM Plus, will be convened on Sunday morning, May 17, for detailed discussions of Antarctic research and fieldwork.

Visit the website <http://www-bprc.mps.ohio-state.edu/GDG/mgm/mgm.htm> for additional information regarding the meeting and online registration. Please advise us as early as possible if you plan to attend.

Contact: Gordon Hamilton, Byrd Polar Research Center, The Ohio State University, 108 Scott Hall, 1090 Carmack Road, Columbus, OH 43210-1002, Tel: [1] (614) 688-3793 Fax: [1] (614) 292-4697; hamilton@cfm.ohio-state.edu.

Workshop on Methods of Mass Balance Measurements and Modeling

Tarfala, Sweden, 10–12 August 1998

The International Commission on Snow and Ice is convening a workshop to address techniques of measuring glacier mass balance and methods to model mass balance.

The specific goals of the workshop include: 1) Approaches to measuring and modeling "problem" glaciers, including large glaciers (greater than 50 km^2), debris covered glaciers, calving glaciers, highly crevassed glaciers, and where ablation/accumulation periods do not normally coincide with the summer and winter seasons; 2) alternative methods for measuring mass balance including remote sensing, flux divergence, volume change; 3) strategies for reduced field programs; and 4) analysis of errors in all methods.

The workshop will be held prior to the IGS Symposium (17–20 August), for three days on 10–12 August 1998 at the Tarfala Research Station, adjacent to Storglaciären, site of the longest continuous mass balance data set in the world, and will be limited to 25 participants.

Conveners of the workshop are Andrew G. Fountain, Department of Geology, Portland State University, Portland, OR 97207-0751 USA, Tel: +1 503-725-3024; Fax: +1 503-725-3025; fountaina@pdx.edu, and Peter Jansson, Department of Physical Geography Stockholm University, S-106 91 Stockholm, Sweden, Tel: 46 8-16-48-15; Fax:+46 8-16-48-18; pete@natgeo.su.se

Eastern Snow Conference, 3–5 June 1998, Jackson, New Hampshire

The 55th annual meeting of the Eastern Snow Conference (ESC), jointly hosted by Mt. Washington Observatory and CRREL, will be held at Jackson, New Hampshire, 3–5 June 1998. The main theme of the meeting is documenting current progress in forecasting, modelling, measuring and managing snow. Details on the meeting theme and location are provided on the ESC Homepage http://www.tor.ec.gc.ca/CRYSYS/esc/.

International Conference on Snow Hydrology: the Integration of Physical, Chemical and Biological Systems

6–9 October 1998, Brownsville, Vermont USA (near Hanover, New Hampshire)

In 1978 the Cold Regions Research and Engineering Laboratory (CRREL) sponsored the successful conference, "Modeling of Snow Cover Runoff," which focused on snow-cover distribution, mass and energy transfer through the snow, snow/soil interactions, and runoff models. Twenty years later those issues remain important. The 1998 conference will be a forum for sharing new knowledge and techniques on their broader aspects. To encourage exchange between disciplines, we seek papers that address the relation between processes — physical, chemical, and biological — and the integration and distribution of these processes over different spatial and temporal scales.

The conference will be organized into five themes, with an invited speaker addressing the current state of knowledge of each theme.

1. Snow cover properties and processes (Philip Marsh)
2. Chemical processes in the seasonal snow cover (Martyn Tranter)
3. Biotic interactions with the seasonal snow cover (Gerry Jones)
4. Distributed snowmelt models (Robert Davis)
5. Scaling problems in snow hydrology (Guenter Bloeschl)

Additional information, conference updates and forms for electronic registration and submission of abstracts are available on the web site: http://www.crrel.usace.army.mil/snow98

Polar Aspects of Global Change: International Symposium and Field Trip to Svalbard, Tromsø, Norway, 24–28 August 1998

The Norwegian Polar Institute and the Polar Environmental Centre in Tromsø will host an international symposium on polar aspects of global change. It will have a bi-polar focus and will have oral and poster sessions. The intent of the symposium is to provide a current assessment of the role of the polar regions in global change and to bring together researchers engaged in any aspect of the physical, biological or social sciences, including field measurements, remote sensing, numerical modelling or data and information processing and analysis, in either polar region. The nine topics identified for the symposium are:

Climatic trends in the Arctic and Antarctic
Teleconnections linking the polar regions to low and mid-latitudes
Terrestrial systems and feedbacks on climate change
Variability of polar snow, ice and permafrost features
Ice sheet and glacier mass balance and sea level
Biogeochemical cycles in the Arctic and Antarctic
The circumpolar Arctic/Antarctic paleoenvironmental record
Atmospheric chemistry, ozone and UV-B effects
Regional and socio-economic impacts of global change

A two-day post-symposium tour to Svalbard is planned immediately following the symposium. Note: space is limited so participants will be selected in the order in which they are registered. The tour will include visits to Longyearbyen and Ny-Ålesund.

For further information, please contact jaklin@tromso.npolar.no. Web site: http:// www.tromso.npolar.no

Sixth International Symposium on Antarctic Glaciology (ISAG-6)

September 5–9, 1998 Lanzhou, People's Republic of China

SPONSORED BY

SCAR Working Group on Glaciology

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Chinese Academy of Sciences (CAS)
Lanzhou Institute of Glaciology and Geocryology, CAS

SECOND CIRCULAR

The SCAR Working Group on Glaciology will hold the Sixth International Symposium on Antarctic Glaciology in 1998. The symposium will be held in Lanzhou, Gansu Province, the People's Republic of China with registration on 4 September, and sessions 5–9 September, 1998

PARTICIPATION

This circular includes a form for registration, and for booking accommodation and the excursions. The form and accompanying payments should be returned, in accordance with instruction given, before 11 June 1998. There will be a surcharge for registrations received after 11 June 1998. Full registration refunds will not be possible for cancellations received after 18 July 1998.

Participants registration fees cover organization costs, copies of abstracts, the icebreaker, banquet, and a copy of the Annals of Glaciology volume of the proceedings. The accompanying persons registration fees include organization costs, icebreaker and banquet.

LOCAL ORGANIZATION COMMITTEE

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EDITORIAL COMMITTEE

T. H. Jacka (Chairman)
Qin Dahe
Li Jun
Ren Jiawen
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REGISTRATION FEES

Participant	US$390
Student	US$210
Accompanying person aged 18 or over	US$120
Late registration surcharge (after 11 June 1998)	US$50

Refunds on registration fees will be made on a sliding scale, according to date of receipt of notification, up to 20 August 1998. After that date it may be impossible to make any refund. See booking form for methods of making payment. All who pre-register will receive a copy of the third circular and programme prior to the meeting.

TOPICS

Snow and ice in Antarctica and the Southern Ocean play an important role in mass exchange between oceans, atmosphere and land. Abundant information on the Earth's environment and even on outer space is preserved in the ice sheet. This symposium will focus on those aspects of snow and ice science related to understanding the snow and ice properties, their variations and global change.

The suggested topics include:

- Mass balance of Antarctic ice sheet and sea level change
- Palaeoenvironmental records from Antarctic ice cores and other sources
- Physical and chemical processes and environmental record formation in Antarctic snow and ice
- Sea ice and climate in the Southern Ocean
- Ice/ocean/atmosphere interaction
- Technical advances in snow and ice science
- Snow and ice properties and modeling of Antarctic ice sheet and ice shelves
- Comparison of climatic and environmental records from the Antarctic and other regions

PAPERS
General regulations governing the *Submission of Papers, Selection of Papers, Distribution of Abstracts and Submission of Final Papers and Publication* are similar to those for the IGS meeting in Kiruna (see page 30). Accepted papers will be published in the Annals of Glaciology Volume 29. All material for this meeting should be sent to the ISAG-6 Secretariat in Lanzhou. The applicable deadlines are listed below.

EXCURSIONS
On Monday (7 September) afternoon there will be a mid-symposium excursion to the Lanshan Park, south of Lanzhou City. There will be three one-week post-symposium tours: 1) Lanzhou–Donghuang; 2) Lanzhou–Tianshan Glaciological Station; 3) Lanzhou–Germud–Qinghai Lake.

ACCOMMODATION:
The following hotels are recommended for participants. All prices are per room or suite, not per person. Bookings should be made on the Registration and Accommodation Form available from the ISAG-6 Secretariat, and returned with deposit cheque by 11 June 1998. The listed rates are only available to those booking accommodation through the Secretariat.

Legend Hotel:
Five star hotel about 5 minutes walk to the Symposium Center. Double: US $120, Single: US $179 B&B
Ningwozhuang Hotel
Three star hotel, 15 minutes walk to the Symposium Center. Double: US $52–83 Suite: US $144 (three rooms). B&B.

JinChen (Gold City) Hotel
Three star hotel, 10 minutes walk to the Symposium Center. Double: US $40–49. Breakfast not included.
Lanzhou Hotel
A popular hotel, about 5 minutes walk to the Symposium Center. Double: US $40 Single: US $61. Breakfast not included.

PAYMENT
Payment for Registration, Excursions, and Accommodation deposit, may be made on a single cheque in US dollars, payable to Qin Dahe. This should be sent, together with the Registration and Accommodation Form , to ISAG-6 Secretariat

IMPORTANT DATES

Abstracts due	28 February 1998
Notification of acceptance	2 May 1998
Preregistration deadline	11 June 1998
Accommodation deposit due	11 June 1998
Papers due	4 July 1998
Deadline for full refund	18 July 1998
Deadline for refund	20 August 1998
Conference starts	5 September 1998
Final revised papers	17 October 1998

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BOOKS RECEIVED

Ancey, C. 1996. *Guide neige et avalanches: connaissances, pratiques, sécurité.* Aix en Provence, Edisud. Association Nationale d'Études de la Neige et des Avalanches.

Friary, R. 1996. *Skate sailing: a complete guide.* Indianapolis, IN, Masters Press. Howard W. Sams & Co.

Haeberli, W., M. Hoelzle and S. Suter. 1996. *Glacier Mass Balance Bulletin. Bulletin No.4 (1994--1995).* Teufen, Switzerland, Kunz Druck + Co. AG. IAHS (ICSI), UNEP, UNESCO.

Menzies, J. 1995. *Modern glacial environments: processes, dynamics and sediments.* Oxford, etc., Butterworth-Heinemann. Vol. 1. Glacial Environments.

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Paterson, W.S.B. 1994. *The physics of glaciers. Third edition.* Oxford, etc., Elsevier.

OBITUARY

Professor Peter Kasser (1914–1996)

Peter Kasser is best remembered among the older generation of glaciologists. Quite a few will recall their visits to Zürich and Peterþs home in Herrliberg, where his wife Gertrud (Mau) served a delicious meal and Peter picked the suitable beverage from his famed wine cellar. I remember one occasion when the shop talk on the lawn was interspersed with tree-climbing and playing with a water hose. Peter liked to tell witty anecdotes from his early days in the field, like the time when he overheard an argument between a Catholic father staying at the same hotel, and the proprietress. When told that she rented her mules, normally engaged to haul ice from the Aletschgletcher to the hotel, too cheaply to Kasser (a Protestant), she replied that the clergyman should stick to matters of heaven and leave the earthly business of mules to her. The story also illustrates how Kasser was able to impress on his surroundings that glacier research was a serious matter worthy of support. In his own work Peter was highly dedicated and thorough-going. Above all, he enjoyed what he did. As the son of a Swiss federal judge, he impressed both friend and foe with his sense of justice and integrity.

Peter Kasser got his academic degree in civil engineering in 1940 at the Swiss Federal Institute of Technology (ETH) in Zürich. Despite his technical training, he was at heart a scientist, as well as an enthusiastic mountaineer. In spite of the shock of being the sole survivor of a party of five in an avalanche accident, he did not shy from the hazards of mountains. On the contrary, he began his professional career in 1941 at Weissfluhjoch in snow research for the Swiss Federal Snow and Avalanche Research Commission. After two years he moved to the Laboratory of Hydraulics and Soil Mechanics at ETH, where he remained through various organizational and name changes till his retirement in 1979. The close contact with Robert Haefeli helped to strengthen his interest in snow and glaciers during his initial time at the laboratory. In 1951 he was appointed chief of the Hydrology Section. He was allowed to investigate water in the solid state from the beginning, but it was a major step forward for glacier and ice research when "Glaciology" was added to the sectionþs name and later even became integrated in the name of the head institution: Laboratory of Hydraulics, Hydrology and Glaciology. Under Kasserþs leadership, the hydrology and glaciology unit prospered and expanded into an organization of international repute. This is reflected in the list of foreign visitors who spent sabbatical time with Kasser and his colleagues, among them Ron Shreve, Barclay Kamb, Will Harrison and Charlie Raymond.

As part of large hydroelectric projects in the Swiss Alps from the late 1940s to the early 1960s, Kasser was involved in estimating the potential runoff from glacierized areas. He recognized, to the dismay of the planners, that recent runoff records were too optimistic because of the abundance of glacial meltwater during a series of warm summers. Less runoff would have to be expected not only in an average year, but even in somewhat warmer summers because of the loss of glacierized area during a period of intensive glacier retreat, loss of capital so to speak. Kasserþs interest in mass and energy balance studies was a logical consequence of that recognition. About 1950 he started an ambitious project on Aletschgletcher, largest glacier of the Swiss Alps. He soon realized there was a need for durable markers on the glacier tongue where annual ablation was 10 m or more. He designed a portable apparatus for drilling 30 m deep holes in 2–3 hours, based on the circulation of hot water pumped to the tip of the drill and brought back to the heater. The drill became known as the "Kasser borer." His highly sophisticated equipment, consisting of burner, pressure pot, hand-pump, hoses, drill stem, ideally shaped tip, packboards and transportation boxes required plenty of machine shop work and special parts. (The total cost was close to that of a Volkswagen!) The deepest hole ever drilled was close to 90 m.

Experience gained on Aletschgletscher showed that for a glacier of that size the combined hydrological and geodetic methods of mass-balance measurement was more appropriate than the glaciological method, based on stake measurements and pits. One of the requirements, not easy to fulfil, was the determination of discharge. Kasser convinced government agencies to act and enforced the participation of the hydro companies who used the water from the glacier by court order. A model gauging station, handling discharge as large as 100 m^3s^{-1}, was installed in the Massa gorge. Governmental support and co-operation was also obtained for the production of a 1:10,000 scale map of the Aletschgletscher area as a contribution to the IGY in 1957. (Fritz Müllerþs enthusiasm for glacier mapping dated from this project). The pure white snowfields presented a major mapping problem. It was decided to mark vast areas of several square kilometers with a mixture of sawdust and soot, partly thrown from an aeroplane, and partly spread from skis like the hand-sowing of fields in the old days. A movie company also stationed at Jungfraujoch, ready to shoot the immaculate snow-covered landscape, became upset at the glaciologists' action and threatened legal action. Typical of Kasserþs commitment and negotiating skill, he insisted the operation could only be called off by the Director of the Swiss Federal Topographic Service — who happened to be out of the country. Another IGY activity was Kasser's involvement in preparations for EGIG (Expédition Glaciologique International au Groenland) and his participation in the summer of 1959, when he teamed up with Albert Bauer on the western edge of the Greenland ice sheet.

Peter Kasser was a proficient surveyor, due to his training as a civil engineer, and he made good use of that skill in his glaciological projects. A compact lightweight theodolite (referred to by a company representative as a "playboy theodolite") became a standard tool for Kasserþs glaciology group. In spite of the ridiculing by professionals, it had numerous advantages. It could be: carried easily in a pack; was stable enough on steel pipes, with a small platform cemented into the bedrock or on large boulders; and gave better results than larger, more accurate instruments when exposed to the sun without an umbrella, unavoidable in large programs without porters. For targeting mobile glaciers, it was a unique instrument for the time. Kasserþs treatment of surveying, as an integral part of glacier research, later proved to be of fundamental importance when dealing with hazards.

Peter Kasser was an active member of the Swiss Glacier Commission from 1948 to 1984, from 1974 to 1980 as its president. In 1964, he took charge of the organization of the annual survey of Swiss glaciers and the editing of reports on the variations after André Renaudþs death. Henceforth he was the sole author of eight annual reports and co-author with Markus Aellen of thirteen additional ones. During that time, the reports were expanded considerably and put on a new base (The Glacier of the Swiss Alps, annual with an English summary). Following the General Assembly of the IUGG in Helsinki in 1960, the International Commission of Snow and Ice (ICSI) decided to collect data on glacier variations world-wide. After meetings in Zürich (Switzerland), Obergurgl (Austria), Berkeley (U.S.A.) and Paris (France), IUGG/IAHS/ICSI entrusted Kasser with a "Pilot-Study" for the compilation of glacier variations outside the polar areas in 1965. The results were published as a contribution to the International Hydrological Decade by ICSI and Unesco in 1967 under the title "Fluctuations of Glacier 1959–1965." The same year the "Permanent Service on the Fluctuations of Glaciers" was established by FAGS/ICSU with the officers of ICSI/IAHS as the board of directors and P. Kasser as Director of the Service. He compiled and edited the second volume of "Fluctuations of Glaciers, 1965–1970." Peter Kasserþs ambition was to serve a purpose; a self-enhancing grasp for influence never entered his mind!

The 1960s and 1970s showed a remarkable number of advancing glaciers in the Alps and, maybe coincidentally, a concentrated occurrence of ice avalanches and outbreaks of ice-dammed lakes. Kasser and his institution were directly involved, and the study of glacier hazards became an important task for the Zürich glaciologists. However, Kasserþs activities were not limited to water in the solid state. In hydrology, he showed his insight into the processes of nature and organizational skill. Under him, methods of forecasting the runoff of the river Rhine on an hourly, daily and monthly basis were developed that found customers from Switzerland to Holland, with a variety of applications. For many years, he served with the Hydrological Commission of the Swiss Academy of Natural Sciences, as well as on various hydrological and glaciological committees.

In acknowledgement of his accomplishments, ETH bestowed the title of Professor on him in 1972 and the Council of the IGS made him an Honorary Member in 1975, followed by the Swiss Glacier Commission in 1987. He was also elected a member of the Commission for Glaciology of the Bavarian Academy of Science.

Peter Kasser, who was a member of the IGS for very many years and served on Council from 1968-70, died on December 9, 1996 after a few months of severe illness. The tracks he once imprinted on the snowfields and glaciers have long ago faded away, and most of his inventions and practices have been replaced by modern techniques. However, his publications remain and, hopefully, the series he applied himself to with heart and soul will continue. His friends and colleagues will miss his friendly presence, but keep a lasting memory of him as a dedicated leader and scientist.

Hans Röthlisberger

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Student members (under 30)	Sterling	£25.00	
Institutions, libraries	Sterling	£170.00	for Volume 44 (Nos. 146, 147, 148)

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Note: Payments in currencies other than £ sterling should be calculated at the exchange rate in force at the time of payment. Then add sufficient money to cover the bank charges (currently £10). The Society needs the full payment, so that the extra £10 to cover bank charges should be paid by you. Payment may also be made by Access/Eurocard/MasterCard or VISA/Delta.

ICE

Editor: C.S.L. Ommanney (Secretary General)
Assisted by S. Stonehouse

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