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COVER PICTURE: Bent icicle under Boirenkopfkees, Austria, close to the snout in a leeward cave. The glacier is moving from left to right (Photograph by Heinz Slupetzky, 7 September 1999).

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 MEETINGS (of other organizations)

SWITZERLAND

(For abbreviations used see page 9)

Skier triggered slab avalanches

(J. Schweizer, C. Camponovo, M. Lütschg, SFISAR)
The forces induced by a skier in the snow cover have been studied with load cells buried in the snow. The skiers' dynamic impact causes stress concentrations in the potential weak layer which may cause failure leading to slab release. The spatial extent of the stress concentration is small so that conditions for fracture propagation are not generally fulfilled. The layering of the snow cover is decisive for force transission. Accordingly, slab properties are essential to consider in snow-slab stability evaluation.

Ten years of avalanche observation data from the Swiss Alps have been analysed in view of skier triggering. 93% of the 23 avalanche fatalities per year were recreationists; 90% of them have triggered the fatal avalanche themselves. The median slab thickness was 45 cm, the avalanche width 50 m and the length about 150 m. Surface hoar, faceted crystals and depth hoar contributed 90% to the grain types in weak layers. However, in about 50% of the cases no weak layer was found, but the fracture was at the interface between two adjacent layers.

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Dry-snow slab-avalanche release

(J. Schweizer, SFISAR)
A review of dry-snow slab-avalanche release has shown that all present models for natural slab release state a superweak or deficit zone necessary for fracture propagation. The range predicted for the size of the deficit zone is large: 0.1–10 m. However, so far, field studies could not detect shear-deficit zones. Deficit zones are supposed to be a transient phenomenon, in particular due to the sintering process. A comprehensive link between snow failure (microscale), described as the result of the two competing main processes: fracturing and sintering, and slab release (macroscale) is still missing.

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Deformation and failure of Alpine snow

(C. Camponovo, J. Schweizer, SFISAR)
Rheological measurements of the viscoelastic properties of snow were performed in a cold laboratory using natural snow samples. A new device, a so-called rheometer, was used. It is a torsional shear apparatus allowing the deformation to be measured precisely with high resolution. Oscillatory measurements showed that there is a linear range within which no structural change of the snow occurs. For the snow types tested, the linear behaviour prevails if the shear strain is smaller than 10^{-4}. If the porous structure of snow is taken into account, this value corresponds to the generally known limit for linear viscoelastic deformation of about 10^{-2}. The deformation in the linear range is primarily elastic. The shear modulus found for snow densities of 180–340 kg m^{-3} is 0.5–3 MPa; the shear viscosity is about 50–400 MPa s.

Snow failure was studied with a direct simple-shear apparatus. At low rates, snow shows predominantly non-linear viscous behaviour. Considerable strain energy can be dissipated. At high rates, the elastic properties dominate and samples break after very limited deformation (brittle failure). The transition between the ductile and the brittle state of failure was at a strain rate of about 1×10^{-3} s^{-1}, for the snow type tested (small rounded particles, size $\leq$0.5 mm). For larger grains (size $\approx$1 mm) the transition is shifted towards lower strain rates at about $1 \times 10^{-4} s^{-1}$. Studying the effect of temperature showed that the stiffness (initial tangent modulus) is the most temperature-dependent property of Alpine snow, strongly decreasing with increasing temperature. The strength is much less temperature-dependent, also decreasing with increasing temperature.

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Submitted by Marcia Phillips and Walter Ammann

U.S.A. (Alaska)

GLACIERS

Benchmark monitoring, Gulkana and Wolverine Glaciers

(R. March, D. Trabant, B. Kennedy, USGS-AK)
Long-term glacier–climate monitoring, begun in 1966, continues at Gulkana and Wolverine Glaciers with continuous measurements of air temperature, precipitation and wind speed, and seasonal measurements of mass balance, surface-altitude change, flow and annual measurements of terminus position. Additionally, continuous stream discharge below the glacier during open-water conditions are being measured at Gulkana Glacier.

To control and assess errors in the long-term cumulative surface-balance measurements, volume-change measurements are occasionally made from photogrammetric remapping or longitudinal and cross-profile surveying of the glacier surface.

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Elevation and volume change, Seward and Malaspina Glaciers, Yukon and Alaska, and mass-balance simulation

(C.S. Lingle, K. Echelmeyer, W. Seider, H. Li, R. Muskett, V. Valentine, GI/UAK-F; W.V. Tangborn, Hymet) The small aircraft laser-altimeter-profile data acquired in June 1995 on Seward and Malaspina Glaciers were analyzed using a terrain-corrected ERS synthetic aperture radar (SAR) image and the relatively high-resolution 15 min. digital elevation model (DEM) of Alaska recently made available by the USGS.

Between the early to mid-1970s and 1995, the upper Seward Glacier, in Yukon, lost 11.5 ± 11.5 km^3 w.e. Lower Seward Glacier, in Alaska, lost 3.0 ± 1.5 km^3 w.e. Malaspina Glacier (Seward lobe), in Alaska, lost 48.5 ± 5.0 km^3 w.e. The entire Seward–Malaspina system lost 63 ± 13 km^3 w.e., equivalent to an area-average mass balance of –1 ± 0.2 m a^{-1} w.e. over the 23 year time interval.

The PTAA (precipitation-temperature-area-altitude) mass balance model of Tangborn (1999) was subsequently applied to the Seward and Malaspina Glacier systems, over the longer 1950 to 1998 time interval for which low-altitude meteorological data are available from coastal weather stations in south-central Alaska. Preliminary results show an area-average mass balance of about –1.1 m a^{-1} w.e. and a total volume loss of approximately 130 km^3 over the 49 year period.

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Subglacial till, Black Rapids Glacier

(W.D. Harrison, M. Truffer, K. Echelmeyer, R.J. Motyka, R. Fisk, GI/UAK-F; M. Nolan, WERC/UAK-F) A commercial wire-line drill rig was used in combination with our hot-water drill to extract samples of subglacial till in the active part of the surge-type Black Rapids Glacier. We found 5–7 m of a sandy till with clasts up to boulder size. Measurements of surface motion, ice and till deformation indicated that up to 60% of the glacier's motion is basal motion, and that most of this occurs deep in the till, >2 m below the ice–till interface. Soil testing on till samples, and the in-situ behavior of the till, suggest a plastic till rheology. The consequences of a perfectly plastic till layer on the dynamics of a valley glacier were explored with a finite-element model and the results compared to field data from Black Rapids Glacier.

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Dynamics of retreating tidewater glacier

(R. Motyka, K. Echelmeyer, S. O'Neal, GI/UAK-F) Le Conte Glacier is a retreating tidewater glacier in southeast Alaska. The dynamics of both the calving terminus and the glacier are being studied. Surface velocities in the terminal region are on the order of 30 m d^{-1}, most of which occurs as basal motion. There appears to be no seasonal variation in speed or ice flux. Detailed motion and calving measurements show there is little correlation between daily calving flux and ice flux into the terminus. The speed of the glacier varies with the tide, and the tidal effects decay exponentially with distance up-glacier from the terminus. The glacier has retreated about 2 km since 1994. It thinned by about 190 m near the terminus and 24 m (0.5 m a^{-1}) as an area-average from 1948–96; the glacier-wide rate of thinning increased to 2.3 m a^{-1} in the 1990s and the glacier is continuing to retreat.

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Mass-balance studies, Mendenhall Glacier

(R. Motyka, S. O'Neal, GI/UAK-F) Mendenhall is one of the most visited glaciers in Alaska, and a measurement program of its geometry, mass balance and surface velocity began in 1997. The glacier has been retreating for many years, and part of it now ends in a large lake. Terminus retreat has been largest along the lake and smaller where the glacier terminates on land. Maximum surface speeds are about 150 m a^{-1}. The glacier presently has a large negative mass balance and the present equilibrium-line altitude is relatively high compared to that estimated in the past. The program is designed to monitor the continuing thinning of the glacier, along with measurements of lake bathymetry and freshwater-calving retreat.

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Juneau Icefield research program

(M.M. Miller, K. Sprenke, H. Slupetzky, W. Welsch, JIRP) A GPS and photogrametric remapping and mass-balance record of the Cathedral Glacier, on the continental flank of the Juneau Icefield, was completed in summer 1999. This is the inland counterpart of Lemon Creek Glacier, the latter situated on the maritime periphery of the icefield and a key site in the International glacier–climate program. Comparison with the 1979 topographic map reveals Cathedral Glacier has lost 20% of its area in the past 20 years. Continuing mass-balance records for Lemon Creek Glacier show a 7% area loss since the previous detailed 1989 topographic map. Annual mass-balance data reveal the years 1996–99 as the most negative on each of these glaciers in the past 54 years of JIRP record.

On the main icefield, seismic profiling continued in 1999, extending the 1992–98 record to 18 transverse cross sections in the Taku Glacier system. Depths of 1100–1210 m, reaching below sea-level, are now recorded on each of the tributaries of the NW, North Central, and NE branches of the glacier system, at points 40–55 km up-glacier from the present terminus. Mass-balance records and GPS surface elevations and flow surveys in the last 4 years reveal substantial net accumulation increases on the higher and crestal névés as well as farther inland. Along with increased negative mass balances on all lower-level glaciers on the icefield, such as Lemon Creek and Cathedral Glaciers, current evidence points to global warming resulting in a notable inland shift in the mean position of the Arctic Front and a substantial rise in the freezing level. Because of the flow-lag effect, Taku Glacier continues its anomalous but steady advance into Taku Fiord.

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GPS surveys on Juneau Icefield

(S. McGee, M.M. Miller, JIRP; W. Welsch, M. Lang, UBund)

GPS surveys on Juneau Icefield have focused on quantifying the system-wide velocity field and surface elevation changes of Taku Glacier and its tributaries. GPS-based techniques have been integrated with traditional test-pit studies in the evaluation of mass balance on the Lemon, Taku and Llewellyn Glaciers, while at the same time geophysical, geological, and meteorological research activities have been enhanced with precise geospatial positioning via GPS.

An extensive project to determine longitudinal surface gradients, elevations and velocities was initiated in 1999. Utilizing a nominal flag spacing of 500 m, 63 km of a total 150 km on Taku Glacier and its tributaries were surveyed via GPS in 1999. Additional fieldwork in 2000 and 2001 will complete this project.

Comparative GPS surveys indicate steady-state velocities on Taku Glacier since 1993, while surface elevations during the same time period have decreased 3–4 m (1.6–2.2 m w.e.). Velocities range from 1 cm d^{-1} at the head of Taku Glacier to 93 cm d^{-1} at the ELA. Full details of all GPS survey activities are available on-line at http://crevassezone.org, while all survey results from 1981 to the present are presented in the joint Foundation for Glacier and Environmental Research/ Universität der Bundeswehr survey monograph.

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Volume changes of mountain glaciers

(K. Echelmeyer, W.D. Harrison, P. Del Vecchio , V. Valentine, GI/UAK-F)

Volume changes of about 70 glaciers in Alaska, northwest Canada and Washington State are being determined using our airborne surface-elevation-profiling system. The set of profiled glaciers covers a wide range of climatic zones, sizes, shapes, altitude distribution and types, including tidewater and surging glaciers. Volume changes over two time scales are being determined: one by comparing our early 1990s' profiles with U.S. Geological Survey maps made from aerial photography in the 1950s, and the second by comparing profiles made in 1999 (and others to be made in the next few years) with those made in the early 1990s. Results show that most, but not all, glaciers are thinning. The rate of thinning for the most recent decade is greater than that over the previous 40 year period. Surface elevations and elevation-change data are being archived at the World Data Center for Glaciology. *(kechel@hi.alaska.edu)*

Climate impacts in Alaska

(G. Weller, UAK-F)

This research is attempting to assess the potential consequences of climate change and variability in Alaska. The warming observed in Alaska over the last few decades is matched by corresponding observed decreases in snow cover and glacier mass balances, by thawing of the permafrost, and by reductions in sea-ice extent and thickness. The available evidence strongly suggests that a major cause of the warming is the anthropogenic greenhouse effect. The thawing of Alaska has led to problems with roads and other infrastructure on permafrost, increased coastal erosion, economic losses to fisheries and forestry, and it has affected native subsistence lifestyles. These impacts will become even more pronounced if present climatic trends continue. *(gunter@gi.alaska.edu)*

Reference surface mass balance and the time constant

(W.D. Harrison, D.H. Elsberg, K. Echelmeyer, GI/UAK-F; R. Krimmel,USGS-AK)

The mass balance of a glacier is determined not only by climate, but by its changing surface as it adjusts to climate. This complication can be removed by defining a balance on a fixed reference surface, usually the actual surface at the beginning of a mass-balance program. This balance can be evaluated as part of conventional mass-balance programs, and should be used, first, for interpreting glacier response in terms of climate, and second, for driving simple analytical models of glacier response. The reference surface-balance record has been worked out for South Cascade Glacier, Washington, and in the process it has been found that lowering of the surface has been almost half as important as retreat of the terminus in determining the difference between the reference surface and conventional balances. The simplest plausible model of response, which is characterized by a single time constant, gives a reasonable approximation to the response of the glacier between 1970 and 1997 because the climate was relatively simple then. This time constant is about 40 years, which is a factor of 1.8 larger than the conventional expression (suggested by Jóhannesson and others) because it takes into account the effect on balance not only of retreat, but also of surface lowering.

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Vertical strain rate, Siple Dome, Antarctica

(W.D. Harrison, J. Morack, D.H. Elsberg GI/UAK-F; E. Waddington, E. Pettit, UWA; M.A. Zumberge, SIO)

The distribution with depth of the vertical strain rate at an ice divide is sensitive to the low transition stress at which the flow of ice becomes linear. A joint project is being conducted at Siple Dome, where the ice is 1000 m thick, to measure the depth distribution of vertical strain rate at two sites and to interpret it in terms of this transition stress. Small strain rates necessitate long-term instrument stability. Two types of strain meters were frozen into the ice in 1997–98 with the help of the Caltech hot-water drill rig. One is an electrical-resistance system that measures strain over a length of about 1 m. The other is an optical-fiber system which measures the change in length of optical fibers from the surface to the maximum depth, which varies from 80 to 1000 m. Subtraction of data from adjacent fibers gives the strain over intervals of about 200 m. Transients associated with the disturbance of installation are still evident in the data, particularly from the electrical-resistance system, but the data are converging and are expected to give the distribution of strain rate at an accuracy of about 10 parts per million per year.

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Geophysical investigations, Fireweed rock glacier, Wrangell Mts, Alaska

(A. Bucki, K. Echelmeyer and R. Elconin, GI/UAK-F)
A geophysical program is underway at Fireweed rock glacier to take advantage of the direct observations of internal structure made in 1994 at the rock glacier's terminus and head. Geodetic survey of surface velocities, and ground-temperature measurements by miniature data loggers, began in 1997. Seismic, radar and resistivity soundings began during summer 1999 and will be completed during summer 2000. Preliminary results from the flow survey show maximum velocity exceeds 3 m a^{-1}. Geomorphologic observations relating to contemporary ice origin indicate ice added to the permafrost body during the last five years has a dominant periglacial origin; during this time snow and firn fields have completely ablated by summer's end.

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Uplift and seismicity in northern southeast Alaska: tectonic stress or glacial unloading?

(C.F. Larsen, R. J. Motyka, J.T. Freymueller, J. Freymueller, J. Beget, GI/UAK-F)
In an ongoing study of postglacial rebound and its history in northern SE Alaska, we have measured uplift rates throughout the region using three techniques — tide gages, GPS, and dendrochronology — which offer information over varying time scales. The goals are to: (1) determine if temporal and spatial variations exist in the uplift pattern; (2) separate tectonic and post glacial rebound signals; and (3) model the lithosphere and mantle responses to these forces.

Uplift rates of up to 4 cm a^{-1} characterize the emergence of this region as one of the fastest on earth. Uplift was gradual at first (< 1 cm a^{-1}) then increased significantly around 1850 ± 15 AD (2 to 4 cm a^{-1}, depending on location) and now appears to be diminishing. Total emergence since onset ranges from 2–6 m, and appears to be roughly correlated with proximity to centers of glaciation.

With tide-gage data, we have determined uplift rates during two or more time periods at 16 locations. These data indicate most sites experienced declining rates of uplift from the mid 1950s to the mid 1980s. At Yakutat, Skagway and Juneau, permanent tide-gage records and GPS-derived uplift rates show an increase in uplift rates over the last 15 years on the order of 60% ± 20%.

GPS horizontal velocities indicate little motion on the Lynn Canal–Chatham Straight Fault. Almost all of the Pacific Plate–North America velocity is found in strike–slip motion on the Fairweather Fault, at the western edge of the study area. Additional GPS measurements are required to determine the possibility of a link between the Fairweather Fault and the Denali Fault via a diagonal trend across upper Glacier Bay. This link has been proposed to explain both the observations of a band of seismicity here and a possible source of tectonically driven uplift.

Dendrochronologic methods applied to the emerged land seaward of the raised shorelines show that the current uplift episode dates back to approximately 1750, with most uplift occurring after 1850. Total uplift from 1750 onward ranges from 2.7–6.1 m.

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SNOW

Snow cover and its interaction with plants

(M. Sturm, J. Holmgren, CRREL/AK; G. Liston, AS/CSU; C. Racine, CRREL/USA; P. Olsson, AEFF/UAK-A)
Studies on the interaction of snow and Arctic vegetation have been carried out at Ivotuk, Alaska about 200 km due south of Barrow. On a 15 km line, detailed snow-depth and stratigraphy measurements have been obtained in early and late winter for three years (1998–2000). These measurements have been compared to observations of vegetation type, plant architecture, and snow-holding capacity of the tundra. A three-dimensional wind-blown snow-distribution model (SNOWTRAN 3D) has been used to assess the topographic influence on the snow distribution, allowing the vegetation–snow interaction to be isolated. Results indicate a complex interaction with dwarf shrubs, even in small amounts, increasing the depth of the snow cover and reducing the total amount of sublimation. The increased depth creates thermal conditions more favorable to the growth of shrubs, thereby producing a snow–vegetation feedback loop that may be important in the response of the tundra to changes in climate.

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Snow cover and weather

(M. Sturm, J. Holmgren, CRREL/AK; G. Liston, AS/CSU; C. Racine, CRREL/USA; P. Olsson, AEFF/UAK-A)
Snow-stratigraphic studies in the Kuparuk Basin, south of Prudhoe Bay, and near Ivotuk, 200 km south of Barrow, indicate that the entire snowpack forms as the result of 5 to 10 key weather events and that it rarely contains more than 8 layers of snow. Wind slabs constitute about 50% of the snow pack water equivalent, but highly specialized weather conditions (simultaneous wind and snow precipitation) appear to be needed to deposit a wind slab, conditions that occur only 2 or 3 times a winter. For the winters of 1995–2000 we have identified the key weather events from stratigraphic analysis and local meteorological data. We are now identifying the synoptic conditions associated with these events, and ultimately hope to be able to predict the snow cover stratigraphy from general weather records or re-analysis products.

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Snow melt and soil moisture, North Slope

(M. Nolan, L.D. Hinzman, WERC/UAK-F)
SAR imagery is being used to detect and analyze changes related to snow melt and soil moisture on the North Slope of Alaska.

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Snow radar

(M. Sturm, J. Holmgren, CRREL/AK)
We continue to develop an FM-CW radar for continuous measurement of snow depth. Most recently, we have reduced the size of the radar, making it suitable for towing in a sled behind a snowmobile. We have also

"ruggedized" the radar, successfully using it in temperatures as low as –35°C. The radar signal has been integrated with real-time kinematically corrected differential GPS so that we get a continuous record of position (x, y, z) and snow depth (s) when the radar is in operation. The radar has been used to take more than 250,000 measurements of snow depth during project SHEBA on the sea ice of the Beaufort Sea, and most recently to take an equal number of snow-depth measurements on the Arctic Slope of Alaska.

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Snow hydrology–snow melt

(M. Sturm, CRREL/AK; S. Li, GI/UAK-F)

During snowmelt, snow depth-distribution patterns can often be "visualized" as melt exposes the areas covered by thin snow first, thick snow last. Using an energy-balance melt model, this sequential pattern can be "inverted" into snow depth-distribution maps. We are using a combination of ground, aircraft, and satellite-based measurements to observe these patterns and create maps from them. During the melt of 1999, we observed a 60 x 60 km area on the Arctic Slope of Alaska. Daily measurements of surface energy balance and snow depletion were made on the ground on transect lines up to 6 km long and over an area 1 x 1 km. Oblique images from a nearby mountain were obtained of the observation area. Four sets of aerial photographs and five sets of SPOT images were obtained during the melt period as the snow coverage changed from 80% to 15%. In addition, sequences of RADARSAT and Landsat 7 images were obtained. These are being analyzed and compared to the ground-based data to determine how to interpret the images. Multi-platform images are being combined and registered to produce a sequence that will then be inverted into a snow-depth contour map that can be compared to the measured data.

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Microstructural and micromechanical properties of snow

(J.B. Johnson, CRREL/AK; M. Schneebeli, SFISAR)

The mechanical properties of snow depend strongly on its internal structure. This dependence makes it difficult to develop methods of characterizing and predicting the mechanical properties of snow needed to improve predictions of vehicle mobility, snow-avalanche stability conditions, and other snow-engineering problems. We have developed a micropenetrometer that detects the rupture of individual microstructural elements in snow and that can detect the very thin layers associated with snow-slab failure. We have also developed a theory to interpret the micropenetrometer output that allows us to determine the microstructural dimension and rupture force, and to estimate the grain diameter of seasonal snow. The penetrometer and theory have been used to classify four different snow types in Alaska and appears to provide a method to uniquely characterize snow by its mechanical and structural properties.

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Snow water-equivalent sensor

(J.B. Johnson, CRREL/AK; G.L. Schaefer, D. Huffman, NRCS)

Fluid-filled snow pillows have been used since the 1950s to provide information about the amount of water stored as snow (the snow water equivalent, SWE). Snow pillows are installed extensively throughout the U.S. and elsewhere and provide information about SWE for flood prediction and the allocation of water for agriculture, power production and recreational use. While generally reliable, the snow pillow has several drawbacks that include under or over reporting SWE in certain conditions (the classic snow-bridging problem), containing an antifreeze fluid, limited to installation on flat ground, and logistics problems associated with its design. CRREL has been working with the U.S. Department of Agriculture (NRCS) to determine physical parameters that affect stress-sensor-based SWE sensors and to design a replacement sensor. Our studies indicate that problems with stress-sensor-based SWE sensors (including the snow pillow) are primarily caused by a difference in the thermal properties of the sensor compared to the surrounding ground. The severity of SWE errors depends on the ratio of sensor thickness to its diameter, the difference in thermal conductivity and heat capacity between the sensor and surrounding ground, and the rate of snow creep. We have developed a model that accounts for these factors and that accurately replicates SWE measurements. We are currently in our third winter of testing an electronic SWE sensor that is significantly smaller than the snow pillow, minimizes thermally induced SWE errors, and can be installed on sloping terrain.

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SEA ICE

Air–ice–water interactions at thaw lakes

(M.O. Jeffries, K. Morris, N. Kozlenko, K. Frey, GI/UAK-F; T. Zhang, CIRES/UCO-B; C.R. Duguay, ULav)

A physically based, two-dimensional, non-steady heat-transfer model with phase change using a finite-element method has been developed to investigate heat and mass transfer between the atmosphere and permafrost through the water, ice and snow at shallow, thaw lakes. The simulated total heat flow to the atmosphere in late winter at Barrow, NW Alaska, has been validated with field measurements, and the area-weighted mean total heat flow has been determined with the aid of SAR data to identify the proportions of tundra, grounded ice and floating ice. The area-weighted heat flow is on a par with that through the sea ice of the nearby Arctic Ocean. Simulation of thawing below these lakes indicates that a talik (thaw zone) with a thickness of 30 m will develop 3000 years after a lake begins to form. Taliks only develop below those lakes where the maximum water depth exceeds 2 m, i.e. lakes that do not freeze completely to the bottom each winter. This is corroborated by previous field observations.

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Ice growth, bathymetry and water availability in shallow lakes

(M.O. Jeffries, N. Kozlenko, K. Morris, GI/UAK-F)
ERS SAR data have been used to investigate ice growth and to elucidate information on the bathymetry and availability of water in shallow, thaw lakes on the North Slope of Alaska. This investigation takes advantage of the fact that there is minimal backscatter from ice that freezes to the bottom of a lake, as indicated by a dark signature in SAR images, while there is strong backscatter from floating ice, as indicated by a bright signature in SAR images. A sequence of SAR images coupled with a simulated ice-growth curve can be used to (1) determine the spatial and temporal variability of water availability based on how many lakes are completely frozen to the bottom at any time during the winter, and (2) develop bathymetric maps of individual lakes based on the changing position of the boundary between floating and grounded ice.

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Energy and mass balance of coastal ice covers in northern Alaska

(H. Eicken, GI/UAK-F; M. Sturm, CRREL-AK; T. C. Grenfell, AS/UWA; D.K. Perovich, CRREL/USA)
Significant change has been observed in sea-ice conditions along the northern coast of Alaska. These changes could represent alterations in the proportion of sunlight reaching the surface, in the quality and quantity of back radiation into the atmosphere from the surface, or in changes in heat content of land and coastal seas. To provide basic information about the radiation inputs, losses, and heat fluxes, four sites near Barrow, Alaska, have been established for detailed monitoring of solar and atmospheric heat fluxes as experienced by snow, sea ice, near surface waters and land. The goal is to establish the local heat budgets, seasonal timing of key thermal events (snowmelt, sea-ice melt, freezing onset, etc.) and feedback mechanisms. Apart from these sites, the approach comprises transect-line sampling on frequent useful intervals to obtain spatial averages and variability, and aircraft sampling and satellite data to evaluate larger scale conditions in the vicinity of Barrow.

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Geophysical constraints on sea-ice bacteria

(H. Eicken, A. Stierle, GI/UAK-F; J. Deming, K. Junge, C. Krembs, OCEAN/UWA)
The overall goal is to understand better the geophysical constraints on bacterial activity and survival at very low temperatures in the brine pores of wintertime sea ice, at relevant spatial scales. The main objectives are (1) to characterize the evolution and spatial distribution of the different phase components in sea-ice pores on scales relevant to microorganisms; (2) to determine the in-situ distribution of bacteria (and other intact microorganisms present in sufficient number) within the ice matrix and their association with different surfaces; and (3) to examine microbial reactions to DOM concentration as a variable (along with temperature, salinity, and presence of surfaces) in laboratory studies guided by geophysical principles relevant to maintenance of liquid water under thermal and chemical extremes. It combines field observations of Arctic sea ice with novel laboratory experiments designed to visualize microphysical features of sea ice as it evolves at decreasing temperature (light microscopy, magnetic-resonance imaging) and to measure microbial reactions to increasingly extreme thermal and chemical conditions (adapting fluorescent staining techniques to in-situ temperature conditions). The potential role of sea ice as a model of extraterrestrial environments (such as the Jovian moon Europa) and the limits on survival of bacteria at low temperatures will be explored.

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Freshwater dispersal, sea-ice formation and large-scale sediment transport in Siberia

(H. Eicken, GI/UAK-F; A. Proshutinsky, IMS/UAK-F; L. Timokhov, I. Dmitrenko, A. Darovskikh, AARI)
With support from NSF's Russian–American Initiative on Shelf-Land Environments in the Arctic (RAISE), we are collaborating with Russian researchers at AARI and with German colleagues in the study of linkages between river discharge, sea-ice formation and sediment transport by sea ice in the central and eastern Siberian Arctic. The project will identify links between riverine freshwater supply, sea-ice formation and sediment export by ice rafting and quantify the regional and temporal variability of the relevant processes. Of particular interest in this context is the area surrounding the New Siberian Islands which has been identified as a location of (possibly basin-wide) importance with respect to entrainment and export of sediments by sea ice. Through analysis of satellite data and numerical modelling, the importance of episodic, massive entrainment events, as compared to a gradual evolutionary regime, will be assessed. Currently, the research is focusing on ice-land interaction in the immediate coastal zone. This will be extended to the wider shelf area affected by the dispersal of (Lena) river water. In support of these studies and a field experiment carried out in 1999 (Russian-German Transdrift VI expedition), AVHRR and RADARSAT SAR satellite data have been acquired for the central and eastern Laptev Sea.

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SEA ICE — ANTARCTICA

Ice thickness and roughness, Ross Sea

(K. Morris, T. Tin, M.O. Jeffries, GI/UAK-F)
During two austral autumn (May/June 1995 and 1998) cruises and one austral summer (January 1999) cruise, data were obtained for a study of the spatial and temporal variability of sea-ice thickness and roughness in the Ross Sea. Ship-based data include ice concentra-

tion, snow and ice thickness, ridge height and areal extent of ridging. In-situ data include direct measurements of snow depth, ice thickness and freeboard/draft on individual ice floes. In autumn 1995, the snow and ice were thicker, and there was a greater volume of snow ice than in 1998. In summer 1999, a combination of deep snow and nearly isothermal ice near the melting point led to more widespread flooding of the snow–ice interface than in autumn. Snow-surface elevation and snow-surface roughness were found to be strongly correlated with ice thickness.

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Ice cover in Terra Nova Bay, Ross Sea

(M.O. Jeffries, K. Morris, T. Makysm, N. Kozlenko, T. Tin, GI/UAK-F)

Terra Nova Bay is the site of a coastal polynya that has previously been studied only by remote sensing and numerical modelling. In late May 1998 we made the first in-situ observations of the ice cover in Terra Nova Bay from the R.V. *Nathaniel B. Palmer*. There was only 6% open water in the bay. The remainder was covered with consolidated sheet ice that was being ridged. Satellite passive-microwave data indicate that an extensive ice cover in Terra Nova Bay is not unusual at this time of year and is probably the result of the blocking effect of the pack ice outside the bay that prevents eastward ice advection and export from the bay. The conductive heat flux from the ocean to the atmosphere through the ice cover was calculated. Despite the extensive ice cover in Terra Nova Bay, the heat flux there was still an order of magnitude greater than that in the pack ice.

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Sea ice motion and rheology, Ross Sea

(N. Kozlenko, M. O. Jeffries, GI/UAK-F)

In late May 1998, an array of seven GPS-equipped buoys was deployed between 75–76°S at 180°W in the south-central Ross Sea. In late January 1999, two GPS-equipped buoys were deployed, one at 72°S, 135°W, the other at 73°S, 135°W in the southeastern Ross Sea. The data from these buoys are being used to investigate ice motion and rheology in areas where few data were previously available. Tidal and inertial oscillations occur in the pack ice above the continental shelf, while only inertial oscillations occur in the ice above the deep ocean. In the western Ross Sea, maximum kinematic energy occurs at a semi-diurnal frequency. In the eastern Ross Sea, maximum kine-matic and deformational energy occurs at semi-diurnal and diurnal frequencies. At ice concentrations of 90–100%, both the semi-diurnal and diurnal oscillations are damped.

(kozlenko@images.alaska.edu)

Snow cover characteristics, Ross Sea

(K. Morris, M.O. Jeffries, GI/UAK-F; T. Kawamura, ILTS)

As part of an investigation of the metamorphosis of the snow cover on Antarctic sea ice, and a program to validate snow and sea-ice products generated from NASA EOS MODIS data, the seasonal variability of the snow cover on Ross Sea ice floes has been studied. Measurements included depth, density, temperature, grain size and morphology, and salinity in May/June 1998 and January 1999. In winter, the snow is subject to temperature-gradient metamorphism and facetted crystals develop. In summer, the snow cover becomes isothermal and close to the melting point. It undergoes considerable transformation due to grain-coarsening and melt-cluster development. Percolating meltwater refreezes to form ice lenses within the snow cover and superimposed ice at the snow–ice interface.

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Seawater flooding and snow ice formation at the snow–ice interface

(T. Maksym, M.O. Jeffries, GI/UAK-F)

During five autumn and winter cruises aboard the R.V. *Nathaniel B. Palmer* in the Ross, Amundsen and Bellingshausen seas, Antarctica, we investigated the occurrence of flooding and snow-ice formation at the snow–ice interface on sea-ice floes. Actual and potential flooding is widespread, with as many as 50% of drill holes having a freeboard ≤0. Snow-ice formation is essential to the thermodynamic thickening of the ice cover; the contribution of snow ice to the total unridged ice mass varies from 12–37% according to time and location. A one-dimensional model of the two-way exchange of brine between the ocean and snow–ice interface has been developed to simulate the flooding and snow-ice formation process. A two-dimensional model of the freezing of the flooded layer has been developed to simulate the evolution of the salt content and oxygen-isotope composition of the snow-ice.

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Validation of MODIS sea-ice products

(S. Li, X. Zhou, K. Morris, M. O. Jeffries, GI/UAK-F)

The MODIS (Moderate Resolution Imaging Spectroradiometer) instrument flies aboard the NASA EOS Terra satellite that was launched in December 1999. Data for validation of MODIS Antarctic sea-ice products have been obtained during cruises aboard the R.V. *Nathaniel B. Palmer* in May/June 1998, January 1999 and February/March 2000. The program included measurements of snow-surface physical and thermal-infrared brightness temperature, bidirectional reflectance, and albedo of new ice, first-year ice and multi-year ice, plus characterization of snow physical properties (depth, density, temperature, grain-size and morphology, salinity and wetness). Radiative transfer modelling of the coupled atmosphere–snow-cover system is used to simulate the total albedo and the spectral albedo.

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PERMAFROST

Synthesis and integration of environmental data along the East Siberian Transect and comparison of active layer and permafrost conditions with an Alaskan transect

(V. E. Romanovsky, T. E. Osterkamp, GI/UAK-F; in collaboration with N. I. Shender, V. G. Rusakov, V. T. Balobaev . Yakutsk Permafrost Institute)

In spring 1998, we started a new collaborative project on comparison and analysis of ecological, climatic and permafrost characteristics along the two north-to-south transects which span most of the permafrost zone in Sakha Republic. Yakutia, Russia, and in northern Alaska. During 1998. Russian data and materials related to this project were collected and data quality assessed. These data were used to establish the first draft of the "East Siberian Transect" GIS which includes information on landscape-types distribution, vegetation, permafrost temperatures and the active-layer thickness. Records of air and soil temperatures and snow-cover characteristics for the 20 locations within the Transect were also obtained.. These data will be used to calibrate our numerical models of the permafrost dynamics. These models will then be applied to reconstruct the active-layer and permafrost temperature and the active-layer dynamics in the past and to predict them in the future. Such work has already been done for one site in Yakutsk. The first attempt was made to estimate the reaction of permafrost in Yakutia to the global warming predicted by the global climate circulation models.

(ftver@aurora.alaska.edu)

Influence of climate and environmental factors on the thermal and moisture regimes of the active layer and permafrost

(V. E. Romanovsky, T. E. Osterkamp, GI/UAK-F)

Recent unexpected and unexplained discoveries of a large-amplitude temperature cycle in active-layer and permafrost temperatures, of large and systematic changes in active-layer thickness, of a large amount of unfrozen water in the frozen active layer and near-surface permafrost at some sites, and of large spatial gradients in active-layer and permafrost surface temperatures indicate that the current understanding of climate–active-layer–permafrost interactions needs improvement.

This project combines field measurements, laboratory measurements, and analyses and interpretations of data to be obtained at six long-term study sites along a transect from Prudhoe Bay across the coastal plain and foothills into the Brooks Range. These sites are in undisturbed areas, span a wide range of permafrost, climatic, and environmental conditions, include drill holes in the permafrost (40–75 m in depth), and have a long time-series of data (since 1983). Research will focus on investigating how the active layer and continuous permafrost, in a variety of climatic and environmental settings, has responded and continues to respond to climatic change. The primary thrust is to investigate the effects of climate (especially air temperatures, snow, wind, and precipitation) and environmental factors (especially vegetation, surface morphology and soil properties) and their interactions on the thermal and moisture regimes of the active layer and permafrost in an effort to answer questions raised by recent research. During fall 1998, we started to equip our sites with soil-moisture sensors to provide year-round information on soil-moisture dynamics within the active layer in addition to soil temperatures. We continue to analyze the active-layer and permafrost temperature data obtained previously.

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Submitted by Matt Nolan

Abbreviations used in the text

AARI	Arctic and Antarctic Res. Inst., 38 Bering Street, 199397 St Petersburg, Russia
AEFF	Alaska Experimental Forecast Facility
AS	Atmospheric Sciences
CIRES	Cooperative Institute for Research in Environmental Sciences, UCO-B
CRREL/AK	Cold Regions Research & Engineering Lab., Alaska Projects Office, Bldg 4070, P.O. Box 35170, Fort Wainwright, Alaska AK 99703-0170, U.S.A.
CRREL/USA	Cold Regions Research & Engineering Lab., 72 Lyme Road, Hanover, NH 03755-1290, U.S.A.
CSU	Colorado State University, Fort Collins, CO 80523, U.S.A.
GI	Geophysical Institute
Hymet	Hymet Co., 2366 Eastlake Ave. East, Ste 435, Seattle, WA 98102, U.S.A.
ILTS	Inst. of Low Temperature Science, Hokkaido Univ., Sapporo 060-0198, Japan
IMS	Institute of Marine Science
JIRP	Juneau Icefield Res. Project, Univ. of Idaho, Moscow, ID 83844-3022, U.S.A.
NRCS	Natural Resource Conservation Service, 101 SW Main Street, Suite 1600, Portland, OR 99724-3224, U.S.A.
OCEAN	Oceanography
SFISAR	Swiss Federal Institute for Snow and Avalanche Res., Davos Dorf, Switzerland
SIO	Scripps Institution of Oceanography, La Jolla, CA 92093, U.S.A.
UAK-A	University of Alaska Anchorage, 2811 Merrill Field Drive, Anchorage, AK 99501, U.S.A.
UAK-F	University of Alaska Fairbanks, P.O. Box 757320, Fairbanks, AK 99775, U.S.A.
UBund	Universität der Bundeswehr München, Germany
UCO-B	Univ. of Colorado, Boulder, CO 80309, U.S.A.
ULav	Université Laval, Québec, Québec G1K 7P4, Canada
USGS-AK	U.S. Geological Survey, 800 Yukon Drive, Fairbanks, AK 99709, U.S.A.
USGS-T	Ice and Climate Project, U.S. Geological Survey, University of Puget Sound, Tacoma, WA 98416, U.S.A.
UWA	Univ. of Washington, Seattle, WA 98195-1360, U.S.A.
WERC	Water and Environmental Res. Center

INTERNATIONAL GLACIOLOGICAL SOCIETY

ANNUAL GENERAL MEETING 1999

MINUTES OF THE ANNUAL GENERAL MEETING OF THE INTERNATIONAL GLACIOLOGICAL SOCIETY

20 June 2000 at the University of Alaska Fairbanks, Fairbanks, Alaska, U.S.A.

The President, Dr Robert A. Bindschadler, was in the Chair.

24 members from 10 countries were present.

1. The Minutes of the last Annual General Meeting, published in the ICE, 1999, No. 121, p.7–9, were approved on a motion by H. Röthlisberger, seconded by M.O. Jeffries and signed by the President.

2. The President gave the following report for 1999–2000:

This is my first report as IGS President and I'm sorry I must begin by informing you of a particularly sad occasion for the Society. Hilda Richardson, our Secretary General for some 40 years and a prime mover behind the growth and extension of the IGS into the well-established international society it now is, died suddenly on February 5th. She had been in failing health ever since her retirement in 1993, suffering from the effects of Wegener's granulomatosis and advancing years. In the latest issue of ICE, now at the printer, we have reproduced the oration given by John Heap at her funeral in Cambridge. We would like to collect anecdotes recording her interactions with members of the Society and recording her influence on its development. In due course, we plan to establish a web site where these can be viewed and additions made. In the meantime, I would ask anyone with such reminiscences to send them, by e-mail or letter, to the Secretary General.

The importance of Hilda to the Society, and to the science of glaciology that it serves, was recognized at the time of her retirement with the striking of the Richardson Medal, two of which will be presented later this week. The incorporation of this medal into our awards system ensures that her memory and her influence in shaping our Society will endure. Those of you who wish to record her passing in a personal and tangible way are welcome to make a donation to the Society. Such donations would be designated by Council for an aspect of the Society's operations that it deems would have met with her approval, possibly an honoring of women in our profession, a particular passion of Hilda's.

Another sad note is that we also lost Akira Higashi earlier this year. An outstanding Japanese glaciologist and a recipient of the Seligman Crystal in 1990, he also served on IGS Council and was a Vice President from 1973-1976.

Shifting to more positive news, I'd like to update you on our extensive publication efforts.

With our *Annals of Glaciology* series, volume 28, containing papers from our meeting in Kiruna, Sweden, on Glaciers and the Glaciated Landscape, edited by Johan Kleman, was printed and distributed late last year. Volume 29, with papers from the Sixth International Symposium on Antarctic Glaciology, held in Lanzhou, China, and edited by Jo Jacka, was completed and distributed earlier this year.

Proofs of all papers from the EISMINT/EPICA meeting, held in The Hague a year last April, and to be published in *Annals* Volume 30, have now been received from the printer, pagination has been completed and we expect this volume to be distributed by the end of this summer.

Copy editing of all accepted papers from the International Symposium on the Verification of Cryospheric Models, held in Zürich, Switzerland, last year, is virtually complete and most proofs have now gone to authors. This *Annals*, Volume 31, should be printed and distributed by the end of this year.

With the *Journal of Glaciology*, since last year's report, we have published the final issue (151) of Volume 45 for 1999 and the first issue (152) of Volume 46 for 2000. Volume 46 will begin a shift to four issues per year. Council has made this decision to reduce the time to bring papers to print. All the material for the next issue (153) has been edited, returned from authors, and is with the printer. It should be mailed by the end of the summer.

We are immensely grateful to our Chief Editors, Will Harrison and Matthew Sturm, and their indispensable assistant, Monica Court, for their management and running of the editorial office here in Alaska. I'm delighted to report that this effective team has agreed to serve another three-year term. Tomorrow morning, a number of the Journal's Editorial Board will meet together to discuss further improvements in the handling of the Journal. We would like to thank all those editors who have served the Society so well for the past three years, R.A. Bindschadler, J.W. Glen, R. Greve, S.J. Jones, W.D. Harrison, D.R. MacAyeal, D.A. Peel and M. Sturm, and hope we will be welcoming many of them back onto the board for another term.

At Council's suggestion, the editors have instituted a reviewer-recognition program to acknowledge the important contribution referees make to the high quality of the Journal. A list of particularly outstanding referees will appear in the next issue of *ICE*.

Speaking of *ICE*, the first issue for 2000 has now been published. A major feature of *ICE* is the reports from the National Correspondents. I would like to reiterate the request made by my predecessor that all National Correspondents provide the Society with regular biennial reports and that individual members notify their local correspondents if this is not being done. We want all of you to have an opportunity to advertise your current work to your colleagues. This information exchange is an excellent means to promote opportunities for collaboration and to ensure there is a minimum of research duplication.

Still on the publishing front, we were delighted to see the revised edition of *Glacier Ice* this spring; the result of a co-publication venture between the IGS and the University of Washington Press. I would encourage those of you who have not already done so to buy a copy, or even several, as presents for friends and relatives. Some of you may have seen copies for sale in the Museum shop, but we can offer it to participants here at the slightly lower IGS member's price. We are exploring the possibilities of further co-publication ventures on topics of particular glaciological interest, including reprinting Gerald Seligman's seminal work on *Snow Structure and Ski Fields*.

Let me also update you on IGS-sponsored or co-sponsored meetings. A month ago, I met with some members of Council during our conference on snow and avalanches in Innsbruck. The local committee, under the chairmanship of Horst Schaffhauser, in conjunction with Congress Innsbruck, did an excellent job organizing that symposium. The facilities provided by Congress Innsbruck were excellent and their staff ensured that any problem was addressed immediately. The participants reported that it was an outstanding meeting. Koli Hutter did a superb job as Chief Editor, ably supported by a small but hard-working Editorial Board. I would like to single out Rand Decker for his willingness to step up to the task of becoming a Scientific Editor once the meeting had already started.

At Innsbruck, some Council members and editors expressed concern at the apparent decline, not only in the quality of papers submitted, but also in some of the presentations. The editors did their job in maintaining standards, but the result was an initial rejection rate close to 40%. For the future of the *Annals* series, it is vital that these high standards are maintained. All *Annals* editors must make sure that the referees and authors are aware of this policy. It is also extremely important for the process that all editors participate in the meetings and make themselves available to their authors for discussion about any flaws or shortcomings in the papers.

With regard to the meeting being held here in Fairbanks, I would like to commend Martin Jeffries and other members of the local committee (the names are listed in the meeting program) on their hard work and organization. Those of you attending this meeting will also know how hard the editorial board has been working on papers from this symposium. Martin Jeffries and Hajo Eicken have provided the leadership for this group of editors, who were introduced yesterday. All the various components, selection of abstracts, publication of the 2nd and 3rd circulars and program, and acquisition of final papers have gone well and on time. Insistence on deadlines means that we should be able to expect most of the papers in Cambridge by September with publication of *Annals* Volume 33 in 2001.

Next year, we will be hosting meetings on Remote Sensing in Glaciology at the University of Maryland, and on Ice Cores and Climate in Kangerlussuaq, Greenland. Presently, we only have one meeting scheduled for 2002, that in France on Modeling Physical and Mechanical Processes in Ice. We are looking for topics and venues for a second meeting that year and for meetings in 2003 and beyond. If you would like to host an IGS meeting on some aspect of glaciology that is timely or overdue, then please prepare a proposal and send it to the Secretary General so it can be brought before Council.

Later this year, we are co-sponsoring the Second International Conference on Mars Polar Science and Exploration, in Reykjavík, Iceland. Next year, we will be co-sponsoring special sessions on snow and ice and the Arctic at the Canadian Geophysical Union meeting to be held in Ottawa, Canada, and a meeting on Millennial-scale Events in the North Atlantic Region during Termination 1, being held at the University of Ulster, Northern Ireland. All are indicative of the broad range of glaciological subjects that appeal to members of the Society.

Now for my favorite part — awards.

At the conclusion of today's sessions, I will have the pleasure of presenting the Seligman Crystal to Charlie Raymond and at Thursday's banquet I will be presenting Richardson Medals to Doug MacAyeal and John Heap. This is news of which you were probably aware.

This morning Council approved the two latest recipients of IGS awards. It is my privilege to announce that Gunnar Østrem is to be made our newest Honorary Member and that the next Seligman Crystal will be awarded to Sam Colbeck. Gunnar has been a major figure in glaciology for many decades. He was instrumental in founding the glaciological program in Canada and in maintaining a vigorous glaciological research program in Norway. He also co-authored the book, which is the standard on how to make glacier mass-balance measurements. Sam Colbeck has made numerous fundamental advances in snow studies, including its metamorphism and in the manner in which water percolates through this porous medium. His research has been so significant as to redefine the terminology glaciologists use to discuss snow metamorphism.

I have not had a chance to contact either Sam or Gunnar so please don't congratulate them yet.

On to financial matters.

We are fortunate to have our Treasurer, John Heap, with us today. In a moment, he will be presenting the accounts and reporting on the state of our finances. At its next meeting, Council will be considering a slight increase in the rates for 2001 to £54. This is below the expected rate of inflation. I will remind you that there was no dues increase last year to help cushion non-UK members from the impact of the strong pound. Unfortunately, a flurry of new legislation and regulations will be driving up our operating costs.

Before closing, I would like to repeat my appeal to all those who may be observers at this meeting to consider joining the Society and for present members to help recruit new members. The founders of the IGS were quite clear and definite that glaciology covered every form of ice and any tendency to limit glaciology to the study of glaciers was incorrect. This society is for all those working on ice in any form. Its future, and the future of the *Journal of Glaciology* and the *Annals of Glaciology*, depend very much on the personal commitment you, as an individual, are willing to make in support of your professional organization.

Finally, on behalf of all glaciologists served by the Society, I would like to express our community's gratitude to our headquarters' staff: to Simon Ommanney, our Secretary General; his assistant Linda Gorman; to Dave Garbett, responsible for production; and to the others who work behind the scenes to help maintain the quality of our publications and our service to members. Ken Moxham and Sylva Gethin are our copy editors, and Liz Farmar and Joan Keating process your manuscripts. They face a very heavy workload and to ease this slightly we will be hiring a student, Emily Harker, to help in the office for the rest of the summer. I also express our thanks to the chairmen of our three committees: Charlie Raymond, who heads the Nominations Committee; Julian Dowdeswell, who directs the Publications Committee; and Bill Budd, who recently ended a term leading the Awards Committee, and to all the members of these committees who have helped them during the past year.

This has been my first year as your President. During this time, I have learned a great many things about how the Society operates. My service has only deepened my commitment to glaciology and to this exceptional professional society. I have enjoyed the opportunity and look forward to continuing to serve you.

Thank you for your kind attention.

I. Allison proposed, and W.F. Weeks seconded, that the President's report be accepted. This was carried unanimously.

3. The Treasurer, Dr J.A. Heap, presented the following report with the audited Financial Statements for the year ended 31 December 1999.

"The state of the Society's finances is best summarized by considering the changes from 31 December 1998 to 31 December 1999 in the following funds, as shown on page 13 of the accounts:

Seligman Fund: increased from £2354 to £2421, as a consequence of interest accrual;

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

Annals Fund: increased from £70,248 to £75,893;

Publications Fund: increased from £14,102 to £16,681, as a consequence of sales, royalties and interest accrual;

Future Volumes: decreased from £27,807 to £26,249 reflecting lesser amounts of advanced income received with respect to *Annals* 30 and *Annals* 31;

Accumulated Fund: increased from £112,873 to £141,373 (page 6) consequent upon a profit in that account for the year of £27,572 plus a gain of £928 in the value of investments due to an adjustment to market value (page 12, note 7).

In 1999, the Society published 598 pages in the *Journal of Glaciology* and 600 pages in the *Annals of Glaciology*. In 1998, the figures were 682 for the *Journal* and 1122 for the *Annals*, a year with two issues of the *Annals*. As I noted in my report for 1998, the Society's publications are still very much dependent on the provision of page charges; the revenue exceeds that derived from the total of members' dues. I wish to register the Society's warm 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. Although Junior memberships have increased, there has been a disturbing decline in Full memberships. If the Society is to continue to serve the science, we need to increase our membership base to at least 1000. If you know of colleagues or students who are not members, please encourage them to join. I believe they will find it is extremely good value for money. Also, please ensure that libraries in any institutions in which you have influence either maintain their subscriptions or take one out."

S.J. Jones proposed, and C.S. Lingle seconded, that the Treasurer's report be accepted. This was carried unanimously.

4. Election of auditors for the 2000 accounts. J.A. Heap proposed, and W.F. Weeks seconded, that Messrs Peters, Elworthy and Moore of Cambridge be elected auditors for the 2000 accounts. This was carried unanimously.

5. Election to the Council. After circulation to all members of the Society of the Council's suggested list of nominees for 2000–2003, no further nominations were received, and the following people were therefore elected unanimously:

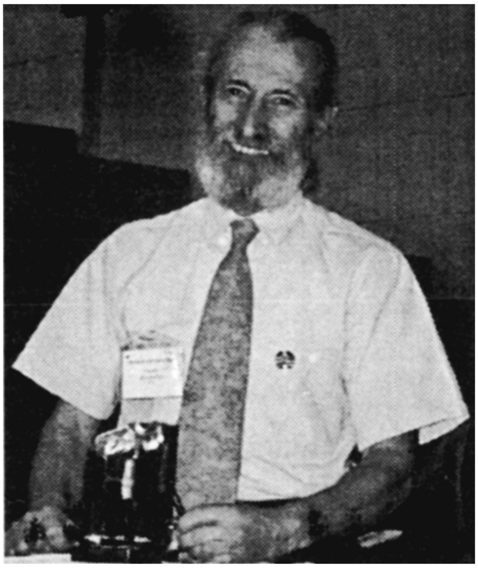
Vice President:	Elizabeth M. Morris
Elective Members:	Takeo Hondoh
	Gino Casassa
	Mary Albert

The AGM was adjourned on a motion from S.J. Jones seconded by M.O. Jeffries.

1999 SELIGMAN CRYSTAL AWARD
Charles F. Raymond

20 June 2000, Fairbanks, Alaska, U.S.A.

The Society's Council agreed unanimously in 1999 that a Seligman Crystal be awarded to Charles F. Raymond. The Crystal was presented at the International Symposium on Sea Ice and its Interactions with the Ocean, Atmosphere and Biosphere, after the following introduction, by the IGS President, Bob Bindschadler.



Numerous past presidents of the International Glaciological Society have said that presenting the Seligman Crystal is one of the most pleasant duties of this position. Tonight I am able to go them one better by presenting this Seligman Crystal to my former advisor, Charles Forrest Raymond. Thus, this introduction is based on many personal experiences I have shared with our distinguished recipient over the years.

Charlie, as many of us are privileged to call him, has had an exceptionally productive and influential career, spanning a variety of research topics. What has not varied is the high quality of his research and of his contributed papers to glaciology. I can think of no better mentor from whom I could have learned glaciology. It is upon the excellent foundations Charlie provided during my years at the University of Washington that my own glaciological career rests.

He taught me what I had to know to be a glaciologist: how to think to make the most of both observation and theory, and how to behave in the field to get the most out of time spent there. I am unreserved in proclaiming my good fortune to have studied under Charlie for six years at the University of Washington, where Charlie continues to train some of the best glaciologists in our Society.

Few of you probably know the steps that led Charlie to take up glaciology as his professional career. From the wandering discussions that emanate from long hours in the field with Charlie and other close colleagues who know him well, I believe I have pieced together a rather complete and relatively unknown knowledge of his early career. Well before Charlie had a rigorous scientific interest in aspects of snow and ice such as stress-strain relationships and finite-element modeling, Charlie's involvement with ice and snow usually was in the form of mountaineering. He was one of the best climbers in this country in those days and, as one who had had to keep up with him at the end of a rope between us, I can attest to his surefootedness on the most fragile of mountain ridges. As a Berkeley physics student, he would roar off into the Sierra on his motorcycle to bag a few peaks before returning to classes. He is credited with a long list of first ascents and you will find his name listed again and again in climbing guides to any of the mountain ranges in the western U.S.

Fortunately for glaciology, it was during this period that Charlie shared a dinner table with Ed LaChapelle, one of the most prominent snow researchers ever to belong to our Society. It was Ed who described to Charlie that he made his living in the mountains studying the physical properties of snow and the dynamics of avalanches. The possibility to get paid for working in an environment Charlie already loved was irresistible. From that moment on, Charlie was hooked on glaciology and the dye for this evening was cast.

Charlie's brilliant mind was honed on glaciological problems under the tutelage of Barclay Kamb at CalTech. Charlie's thesis work on Athabasca Glacier, in the Canadian Rockies, stands as a seminal work that measured, for the first time, the three-dimensional strain field of a valley glacier. It is against Charlie's measurements that all numerical models of three-dimensional glacier flow continue to be compared. It was during this fieldwork that our paths nearly crossed. A wet-behind-the-ears undergraduate on a summer vacation with my family, I happened to take the tourist's snowbus trip on Athabasca Glacier where the tour guide, stumped by some of my father's questions, said that he would have to ask the CalTech student who was working on the glacier that summer. That CalTech student was Charlie. Little did I realize my proximity at that moment to glaciological greatness.

In the years to follow, Charlie graduated and took a position at the University of Washington providing their Geophysics Program with a "glacier"-ology component to go along with the snow and avalanche expertise of Ed LaChapelle and the sea-ice expertise of Norbert Untersteiner. Again, on a personal note, it was this breadth of expertise that attracted me to come to the University of Washington, along with the initiation of a new project of surging glaciers Charlie and his University of Alaska colleague, and fellow CalTech alumnus, Will Harrison, were about to begin.

My first day at the University of Washington, Charlie showed me the office I would be sharing with other graduate students. Once Charlie left, one of my officemates, Alan Thorndike, said to me: "the best piece of advice I can give you is, listen to everything that man says!". It did not take long for the truth in his words to become apparent. Many were the times that I went into Charlie's office with a single question only to leave an hour later with my head swirling from the intense discussion that transpired. I would rush back to my desk and try to write down all he had said or scribbled on his blackboard before I forgot it.

With the Variegated Glacier project, Charlie began his second seminal work: the study of glacier surges. The papers documenting the quiescent and surge phases of Variegated Glacier are required reading on the subject. Year after year, for more than a decade, Charlie, Will and Barclay brought field teams to the glacier where windstorms, heavy snows and mosquitoes were routinely overcome to insure that the necessary data were collected. Charlie showed by example how successful fieldwork requires a combination of patience, determination and good humor, to say nothing of good planning and extremely hard work. Never mind that I once caught him standing on a sled that I was laboring to pull through deep snow, or that after a night spent in a cramped snow cave, because a windstorm had leveled our camp, he announced to us all that it was time to go to work, even though the wind had increased in ferocity. Lifelong friendships were forged during this period and it became clear to me not only what a brilliant scientist Charlie is, but what an exceptional person he is.

After I left the University of Washington with my degree, Charlie's research on surging continued. Variegated Glacier surged — finally, and Charlie, still working with Will, instrumented other surging glaciers in Alaska. This work led to the idea that it was high basal water pressures, sometimes peaking in midwinter, that triggered surges.

At this stage, Charlie's interest turned toward the information that could be gleaned from internal layers and an entirely new phase of his research began. Joining up with colleagues at Ohio State University and the British Antarctic Survey, to study Dyer Plateau in the Antarctic Peninsula, Charlie used a ground-based higher-frequency monopulse radio-echo sounder to record internal layers at high resolution. Charlie was the first to explain how the non-linear rheology of ice led to the formation of an elevated "bump" in the internal layers directly underneath an ice divide. Despite his reluctance to accept the term, this feature is now known as a "Raymond bump".

Most recently, Charlie has addressed ice streaming in West Antarctica and our research interests have intersected once again. He has completed an elegant treatment of the transfer of horizontal shear stress at the ice-stream base to vertical shearing within the stream's margins, where heat generated by vertical shear competes against cold advecting into the stream. The balance of these two processes determines whether the ice stream widens or narrows with time. Other West Antarctic contributions he has made in collaboration with his students and colleagues at the University of Washington, have included constraints on ice-stream history based, again, on internal layer structures on the interstream ridges. Present work tracking internal layers across stream margins promises future significant advances in our understanding of the West Antarctic ice sheet.

I want to close with two final observations that, in addition to all his scientific accomplishments I have already mentioned, most impress me about Charlie. First, throughout his career, he has demonstrated a unique combination of strengths in field research, theoretical treatments, and instrument development. And second, and perhaps most important of all, I have never known Charlie to flash any ego. His brilliance is unassuming. For all his achievements, as a glaciologist, as a scientist and as a person, to me he is the consummate glaciologist and it pleases me enormously to now ask him to step forward where, on behalf of the International Glaciological Society, I can present you, Charlie Raymond, with the Seligman Crystal.

Thank you Bob for your very kind and generous description of my contributions to glaciology. Thank you all for joining us today. I was certainly overwhelmed, and extremely surprised, when Bob phoned to tell me I was to receive the Seligman Crystal. I am certainly thrilled to be listed with the other recipients, many of whom have had considerable impact on my professional life as a glaciologist. It is hard to imagine that I could have had a similar impact on many others, but I am happy to know that some people believe they have learned useful things from me.

It is especially heartening to have Bob Bindschadler give the citation. I have had a long association with Bob. He worked with me as a graduate student, and helped initiate the work on Variegated Glacier that he mentioned. Later Bob became one of the leaders in the U.S. program examining the history and dynamics of the West Antarctic ice sheet, and I sort of followed him there. It is especially satisfying to be led by one's students.

I am also happy that this event is happening here in Fairbanks. Will Harrison helped me cope with burned plugs, tangled wires and other messy problems when I drilled through the Athabasca Glacier, a long time ago, as part of my thesis research. Since then we have collaborated often, including work on glaciers here in Alaska. Fairbanks is somewhat of a second home to me because of this collaboration and Will's generous hospitality.

Bob has already given you a brief history. I will say a little more. The most important thing is that whatever I have accomplished has flowed from collaborations with many colleagues. Tonight, I would like to honor them as best as I can. First, I will tell about how I entered glaciology and how glaciology has affected me.

I grew up in the Bay Area of California. There was no ice outside the refrigerator. My main enjoyment was walking in the hills. I was captured by the books of John Muir, a reclusive, turn-of-the-century naturalist of Scottish decent. He wrote about his wanderings in the mountains, but also had an interest in glaciers. However, it was the wandering that first attracted me. When I was in high school, I would load my pack with bricks and walk the hills to strengthen myself. However, in college, I spent a lot of time figuring out how to make my pack as light as possible, which shows that at least I was able to learn some things.

My hiking moved from the coastal hills of central California to the canyons and mountains of the Sierra Nevada. Summits decorated by glaciers were especially intriguing. I remember wishing I had been there a century earlier, at the time of Muir, when the glaciers were bigger. I was astounded to realize that this range, in the hot climate of California, had earlier been covered with ice many times down to low elevation. Rock climbing was perhaps my top priority, and I spent a lot of time on the glacier-polished cliffs of Yosemite Valley, admiring their brilliance. I had a passion for the mountains and climbing, but realized reluctantly that I probably could not make climbing the complete focus of my life.

While I was carrying bricks in high school, I discovered that science and math were subjects I could do. I was totally intrigued by the wildlife and plant communities that I saw in the hills and thus very attracted to biology. But in the academic environment, physics and math were what enthused me. So that is what I decided to study in college at the University of California in Berkeley.

Physics and math were a great intellectual adventure. For example, I found special relativity especially enthralling, with far-reaching conclusions coming from one simple observation that the speed of light is the same for all observers. This was elegant and beautiful. I enjoyed my undergraduate years at UC Berkeley and have always valued the great instruction I received there. After a year of relatively aimless wandering in Europe, following graduation, I returned to UC Berkeley as a graduate student in physics. I passed my qualifying exams and found myself being recruited by a number of groups to work at the Lawrence Radiation Lab. which was then one of the world centers for high-energy physics. This prospect was intriguing, but I had some doubts that became stronger.

I was startled by the sheer size of the operation, the huge machines in great cavernous buildings partitioned by immense numbers of lead bricks. Perhaps I had had enough of bricks. I thought back to a public lecture by Edward Teller I had heard when still in high school. It exposed a side of science that troubled me then and continues to do so. Teller had the ominous title of "Father of the H-bomb", which he disliked. Teller was a brilliant, honest and convincing man, but very complex with a dark side to his legacy. This was a time of considerable societal angst concerning the implication of thermonuclear bombs. However, his lecture focused on the peaceful uses of really big explosions. His was a vision of explosively excavated pits all over the world, for harbors, mining or whatever! What grabbed me most was his suggestion that, with enough energy, humans could even control the weather; for example, order up the appropriate weather for 6:30 p.m. on 20 June 2000. He seemed unconcerned with exactly who might be doing the ordering. This vision of complete control of nature by humans was appalling me. I wondered how much damage I could do as a physicist given my perception that humanity was certainly confused about where it is going.

So I had two parallel lives: in simplified form — the mountains and physics. Neither one was really complete. The two were certainly not integrated and they were in conflict for my time, which I began to realize was limited.

Then I discovered the *Journal of Glaciology* in the library at UC Berkeley! I found it really interesting. I saw intriguing applications of continuum mechanics by John Nye, from the bare essentials of glacier flow to the complexity of glacier response to climate. I was impressed by the elegance and clarity of Nye's papers, something I have aspired to but never quite attained. Papers by Hans Weertman got right down to the basic physics of interesting problems with a minimum of mathematical detail. His knack for defining simple and revealing problems was something to aim for. Louis Lliboutry at times overwhelmed me with mathematical detail, but I found rich messages. Gordon Robin was the first to make heat advection real to me. I was amazed by the internal grain-scale working of snow and glacier ice then emerging from the research of Tony Gow and Barclay Kamb. The flatness of sea ice held little attraction for me, but its inner structure revealed in early articles by Willy Weeks was quite intriguing. I was seeing articles that were to become the classics of glaciology. As I read articles from the *Journal*, I thought "this is good stuff". Perhaps I can do this kind of science. It was clearly intellectually challenging, and potentially adventurous. Perhaps I could integrate my two lives with little danger of doing big damage.

So you can see that the Glaciological Society got me started toward glaciology. The Seligman Crystal recipients mentioned above were some of the most important messengers. Of course there were others as well.

I also had heard about this guy Ed LaChapelle, who studied avalanches in the mountains of Utah. I decided that a skiing trip in Utah might be informative and fun, so off I went to talk to Ed about glaciology. Another character, Norbert Untersteiner, was there as well on a ski vacation. You will know Norbert as one of the initiators of modern sea-ice research. Anyway Ed and Norbert educated me about opportunities in glaciology and suggested I should work with Barclay Kamb at CalTech.

Going to CalTech was like jumping into an academic frying pan. It was incredibly intense and dedicated. Although it definitely did not relax the competition for time between my two lives, it was a fantastic initiation into serious research. There were many incredible role models. In addition to Barclay, I mention especially Bob Sharp, an honorary IGS member. Barclay is well known for his leading theoretical work on glacier flow, rich experimental work on the structure and flow of ice and very revealing field programs. Barclay opened up to me new ways of thinking and new paths to explore. Most importantly, his example showed that you can (and sometimes need to) work on all angles of a problem, from design of equipment and observation to theory. This was a great release from the distinct roles of theoretician and experimentalist characteristic of big-time UC Berkeley physics.

My thesis research took me to the Athabasca Glacier in Canada to investigate the pattern of flow in the cross section of a glacier. With a lot of help, I soldered, used milling machines, had the world record in length of holes drilled through glaciers for a while, and discovered a few things about how the sides of a glacier affect its motion. In a nut shell, I learned that the effect on the flow and stress from valley walls is larger than one might think, because the very bottom of a glacier tends to be slippery.

Norbert Untersteiner helped guide my entry into glaciology and 5 years later, in 1969, he opened the way to the foundation of my professional career at the University of Washington, in the Geophysics Program. This was conceived as an interdisciplinary Earth-science program. It was new and formed mostly from a group of young energetic faculty with diverse and generally oddball interests that were not fully appreciated in the established departments. I had hard-working, able and congenial colleagues with interests from deep-Earth processes to the magnetosphere. I was lucky to find such a compatible environment for teaching and research. Of course, glaciology was, and is, well represented at the University of Washington: I have already mentioned Ed LaChapelle and Norbert Untersteiner. More recently, I have particularly benefited from continual and stimulating interactions with Ed Waddington (the quizzical inventor of revealing analytical and simple numerical models), Steve Warren (who turns the simplest observation into really interesting science), Howard Conway (the science integrator with a very warm personality and enthusiastic interest in everything) and Bernard Hallet (a wide-ranging geomorphologist with a new look on many phenomena, including the workings at the beds of glaciers). There are others in vital groups in glacial geology, sea ice, atmospheric ice and basic ice physics in various departments. This has been a great environment for graduate students captured by the adventure and romance of glaciology, but who also need to develop into well-rounded geophysicists. All of this was immensely important for me as a platform for successful research and teaching.

The Pacific Northwest was a great place for a glaciologist like me to get started. The U.S.G.S. Glaciology Office directed by Mark Meier and an energetic group led by Garry Clarke at U.B.C. were nearby. Both Mark and Garry are glaciological heroes in my mind. In addition to their outstanding research, Mark and Garry have both done great service in keeping glaciology on track in the IGS and other organizations. Mark and Garry, with some help from Ed LaChapelle and myself, conceived the Northwest Glaciologists. This became a forum for west-coast glaciology and a wellspring of glaciological lore and energy from CalTech to UA Fairbanks. Students working with me, and I, enjoyed the interactions of Northwest Glaciologists immensely and reaped great benefits.

I especially want to draw attention to one northwest person, who has had a profound influence on glaciology and me. That is Austin Post, now retired from the U.S.G.S. He, together with Mark Meier, was the first to really encapsulate the phenomenon of glacier surges as an internally controlled threshold phenomenon. His pair of pictures of the Variegated Glacier, 1964 and 1965, is the most graphic description of the surge phenomenon. Austin was the first to clearly state that surges are the result of an internal threshold associated with a jump in the dynamics. The cause was in the glacier bed, not a large external push like an earthquake, avalanche, etc., as had been hypothesized earlier. He showed that surges are repetitive. Surges became the main mystery of glacier physics.

Will Harrison convinced me that we should go out and investigate this mystery with some good long-term glaciological measurements spanning the build-up to a surge through the surge itself. The foundations laid by Austin's observations made that possible and we chose Variegated Glacier. This was a beautiful spot with many challenges that fulfilled our yearning for adventure. Sometimes we were confronted by what we called the "death winds". Although this name is an overstatement, because we did survive, occasionally they did blow down our tents. Bob Bindschadler was wrapped up in his tent for almost a full day, performing the vital role of tent anchor, perhaps illustrating his endurance and tenacity. The rest of us could not contain other needs for so long. Occasionally we had to live under the surface in snow caves.

Over a 13 year period, we were joined in our adventure by a number of graduate students. The ones particularly close to me were Bob, Neil Humphrey, Tad Pfeffer, Tómas Jóhannesson, Mike Balise and Magnús Magnússon. They did some great work and the mix of personalities was really interesting. You will recognize some of these names as participants in the IGS enterprise and current glaciological research.

It is interesting to look back on our methods: man-hauling of equipment; seismic, not radio sounding; theodolites, not GPS; strain gages feeding chart recorders, not data loggers, and so forth. I would have been delighted to have had some of our modern tools.

We were joined eventually by the group from CalTech, led by Barclay Kamb and Hermann Engelhardt. These colleagues brought new energy and direction to our work including exploration of the subsurface. I am sure that Hermann now holds the record for length of holes drilled in glaciers and ice sheets. Direct examination of the bed was the hope. Barclay eagerly anticipated loads of wisdom sucked from the bottom of Variegated Glacier. A number of CalTech graduate students were involved, especially Mindy Brugman and Keith Echelmeyer. Keith is now here at the University of Alaska, and I am happy to have had the good fortune to work with him.

We were, of course, excited by the prospect of probing the mechanism of a spectacular surge. We got our chance in 1982 and 1983 when the Variegated surged again. Travel on the glacier surface, which had been straightforward, became more difficult, then very challenging, and finally effectively impossible. Nevertheless, work continued.

We discovered, from many lines of evidence, that the surge was caused by enhanced lubrication of the bed associated with collapse of the normal drainage system and retention of water in the glacier. Perhaps the most graphic illustration was the appearance of dirty water, forced upward from the bed of the glacier into a marginal lake. The surge stopped by release of the water and a tremendous amount of sediment in a sequence of floods. In essence, this was the same explanation proposed by Austin Post 15 years earlier. We were able to support this notion with many different measurements and defined new ways to analyze it.

Will Harrison and I, perhaps more than others, were intrigued by the evolution of the glacier between the surges. As the glacier built up to the next surge, each year we saw a slightly different glacier in the same valley. So we observed a remarkable sequence of controlled experiments, performed by Nature, that showed us how the normal flow of a glacier changes as it thickens and its surface tilts. We found some of the answers in the classical analysis of glacier flow made by John Nye and the flow law first established for ice by John Glen, but there was a residual that we ascribed to motion over the base driven by changing hydraulic conditions at the bed.

The really interesting and challenging part, for both the surge and the normal flow, had to do with the glacier plumbing. So we were always looking back to the foundations laid by Hans Röthlisberger.

Our work on Variegated Glacier lasted more than a decade. After the excitement of observing a surge, I was ready for a new direction. I was attracted to the, let's say, very dynamic, research on the dynamics of the West Antarctic ice sheet. Ice streams were the main dynamic components and key to understanding possible rapid changes in the mass balance of the ice sheet. The potential for rapid rise in global sea level was the main motivation. This research grew out of the pioneering work of Charlie Bentley and many others. It was dramatized by the imagination, and I think penetrating perception, of Terry Hughes. Ian Whillans was an especially energetic observer and creative interpreter. Doug MacAyeal was the supreme analyzer using inverse methods and was prominent in bringing the other non-ice elements into consideration. Bob Bindschadler brought the big view of satellite remote sensing, and his leadership welded the effort into an ever-broadening multidisciplinary program including glacial geology, marine geophysics, oceanography and meteorology. These, now old-timers, have been joined by a number of off-spring like Richard Alley, who is always inspiring, and the inventive Don Blankenship. Many even younger stars have appeared on the scene.

I have described this in the past tense, but all of these players are still at work on the problem. I have been lucky to be able to join them. I would like to tell you how this came about because it illustrates how science sometimes works. It was not the result of any clear vision on my part.

A fellow named Bruce Weertman entered our Geophysics Program at the University of Washington with an interest in instrumentation, not glaciology. However, as the son of Hans Weertman, who I have already mentioned, he certainly had a glaciological heritage. Bruce had been a field assistant with Charlie Bentley's group at the University of Wisconsin. He hung around with other technological buffs in geophysics at the University of Washington, and he, and an electronics engineer named John Chin, conceived a new-style, very powerful, radar transmitter that could be used to detect internal layers in ice sheets. There is a long tradition of radar sounding in glaciology. Airborne radar has been used to map much of the ice sheets. We move slowly on the ground, but pick up interesting detail in crucial transition areas. An example is the work on Siple Dome, between Ice Streams C and D, in West Antarctica.

What vision I did have is that we would map the internal layers, which are believed to be isochrones. Through that, we could extend the age vs depth at core sites to establish the three-dimensional age field in the ice sheet. That would be the key to inverting for the flow history of the ice sheet.

We may never reach this goal for a complete ice sheet, but have taken some useful steps in that direction on Siple Dome, working with colleagues Robert Jacobel and Ted Scambos. A very energetic young woman, Nadine Nereson, who came to UW as a graduate student, has played a leading role. She developed several themes for interpreting the layers. Most obvious is the spatial pattern of accumulation found from thickness variations of layers. Note that the layers are not all smooth. There are distortions and disruptions at certain key transition areas associated with the flow divide and at the boundaries with adjacent ice streams. These are key areas where there is information about changes in the configuration of the ice including the ice streams. We seem to be the ones dragging the information out from the details revealed by high spatial resolution of on-the-ground profiling. Nereson has shown that Siple Dome is slowly migrating northward because the ice stream on the south has thinned more than the one on the north. Other inter-ice-stream ridges are beginning to reveal similar information. I am looking forward to discovering with these methods more about how the West Antarctic ice sheet shrank since the Last Glacial Maximum and what the future holds.

My most recent focus has been the margins of ice streams. For certain ice streams, good lubrication of the bed is the crucial factor. This is another slippery bottom story. Several people, most notably Ian Whillans, have argued that the edges of the ice streams can provide important restraining forces, limiting the discharge of ice and stabilizing the ice sheet. Keith Echelmeyer and Will Harrison, here at the University of Alaska, have played a prominent role in showing this to be true in parts of Ice Stream B. I have jumped on the Whillans bandwagon too. My place is to question where the heat generated by the down-slope motion goes. In fact, it may appear predominantly in the margins. Perhaps melt water may not be so available for lubricating the ice-stream base and the margins are even more important than we thought. There is still a lot to explore as we recognize that most of the ice streams draining West

Antarctica may not have the same kind of controls as are active in Ice Stream B.

After all these years I am still on the surface of the glaciers, pulling sleds, seeking adventure, using relatively simple techniques, getting excited by the little bits of information revealing secrets of how things work, and still confounded by slippery bottoms.

As I fell into holes in the fractured ice during our recent radar profiling of the margin of Ice Stream B, I thought that I have indeed managed to integrate my two conflicting lives. It has been a great adventure and lots of fun.

Now I have not said much about my personal contributions. What is the most important thing that I have done? Most importantly, I have tried to provide an opportunity for students to develop their potential. I hope those who have worked with me have learned as much from me as I have from them. I have tried to stimulate them to think in new ways. Perhaps an important message is to improvise with what is available. You do not have to have the best resources to do interesting and worthwhile science.

I am inclined to consider whether I have avoided doing any major damage, which was, I guess, my rather naïve motivation for leaving physics and entering glaciology. I suppose one never knows what one's work will bring. However, what is evident is that the field I choose to enter, glaciology, has turned out to be important science and very relevant to modern human concerns. Glaciology, in consort with other environmental sciences, prompts humans to look at the impacts of their actions on the natural world and to realize that there are big consequences affecting even the most remote regions. Teller's world view of unlimited human control of Nature appalled me. But now we see that humans are probably having a very significant global influence on the Earth's environment, even climate. We need to know what we are ordering up inadvertently. This is amongst the top scientific priorities: it is important, rich in complexity and challenging. Glaciology has been at the forefront, in its broadest sense, encompassing not only the thick long-memory glaciers and ice sheets, but also the thin, fast-reacting sea ice and snow. Therefore, I am confident my small contributions in a small compartment of this large endeavor have not been very damaging. I am indeed thrilled that some people think that I might actually be helping in a significant way.

Finally these challenging questions about ice on Earth can surely keep glaciologists busy for a long time, but there is no need for glaciology to remain Earth-bound. The outer solar system is populated with fantastic ice worlds, so the romance and adventure of ice in the mountains and surrounding the poles is certainly expanding to some exciting new science opportunities.

There are a lot of things that do not fit smoothly into my short story.

I will just list a few other people who I have not yet mentioned. Stan Paterson is the scribe of glacier and ice-sheet physics. I refer to his book constantly for teaching and research. I have always admired Bill Budd's energy and direct, pragmatic attack on the big problems. He is so energetic that I need to eat a few extra meals before stepping up to discuss issues with him.

Here I am at a conference on sea ice and I have said nothing about sea ice. That is because I have done nothing on it. But I can say that rubbing shoulders with the sea-ice research community has had some effect on me. One of the most fun things I did was to examine the growth of snow grains in water-saturated snow. Some of the early work by Alan Thorndike and Drew Rothrock on the thickness distribution of sea ice had quite an influence on my thinking. I will leave it to you to puzzle about the connection.

Thank you all for coming, and thank you to the International Glaciological Society for this recognition and, most important, for providing a great support system for my work.

IGS WEB SITE

We have received the following notice from the Institute for Scientific Information (ISI).

"You are publishing important, high-quality material on the Web. For this reason, ISI has selected your site (http://www.spri.cam.ac.uk./igs/home.htm) for inclusion in Current Web Contents (http://www.isinet.com/products/webselect/webselect.html), a new section of Current Contents Connect™ (CC Connect™). ISI editors — following carefully structured evaluation criteria — have visited your site, reviewed it, developed a standardized descriptive record, written an abstract and created a link from CC Connect to your site.

CC Connect (http://www.isinet.com/products/cc/ccc.html) offers Web access to Current Contents, the ISI premier current awareness database that provides information in the fields of science, social science, technology, and the arts and humanities.

For more than 40 years, ISI has delivered this multi-disciplinary table-of-contents database to researchers, scientists and information professionals around the world. Since its inception, this journal-based resource has reflected the strict guidelines for selection developed by the ISI Editorial Development Staff. The result is the most prestigious database available internationally.

High standards of selection – and data quality – have made ISI a leader in the information industry.

ISI has now applied these selection standards to the creation of Current Web Contents (http://www.isinet.com/products/webselect/faqwebselect.html), an ever-growing collection of high-quality, scholarly Web sites".

James Testa (ISI)

Our thanks and congratulations to Dave Garbett who has worked so hard to develop and expand this site.

RICHARDSON MEDAL AWARDS
Douglas R. MacAyeal (1997) and John A. Heap (1999)
22 June 200, Fairbanks, Alaska, U.S.A.

The presentation of two Richardson Medals took place during the banquet/cruise of the International Symposium on Sea Ice and its Interactions with the Ocean, Atmosphere and Biosphere on the Riverboat Discovery II. The Secretary General addressed the audience and read the citations as follows.

Douglas R. MacAyeal

John A. Heap

This is not an occasion on which I had expected to address you, but unfortunately our President was called away suddenly on Wednesday so he cannot be with us tonight.

While the Seligman Crystal honours contributions to the science, the Richardson Medal honours those who have given freely of their time and effort in support of the Society itself.

Many of you here this evening are not IGS members. However, I hope your experience this week, interacting with those who are, and benefitting from the efforts that Society members, and others, have made in hosting this symposium, will persuade you this is an organization worthy of your support. The fact that IGS members are in a minority here, probably means that many of you have little idea what the Richardson Medal is and what it means.

It was struck and presented to Hilda Richardson on the occasion of her retirement party in 1993. She was my predecessor and Secretary General of the Society for 40 years. During that time, she saw the Society grow from a group of British snow and ice and glacier enthusiasts into the broad-based, highly regarded, scientific society you know today. Hilda's influence on this development was immense and you will be able to read a little of this in the next issue of ICE, which should be on its way to members this month.

The Medal, as some of you may see tonight, reflects a number of significant events in Hilda's life, not least being Austerdalsbre, the glacier in Norway where she went as a Cambridge student with Vaughan Lewis, John Glen and John Nye.

After her retirement, the Society decided to adopt the Medal as an award, principally for service to the Society. Tonight, I am immensely privileged to preside over the presentation of two of these. Hilda had planned to attend this meeting, but as those of you who are members, or who sat in on the AGM, will know, she passed away in February.

The *Journal of Glaciology* started publication in 1947. For the first 40 years or so, it was managed by an editorial board based in Britain. John Glen, Ray Adie, Doris Johnson, David Homer and others developed and maintained the high standards that are recognized today. However, as the Society became more international in outlook and name, it became apparent that for the *Journal* to appeal to that same audience, efforts should be made to make the editorial board itself more international. This was very much in line with the direction espoused and promoted by Hilda. Some way, I know not how, but he may tell us, Hilda persuaded Doug MacAyeal to take on the role of first international Chief Editor of the *Journal of Glaciology*. He brought together a team of specialists to cover the wide variety of papers submitted to the *Journal* and, from 1991 to 1997, single-handedly ran the office of Chief Editor from the University of Chicago. This was work that took a considerable amount of his time and effort, meaning he had less to spend on his research. Yet he did this willingly, enthusiastically and cheerfully, jumping into the breach to cover for delinquent editors and taking on an enormous amount of the editing himself. It is for this unselfish commitment to the needs of the Society, and for his dedication in carrying out this task, that tonight we honour him with the Richardson Medal. I should add that, apart from the presentation to Hilda, this is actually the first Richardson Medal awarded, but Doug has been unable to make it to any previous IGS meeting since the announcement of the award in 1997.

The Secretary General then called on Will Harrison, Chief Editor of the Journal to make the actual presentation.

Will Harrison, in making the presentation, indicated that he, probably more than anyone else present, could appreciate the monumental task that Doug undertook, and how astonished he was at how Doug was able to manage so much on his own. The award of the Richardson Medal was a fitting recognition of this achievement.

Doug MacAyeal, in expressing gratitude to the Society for the award, alluded to Hilda's amazing powers of persuasion that he had been unable to resist. He briefly reviewed some of the advice Hilda had given him following his appointment.

The Secretary General then continued...

At the Council meeting in Zürich last year, the President was carrying a recommendation from the Awards Committee for a Richardson Medal to be awarded to John Heap. Because John was present at the meeting, and we did not wish to raise his suspicions, we chose to conclude our discussions of this award by e-mail, leaving him out of the loop. This spring, the President was able to visit England and bring with him the unanimous decision of Council to recognize John's contribution to the Society through this award.

This award is about service to the IGS, so I will not describe for you the highlights of John's professional career. He was elected to the Council of the Society in 1967 and was first appointed Treasurer in 1970, serving for two terms until 1976. He returned to the position of Treasurer in 1980 and has served us continuously as Treasurer since then.

He has played a central role in ensuring that both the Secretary General and the auditors understand what we require in the accounts and that Council has remained informed and well-advised as to the IGS's financial situation.

He has been a pillar of strength and a source of sage advice to both Secretaries General.

His contribution to the IGS, like Doug's, epitomizes the nature of service to the scientific community.

As a mark of our esteem and gratitude for so many years of dedicated service to the IGS, I would now like to call on Hans Röthlisberger, who as a past President of the Society knows John and his contribution well, to present the Richardson Medal.

Hans Röthlisberger briefly described the important role played by Hilda in the development of the Society, her influence on him and the appropriateness of a Society Award in her memory. He explained the symbolism in the Medal and how it related to important elements of Hilda's life; Austerdalsbre, Street Farm, her dogs and a rose with a thorn. As a Past President of the Society he could testify to the important role played by John Heap in helping manage the financial affairs of the Society.

John Heap, in accepting the award, expressed his delight and surprise at his selection while suggesting, in characteristically humble fashion, that he had not done anything special.

JOURNAL OF GLACIOLOGY

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

R S Anderson
Evolution of medial moraines

S A Arcone and N E Yankielun
1.4 GHz radar penetration and evidence of drainage structures in temperate ice: Black Rapids Glacier, Alaska, U.S.A

E L Christensen, N Reeh, R Forsberg, J H Jörgensen, N Skou and K Woelders
A low cost glacier mapping system

A Eichler, M Schwikowski, H W Gäggeler, V Furrer, Hans-A Synal, J Beer, M Saurer and M Funk
Glaciochemical dating of an ice core from the upper Grenzgletscher (4200 m a.s.l.)

H A Fricker, G Hyland, R Coleman and N W Young
Digital elevation models for the Lambert Glacier–Amery Ice Shelf system, East Antarctica, from ERS-1 satellite radar altimetry

H A Fricker, R C Warner and I Allison
Mass balance of the Lambert Glacier–Amery Ice Shelf system. East Antarctica: a comparison of computed balance fluxes and measured fluxes

A Hubbard, I Willis, M Sharp, D Mair, P Nienow, B Hubbard and H Blatter
Glacier mass balance determination by remote sensing and high-resolution modelling

F Ng
Coupled ice–till deformation near subglacial channels and cavities

J F Nye
A flow model for the polar caps of Mars

J Oerlemans
Analysis of a three-year meteorological record from the ablation zone of the Morteratschgletscher, Switzerland: energy and mass balance

B R Rea, D J A Evans, T S Dixon and W B Whalley
Contemporaneous, localised, basal ice-flow variations: implications for bedrock erosion and the origin of p-forms

T A Scambos, C Hulbe, M Fahnestock and J Bohlander
The link between climate warming and breakup of ice shelves in the Antarctic Peninsula

B Stenni, F Serra, M Frezzotti, V Maggi, E Barbolani, S Becagli and R Udisti
Snow accumulation rates in northern Victoria Land, Antarctica, by firn-core analysis

C Vincent, M Vallon and L Reynaud
Dynamic behaviour analysis of glacier de Saint Sorlin (France) from 40 years of observations, 1957–1997

J E Weber
Non-temperate glacier flow over wavy sloping ground

FUTURE MEETINGS (of other organizations)

INTERNATIONAL ICE CHARTING WORKING GROUP (IICWG)

Grand Hotel Reykjavík, Iceland, 3–5 October 2000

The second meeting of the IICWG will provide a forum for focused discussion of all facets of sea-ice chart production and distribution, including system design and engineering, and scientific development. IICWG was formed in October 1999 to promote cooperation between the world's ice centers on all matters concerning sea ice and icebergs. For more information, see the IICWG web page (http://nsidc.org/PROJECTS/IICWG/index.html) or contact Dr. Thor Edward Jakobsson, Icelandic Meteorological Office (thor@vedur.is).

ICE-DRILLING TECHNOLOGY 2000

Nagaoka University of Technology, Japan, 30 October – 1 November 2000

An international workshop on ice-drilling technology will be held at the Nagaoka University of Technology, Nagaoka, Japan, with registration on October 29 and sessions from 30 October to 1 November 2000. (http://www.nagaokaut.ac.jp/english/index.html)

With the advance of ice-core research, ice-core drilling has been carried out widely at many sites in Antarctica, Greenland, the Arctic and on high-altitude mountains. In the last ten years, several deep ice core-drilling projects (e.g. GRIP, GISP2, Vostok, Law Dome, Dome F, Siple Dome etc.) have succeeded and new deep-coring projects (e.g. NGRIP, Dome C, DML, WAIS, Dome F etc.) are in progress. On the other hand, shallow-drilling techniques have been developed for various purposes such as high-speed coring, high-altitude drilling, crack-free coring and contamination-free drilling etc. In addition to these, deep-ice drillings with hot-water drills are being carried out (AMANDA, AMISOR etc.).

To promote the exchange of knowledge, ideas and experience among many countries and individuals who were/are involved in drilling projects, recent progress, interest and problems in the ice-drilling technology will be highlighted and discussed at the workshop. Abstracts and proceedings volumes will be published.

The suggested topics include:
- Electromechanical ice-core drilling
- Access-hole drilling
- Hot-water drilling
- Thermal ice-core drilling
- Borehole liquids
- Stuck problems
- Borehole logging/measurement
- Extraterrestrial ice-core drilling
- Drill-camp operations and logistics
- Ice-core processing
- Ice-core quality
- Physical properties of ice
- New national/international programs

Further information:

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GLACIOLOGICAL DIARY

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11–13 September 2000
International Symposium on Ground Freezing and Frost Action in Soils, Université Catholique de Louvain, Louvain-la-Neuve, Belgium
J.-F. Thimus, Unité de Génie Civil, Université Catholique de Louvain, Louvain-la-Neuve, Belgium (Tel [32](10)472-122; Fax [32](10)472-179; isgf2000@gc.ucl.ac.be)

13–15 September 2000
International Workshop on Debris-Covered Glaciers, University of Washington, Seattle, Washington, U.S.A.
M. Nakawo, Institute for Hydrospheric-Atmospheric Sciences, Nagoya University, Furo-cho Chikusa-ku, Nagoya 464-8601, Japan (Tel [81](52)789-3477; Fax [81](52)789-3436; nakawo@ihas.nagoya-u.ac.jp; http://snowman.ihas.nagoya-u.ac.jp/Research/DebrisWS/1stcclr.html)

21–23 September 2000
H.U. Sverdrup Symposium: the Role of Ocean/Sea Ice/Atmosphere Interaction in Polar and Sub-polar Climate, Tromsø, Norway
Anne Kibsgaard, Norwegian Polar Institute, Polar Environmental Centre, N-9296 Tromsø, Norway (Tel [47]77-75-06-16; Fax [47]77-75-05-01; kibsgaard@npolarno)

28–30 September 2000
WAIS-2000 Workshop, Algonkian Regional Park in Sterling, Virginia, U.S.A.
R.A. Bindschadler, NASA/Goddard Space Flight Center, Code 971, Greenbelt, MD 20771, U.S.A. (Tel [1](301)614-5707; Fax [1](301)614-5644; bob@igloo.gsfc.nasa.gov)

1–6 October 2000
ISSW 2000, International Snow Science Workshop, Big Sky, Montana, U.S.A.
ISSW 2000, The Travel Station, 1822 W. Lincoln, Bozeman, MT 59715, USA (nancy@thetravelstation.com; http://www.coe.montana.edu/ce/issw; www.thetravelstation.com)

3–5 October 2000
2nd International Ice Charting Working Group (IICWG), Grand Hotel Reykjavík, Iceland
Thor Edward Jakobsson, Icelandic Meteorological Office (http://nsidc.org/PROJECTS/IICWG/index.html; thor@vedur.is)

20–21 October 2000
Northwest Glaciologist's meeting, Smith Center, Portland State University, Portland, Oregon, U.S.A.
Andrew G. Fountain, Departments of Geology and Geography, Portland State University, Portland State University, Portland, OR 97207-0751, U.S.A. (Tel [1](503)725-3386; Fax [1](503)725-3025; andrew@pdx.edu)

30 October–1 November 2000
Ice-drilling Technology 2000 International Workshop, Nagaoka University of Technology, Japan
Nobuhiko Azuma, Department of Mechanical Engineering, Nagaoka University of Technology, Nagaoka, Niigata 940-2188, Japan (Tel [81](258)47-9716; Fax [81](258)47-9770; azuma@mech.nagaokaut.ac.jp)

15–19 December 2000
AGU Fall Meeting, San Francisco, California, USA
http://www.agu.org/meetings/fm00top.html
Glaciers and Ice Sheets
D.R. MacAyeal, Department of Geophysical Sciences, University of Chicago, Chicago, IL 60637, U.S.A. (Tel [1](773)702-8027; Fax [1](773)702-8198; drm7@midway.uchicago.edu) C.L. Hulbe, NASA Goddard Space Flight Center, Code 971, Greenbelt, MD 20771, U.S.A. (Tel [1](301)614-5911; Fax [1](301)614-5644; chulbe@ice.gsfc.nasa.gov)

2001

7–9 March 2001
Second Wadati Conference on Global Change and Polar Climate, Tsukuba Science City, Japan
Hiroshi L. Tanaka, University of Tsukuba, Tsukuba, Ibaraki 305, Japan (tanaka@atm.geo.tsukuba.ac.jp)

26–30 March 2001
1st European Permafrost Conference, Rome, Italy
C. Harris, Department of Earth Sciences, University of Wales, P.O. Box 914, Cardiff CF1 3YE, Wales, U.K. (Tel [44](1222)874-336; Fax [44](1222)874-326; harrisc@cardiff.ac.uk)

29–30 March 2001
Glacier-Influenced Sedimentation on High-Latitude Continental Margins: Modern and Ancient, Bristol Glaciology Centre, University of Bristol, Bristol, England, U.K.
C.Ó Cofaigh, Bristol Glaciology Centre, School of Geographical Science, University of Bristol, University Road, Bristol BS8 1SS, England, U.K. (Tel [44](117)928-9830; Fax [44](117)928-7878; colm.ocofaigh@bristol.ac.uk)

14–17 May 2001
* Snow and Ice: Principles, Processes, Management and Use, 58th Annual Eastern Snow Conference with Hydrology Section of the Canadian Geophysical Union and Committee on River Ice Processes and the Environment, Ottawa, Ontario, Canada.
S. Pagiatakis. Geomatics Canada, 615 Booth Street, Ottawa, Ontario K1A 0E0, Canada [Tel [1](613)-995-8720; Fax [1](613)992-6628; sppagiat@NRCan.gc.ca; http://ww.cgu-ugc.ca). J Pomeroy, Centre for Glaciology, Institute of Geography and Earth Sciences, University of Wales, Aberystwyth, Ceredigion SY23 3DB, Wales, U.K. (Tel [44](1970) 622781; Fax [44](1970)622659; john.pomeroy@aber.ac.uk; http://www1.tor.ec.gc.ca/crysys/esc/) T.D. Prowse, National Water Research Inst. at NHRC, Environment Canada, 11 Innovation Boulevard, Saskatoon, Saskatchewan S7N 3H5, Canada (Tel [1](306)975-5737; Fax [1](306)975-5143; terry.prowse@ec.gc.ca)

4–8 June 2001
** Fourth International Symposium on Remote Sensing in Glaciology, College Park, Maryland, USA
Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, UK (www.spri.cam.ac.uk/igs/home.htm)

13–18 June 2001
* Millennial-scale Events in the North Atlantic Region during Termination I, International Conference and Associated Field Meeting University of Ulster, Northern Ireland, UK
J. Knight, School of Environmental Studies, University of Ulster, Coleraine, Co Londonderry BT52 1SA, Northern Ireland, UK (Tel [44](28)7032-3179; Fax [44](28)7032-4911; j.knight@ulst.ac.uk)

17–22 June 2001
ISOPE-2001, 11th Annual International Offshore and Polar Engineering Conference, Stavanger, Norway
ISOPE-2001, P.O. Box 189, Cupertino, CA 95015-0189, USA (Tel [1](408)980-1784; Fax: [1](408)980-1787; meetings@isope.org; http://ww.isope.org)

18–27 July 2001
A New Hydrology for a Thirsty Planet, 6th Scientific Assembly of the IAHS, Maastricht, The Netherlands
IAHS Maastricht 2001, c/o Conference Agency Limburg, P.O. Box 1402, NL-6201 BK Maastricht, The Netherlands (Tel [31](43)36-19-192; Fax [31](43)36-19-090; cal.conferenceagency@wxs.nl; http://www.wlu.ca/~wwwiahs/index.html)
Note: Symposium S5.4. Snow-Vegetation Interactions; Workshop W4. High-Mountain Regions

12–17 August 2001
16th International Conference on Port and Ocean Engineering under Arctic Conditions (POAC'01), Ottawa, Ontario, Canada
poac@nrc.ca or G.W. Timco, Canadian Hydraulics Centre, National Research Council of Canada, Ottawa, Ont., K1A 0R6, Canada (Tel [1](613)993-6673; Fax [1](613)952-7679; garry.timco@nrc.ca)

19–23 August 2001
** International Symposium on Ice Cores and Climate, Kangerlussuag, Greenland
Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, UK (www.spri.cam.ac.uk/igs/home.htm)

20–24 August 2001
3rd International Conference on Cryogenic Soils, Copenhagen, Denmark
B.H. Jakobsen, Institute of Geography, University of Copenhagen, Øster Voldgade 10, DK-1350 Copenhagen K, Denmark (Tel [45]35-32-25-00; Fax [45]35-32-25-01; bhj@geogr.ku.dk; http://www.geogr.ku.dk/cryosols)

20–24 August 2001
Climate Conference 2001, Utrecht, The Netherlands
M. van Haersma Buma, Utrecht University, P.O. Box 80125, NL-3508 TC Utrecht, The Netherlands (Tel [31]30-25-33-154; Fax [31]30-25-35-851; m.buma@fbu.uu.nl; http://www.phys.uu.nl/~wwwimau/cc2001.html)
Note: sessions on land ice and climate; katabatic flows over glaciers and ice sheets

23–28 August 2001
5th International Conference on Geomorphology, Chuo University, Tokyo, Japan
K. Kashiwaya, Department of Earth Sciences, Kanazawa University, Kakuma, Kanazawa 920-1192, Japan (kashi@kenroku.kanazawa-u.ac.jp; http://wwwsoc.nacsis.ac.jp/jgu/)

8–13 October 2001
2nd International Conference on the Oceanography of the Ross Sea, Ischia, Naples, Italy
Ross Sea 2001, Istituto di Meteorologia e Oceanografia, via De Gasperi 5, I-80133 Naples, Italy (Tel [39](081)-547-5586; Fax [39](081)551-3157; RossSea@nava3.uninav.it; http://antartide.uninav.it

2002

August/September 2002
** International Symposium on Modelling Physical and Mechanical Processes in Ice, France
Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, UK (www.spri.cam.ac.uk/igs/home.htm)

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1998 G.K.C. Clarke
2000 J.A. Heap

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Lensfield Road, Cambridge CB2 1ER, England

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ICE

Editor: C.S.L. Ommanney (Secretary General)
Assisted by D.J. Garbett

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