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ICE

NEWS BULLETIN OF THE INTERNATIONAL GLACIOLOGICAL SOCIETY

NUMBER 80 1st ISSUE 1986

INTERNATIONAL GLACIOLOGICAL SOCIETY

FIFTIETH ANNIVERSARY CELEBRATIONS

10 September 1986
(during the week of the Symposium on Remote Sensing in Glaciology)

LECTURES ON THE DEVELOPMENT OF GLACIOLOGICAL STUDIES IN THE PAST 50 YEARS

in Lecture Theatre No. 1, University Chemical Laboratory (east entrance)
Lensfield Road, Cambridge, England

0900 – 1230 *and* 1400 – 1800

Introduction	The President (Hans Röthlisberger)
Glacial geology	G.S. Boulton
Valley glaciers	G.K.C. Clarke
Ice sheets and ice shelves	C.W.M. Swithinbank & G. de Q. Robin
Sea ice	N. Untersteiner
Ice physics	J.W. Glen
Snow	S.C. Colbeck
Engineering	L.W. Gold
Technology in the advancement of glaciology	H.J. Zwally
Impact of the Society on the development of glaciology and its future role	J. Weertman

GOLDEN JUBILEE BANQUET
in King's College

1930 *for* 2000

Tickets for the Banquet may be obtained from the IGS office, price £25; this includes all wines. (Participants in the Remote Sensing Symposium have the cost of this included in their registration fee and therefore need not apply for a ticket.) Last date for booking tickets – 1 August 1986

13 – 20 September 1986
GOLDEN JUBILEE TOUR
SWITZERLAND

JUNGFRAUJOCH AND THE WESTERN PART OF THE SWISS ALPS
ORGANIZED BY THE LABORATORY OF HYDRAULICS, HYDROLOGY AND GLACIOLOGY OF THE FEDERAL INSTITUTE OF TECHNOLOGY (ETH), ZÜRICH, SWITZERLAND

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CONTENTS

COVER PICTURE: An automatic weather station on the summit of Cairngorm, 1245 m, in the Scottish Highlands. Installed by the Heriot-Watt University, Edinburgh, the station telemeters data to the settlement at Glenmore Lodge below the mountain. The station experiences conditions of rime, ice and high winds in the winter, and is now sharing the summit with a new station designed by the Institute of Hydrology for use in such hostile environments.
Photograph by I.C. Strangeways, Institute of Hydrology

CANADA

General Glaciology

IMD, ICE TANK - ST. JOHN'S, NFLD
(S.J. Jones, IMD/NRC*/St John's, Newfoundland)
The Institute for Marine Dynamics (IMD) of the National Research Council of Canada was officially opened on 5 November 1985 by the Hon. John Crosbie, Minister of Justice and Attorney General for Canada. The ice tank, one of the three tanks in the Institute, is the largest in the world, 90 m long x 12 m wide x 3 m deep. A 1:20 scale model of the Canadian "R-class" icebreaker was towed through a 5 cm thick ice sheet for opening day and a cylindrical structure, 0.5 m diameter, is currently being used to generate high loads for acceptance tests on the carriage. The model ice being used was developed at NRC by G. Timco; it is grown from an aqueous solution containing ethylene glycol, aliphatic detergent and sugar. A two-day Symposium on Arctic Vessel Research was held on 5/6 November to celebrate the opening.

* (For abbreviations used see ICE, No. 59, 1979, p.15)

Glacier Studies - General

GLACIER INVENTORY OF CANADA
(A. Champoux, J.W. Clarkson and C.S.L. Ommanney, SWD/NHRI/EC)
A total of 513 glaciers were inventoried in the McGregor River basin (4*8KB), in the headwaters of the Columbia River. Work on the neighbouring Fraser River headwaters is in progress. Results of the analysis of data from the tripartite inventory of Glacier National Park were presented in Iceland. Two theses have also been accepted at Université de Sherbrooke. Landsat 5 TM imagery is being evaluated for future inventory use.

ISOTOPE GLACIOLOGY
(M.G. Maxwell, R.D. Russell and G.K.C. Clarke, GPHYS/UBC)
Maxwell is studying the processes of ice accretion and debris entrainment at the base of glaciers. The work involves analyses of water quality, crystal fabric, debris properties and isotopic fractionation of D/H and $^{18}O/^{16}O$ for 600 ice samples taken from the Backe and Trapridge glaciers, Y.T. Maxwell's measurements enable various ice types to be distinguished and suggest that water flux through permeable substrate leads to ice and debris accretion at the bed.

ICE DEFORMATION
(M.N. Demuth, SWD/NHRI/EC)
A study has been initiated to investigate borehole deformation in firn and glacial ice for the study and modelling of ice deformation in the vicinity of ice divides and to provide additional field data on the flow law of ice. A new borehole logging tool is being developed to assist in this study and a theoretical analysis of closure at the Mount Logan site has been undertaken to determine the feasibility of a resurvey.

Glacier Studies - Arctic

POLAR CONTINENTAL SHELF PROJECT
(R.M. Koerner, D.A. Fisher, B.T. Alt, M. Parnandi and J.C. Bourgeois, PCSP/EMR)
Laboratory Investigations - Further work was done using the Reeh ice sheet model to compute a 3-dimensional Laurentide Ice Sheet using known marginal positions. Analysis of all data on the unique properties of Pleistocene ice and its rheological implications was completed. In cooperation with AES (L. Barrie), variations of acid levels in High Arctic snows were analysed. Pollen analysis of one of the Agassiz Ice Cap cores has been completed. Mass balance results from four ice caps were studied. A new method for obtaining and using such measurements for climatic monitoring purposes was developed. In cooperation with S. Edlund (GSC), the relationship between summer climate and vegetation patterns in the High Arctic was studied. Work on the summer climate in the Queen Elizabeth Islands during the Franklin Period (as deduced from ice cores), and the part it played in the demise of the Franklin Expedition, was submitted for publication.

Field investigations - The mass balances of Meighen, Melville, Devon (northwest side) and Agassiz (northern side) ice caps were measured. Boreholes drilled on Agassiz Ice Cap were monitored for closure rates and bulk samples from one hole were melted from seven separate depths of over 100 m. A suite of snow/firn samples was collected for chemistry studies from the same site. Levelling traverses were made over Meighen Ice Cap and across Sverdrup Glacier (Devon Island) to check for advance or retreat of these glaciers.

WARD HUNT ICE SHELF
(G. Holdsworth, SWD/NHRI/EC)
A study of the dynamics of the Ward Hunt Ice Shelf, Ellesmere Island, is in progress to determine the factors which are associated with or lead to calving of ice islands. This includes creep simulation, interaction with pack ice forces and vibration modelling. A

paper has been prepared on the preliminary creep simulation studies.

WHITE GLACIER, AXEL HEIBERG ISLAND
(W.P. Adams, GEOG/TRENT)
Mass balance measurements were made on White Glacier, Axel Heiberg Island, N.W.T.

Glacier Studies - Yukon Territory

TRAPRIDGE GLACIER
(G.K.C. Clarke, F.H.M. Jones, J. Schmok and M.G. Maxwell, GPHYS/UBC)
Trapridge Glacier last surged around 1945 and its next surge is expected to occur within several years. In 1985, we resurveyed the glacier, drilled four holes to the bed, installed a water pressure sensor in the one hole that connected to the subglacial drainage system, injected 25 kg Rhodamine WT into the connected hole, failed to detect any dye in Trapridge Creek, tested a new digitally-recording impulse radar, measured ice flow fluctuations using a computer-controlled laser ranger and analyzed the "slurry till" layer exposed in the lower part of Trapridge basin.

TRAPRIDGE GLACIER - RADIO ECHO SOUNDING
(F.H.M. Jones, B.B. Narod and G.K.C. Clarke, GPHYS/UBC)
Jones tested a prototype of a new impulse radar system on Trapridge Glacier in 1985. The system is fully back-portable and records sounding results on digital cassettes. A complete and reliable system will be ready for use in 1986.

ICE-DAMMED LAKES - RECENT LAKE ALSEK
(J. Schmok and G.K.C. Clarke, GPHYS/UBC)
In 1984 and 1985, J. Schmok visited 23 small lakes and ponds situated within the basin of former glacier-dammed Lake Alsek. Cores from these lakes contain a record of past fillings and outburst floods from Lake Alsek. From the sedimentology of these cores, three distinct environments can be recognized: (1) Lake Alsek phase (varved silts and clays); (2) Lake Alsek flood deposits (sands and gravels); (3) Normal (organic horizons). This sequence is repeated many times within a single core.

ICE CORE/CLIMATE CHANGE PROJECT - MT LOGAN
(G. Holdsworth and M.N. Demuth, SWD/NHRI/EC)
The 103-m ice core retrieved from Mount Logan in 1980 is still being analysed for $\delta^{18}O$, trace chemistry and structural characteristics. The carbon dioxide concentrations in the air bubbles have been measured and the results presented. The relationship between volcanic events recorded in the core and climate perturbations is being examined.

Work is continuing on the modification and redesign of the Canadian-Rufli-Rand ice-coring drill system. Improvements in core quality, operational ease and overall drilling efficiency in the retrieval of shallow cores is expected. The drill will continue to be used to study borehole deformation at sites currently being reconnoitered. Preparations are underway to return to the Mount Logan NW Col drilling site to recover previously collected ice cuttings for soot analysis and for short-term air sampling for ambient air/CO_2 analysis as part of an ongoing study of global atmospheric CO_2 variations (with D. Raynaud, CNRS).

Glacier Studies - Cordillera

ISKUT RIVER GLACIERS, N. COAST MTS
(O. Mokievsky-Zubok, SWD/NHRI/EC)
After seven years of study, the regular mass balance measurements and monitoring of the periodicity of sudden discharges of several ice-damned lakes in the Iskut/Stikine River basins were discontinued, in summer 1985.

Winter balance was measured on Andrei, Yuri and Alexander glaciers and found to be 2.17 m, 1.58 m and 2.07 m of H_2O, respectively.

TIEDEMANN AND BENCH GLACIERS, COAST MOUNTAINS
(O. Mokievsky-Zubok, SWD/NHRI/EC)
Mass balance on the above two glaciers was strongly negative. Tiedemann Glacier had exceptionally high losses at the snout with an estimated 10.9 m of vertical ice melt. Net mass balance was −1.37 m on Tiedemann and −0.88 m of H_2O on Bench Glacier. 1985 was the final year of measurement.

BRIDGE RIVER GLACIERS, COAST MTS.
(O. Mokievsky-Zubok, SWD/NHRI/EC)
The highest negative mass balance since studies began in 1976 occurred on all three glaciers. Net balances for Bridge, Sykora and Zavisha glaciers were −1.87 m, −1.37 m and −1.22 m of H_2O respectively.

Meteorological and river level data were obtained via satellite and will continue in the future. Mass balance measurements will be discontinued.

GLACIER MASS BALANCE, SW COAST MTS
(O. Mokievsky-Zubok, SWD/NHRI/EC)
Mass balance measurements continued on Sentinel, Helm and Place glaciers. All showed pronounced negative balances; even Sentinel Glacier which has only had 5 negative years during the 21 years studied. Net balances were −0.84 m, −1.73 m and −1.89 m of H_2O respectively.

As a result of heavy rain in early October 1984, the river-level gauging station below Sentinel Glacier was washed away and melt water flow records are not available.

WEDGEMOUNT LAKE AND GLACIER
(K.E. Ricker; W.A. Tupper, BCIT)
The lower glacier was rephotographed (photo-theodolite) at the end of the 1985 melt season. This provided data on: surface velocities across two lines of monuments, the position and the height of the terminus and

the amount of net ablation on the glacier. Lichenometric data on the moraines about the lake were compared to growth curves of a nearby Northern Cascades site (Mt Shuksan). The dates for the climax and inset subclimax moraines of Wedgemount Glacier compare quite favourably to dendrochronologic data reported previously.

FYLES GLACIER & APE LAKE JÖKULHLAUP
(K.E. Ricker; J. Desloges, GEOG/UBC; R. Gilbert, GEOG/Queen's; BC Forest Service and Geological Survey of Canada)
The first technical report on this damaging jökulhlaup was released (GSC Open File 1139). Since then the following studies have been undertaken: historic glacier fluctuations in the area, radiocarbon dating of Neoglacial glacier advances, lake bottom seismic profiling and varve studies, lichenometry of annual (?) moraines located between the Fyles Glacier margin and its climax position, and monitoring the rate of refill of the lake after the Oct. 20/84 drainage event. The lake was refilled, reaching full pool level on Aug. 2/85, and has not re-drained as of Dec. 10/85. However, it is expected to release a jökulhlaup under the thin lobate Fyles Glacier snout next autumn or at least before 1989. A pressure sensor has been deployed to monitor the rate of drainage. Engineering studies are underway to find a method of ameliorating the damaging consequences of future floods.

Glacier Studies - Rocky Mts

PEYTO GLACIER, ROCKY MOUNTAINS
(J.M.Power & M.N.Demuth, SWD/NGRI/EC)
Collection of mass balance data at Peyto Glacier continued on a limited basis with spring and fall surveys. A drastic summer melt threatened the continuity of the record due to the loss of many stakes; an early winter upper basin profile showed that all the 1984-85 accumulation had melted. Work continued on incorporating glacier-melt runoff into conceptual hydrologic forecasting models such as the UBC model.

BOUNDARY GLACIER
(J. Gardner, GEOG/Waterloo)
Continuing ice surface velocity, meltwater discharge, glacial meteorological and bergschrund temperature measurements were made in June, July and August 1985. Studies of eolian deposits on snow and ice surfaces of the glacier and surroundings are being completed. Measurements of mass wasting and degradation of adjacent ice-cored lateral moraines were made. Glacier terminus debris deposition processes and rates were monitored. A sediment budget for Boundary Glacier will be produced.

ROCK GLACIER ON HILDA PEAK
(J. Gardner and I. Bajewsky, GEOG/Waterloo)
Meltwater discharge observations were initiated during July 1985 to describe the rates and temporal variations of meltwater discharge from a rock glacier. This is done in the context of the relatively well-known hydrology of glacier meltwater streams and the little known hydrology of rock glacier streams. Suspended sediment load and dissolved load are also being monitored.

Glacier Studies - Worldwide

RAKHIOT GLACIER, PAKISTAN, WESTERN HIMALAYA
(J. Gardner, GEOG/Waterloo)
Resurveys of the terminus position and ablation zone surface velocities were made on the Rakhiot Glacier (Mt Nanga Parbat, upper Indus Basin) in July 1985. This glacier has been subject to repeated surveys since 1934. The 1985 data indicate retreat of about 125 m since 1934, compared to the 175-m recession measured in 1954 by Pillewizer. Although data analysis is not complete, field observations indicate that the Rakhiot still demonstrates the high velocity, blockschollen flow first described by Finsterwalder. This research is a collaborative project between IDRC (Canada), Wilfrid Laurier University and the Water and Power Development Authority (Pakistan).

Glacial Geology

A number of reports on glacial geology covering the areas listed below were received. Further information is available from the National Correspondent. Continuing studies are those on glacial Lake Agassiz (J.T. Teller, ES/Manitoba), Quaternary mapping of Canada (J.A. Heginbottom, GSC), in Quebec (J.-M.M. Dubois, Q.H.J. Gwyn, M. Parent, P. Bail, A. Larocque, G. Larocque, A. Morrissette, J.-C. Dionne, D. Gratton, L. St-Pierre, P. Bigras, D. Côté, GEOG/Sherbrooke; S. Occhietti, GEOG/UQUAM), in the area offshore of the Atlantic Provinces (G.B.J. Fader, L.H. King, GSC/BIO, by the Department of Energy and Mines, Government of Newfoundland and Labrador in Labrador (D. Vanderveer, M. Batterson), in Newfoundland (B.G. Sparkes, M. Ricketts, M. Mihychuk, F. Kirkby, D. Bragg) and radiocarbon dating for the whole Province (B. Downton), and ice histories in northern Alberta and the District of Mackenzie (G. MacDonald, GEOG/McM) and Yukon Territory (A. Duk-Rodkin, L.E. Jackson, Jr, GSC; O. Rodkin, GEOL/UofA).

Atmospheric Ice/Climate/Meteorology

ENVIRONMENTAL STUDIES SCHEFFERVILLE
(H.B. Granberg, GEOG/McG)
A program to digitally model permafrost - microclimate - snow - terrain relationships is underway at Schefferville. It includes the development of microclimate extrapolation routines, snowcover simulation routines and routines for relating observed ground

temperatures to predicted spatial variations in surface equilibrium temperatures. The routines form part of a digital geographic information system which employs digital terrain models and weather information as part of its database.

BOUNDARY LAYER PROCESSES - HUDSON BAY COAST
(A. Silis, GEOG/McM)
Complete and continuous energy balance measurements were made over fast ice and from an ocean tower after ice melt in the intertidal zone between late April and late September, 1985 at Churchill. Boundary layer processes will be studied in terms of wind field characteristics and the ground and atmospheric fluxes under varying seasonal and tidal conditions.

AIR FLOW MODIFICATION ACROSS HUDSON BAY COAST
(V. Bingham, GEOG/McM)
Boundary layer development and vertical temperature and humidity profiles were studied for offshore and onshore wind flows between a Sea Site, a Coastal Site and an Inland Site and for conditions of high and low tide at Churchill.

ICING ON ELECTRICAL CABLES
(B. Félin, Hydro Québec)
A program, in existence since 1974, measures the amount of ice on transmission cables at 150 stations throughout Quebec. An experimental station has been set up at Mont-Valin, in which the amount of icing is measured on a 100-m long conductor cable in an area which is fully instrumented with respect to temperature, wind speed, etc. A patent for a micro-processor based system, which can be used in remote areas for the detection and measurement of icing, has been applied for.

Floating Ice - Sea Ice

INFLUENCE OF TRANSVERSE ANISOTROPY
(J.R. Murat and G. Degrange, CINEP)
The importance of shear deformations, caused by the transverse anisotropy of sea ice, is being investigated. Short- and long-term tests have been performed on sea ice beams subjected to two-point loadings. Direct shear tests under controlled strain rates will be carried out on sea ice samples of various crystallographic orientations.

FLEXURE OF SEA ICE PLATES
(R. Tinawi and L. Gagnon, CINEP)
A number of short- and long-term tests have been performed on circular plates under various load levels and temperatures. They have confirmed the importance of anisotropy, where the transverse shear modulus has been identified as an important parameter to evaluate, as it affects the deflection prediction. A finite-element program has been used to evaluate the shear modulus.

CHUKCHI SEA SHIPPING ROUTES
(D.F. Dickins Assoc. Ltd., Vancouver)
Data, describing ice conditions affecting shipping in the Chukchi Sea, were presented on maps, graphs and computer tape. Eleven years of weekly ice chart data were stored on computer tape for each of 134 grid points.

BEHAVIOUR OF OIL IN ICE
(D.F. Dickins Assoc. Ltd., Vancouver)
The 1984/85 study was expanded to more than double the Beaufort Sea data base. Short-term ice motions (measured in minutes or hours) were included for the Beaufort and Labrador Seas. The additional data allowed comparisons between ice speed, floe size, ice concentration and geographic location.

ICE PACK DYNAMICS
(R.J. Robbins, PetroCan/Calgary)
Various aspects of ice pack motion were investigated off the east coast of Newfoundland. During February and March 1985, five satellite tracking beacons were deployed on ice floes within the pack 150 to 250 km offshore, marking the first time such a procedure has been used to monitor ice motion in southern Canadian waters. The study provides valuable insight into pack ice behaviour as it relates to meteorological and oceanographic conditions near the Terra Nova field.

OCEANOGRAPHIC FIELD PROGRAM
(R.G. Ingram, Inst. of Oceanography/McG)
Large-scale oceanographic field programs were undertaken in the late winter - early spring of 1984 and 1985. Primary goals were to: understand the under-ice mixing of fresh water plumes with underlying marine waters; describe the small scale dynamics at the ice-water interface and its importance on the growth of ice microalgae; and observe the changes in the surface water characteristics (vertical mixing, circulation, etc.) during the transition from ice-covered to open-water conditions. This work was done in conjunction with GIROQ and Fisheries and Oceans Canada, Québec.

BEAUFORT SEA BREAK-UP PATTERN
(W.D. Hume, AES/Edmonton)
The Scientific Services Division has updated (to 1983) information on break-up patterns of the southern Beaufort Sea landfast ice regime. The purpose is to determine if detectable changes in the break-up pattern are being produced by the construction of artificial islands. Satellite imagery was examined and a series of simple regression analyses were performed on selected parameters suspected of influencing the ice barrier across Kugmallit Bay. Although no conclusive statements are made, available data suggest that since 1974 the trend has been for an earlier break-up of this ice barrier.

PHYSICAL MODELLING AND FRACTURE TOUGHNESS
(B.L. Parson and D.B.Muggeridge, ENG/MUN)
A combined field, laboratory and theoretical program has been initiated to investigate the fracture toughness of saline ice and to reproduce appropriate values of K_{Ic} in model (doped) ice. This work fits into the general framework of treating a number of ice-structure interaction problems from a fracture mechanics point of view.

SEA ICE AND ICING
(R.J. Robbins, Petro-Can/Calgary)
Sea-ice incursion and the accumulation of atmospheric and sea spray icing have been studied. The distribution of sea ice by ice age/type/thickness at the Terra Nova field was examined using 23 years of sea ice records. Additional studies were undertaken to examine the relationship of sea-ice severity to meteorological conditions and iceberg flux. One sea spray and two atmospheric icing models were executed using local meteorological data. The study provides 25-year return periods for sea-ice incursion and ice accretion rates.

Floating Ice - River and Lake Ice

LAKE REGIMES, MACKENZIE DELTA, NWT
(S.C. Bigras, SWD/NHRI/EC)
The interaction between various lake types (unconnected, high-closure, low-closure and connected) and the Delta channel network is being assessed by monitoring water levels at nine sites along the eastern sector of the Delta from April to September. Field measurements of snowpack water equivalents, lake and channel ice thicknesses, and climatic conditions are being observed to establish the importance of break-up to the hydrological regime of the Delta lakes and channels.

HYDROLOGICAL STUDIES, MACKENZIE DELTA LAKES
(P. Marsh, SWD/NHRI/EC)
A lake hydrology study to determine the relative importance of the processes controlling lake level is continuing in the Mackenzie Delta, N.W.T. The lakes studied include both high- and low-connection lakes. They have a unique and sensitive hydrologic regime since they are underlain by taliks and receive a large input of floodwater during spring break-up when water levels in the Mackenzie River are controlled by ice jamming. Work is continuing on developing a model to predict changes in lake level.

CHEMISTRY OF LAKE ICE
(W.P. Adams, GEOG/TRENT)
Studies of the ice, including snow, cover of lakes in northern Quebec-Labrador and on Colour Lake, Axel Heiberg Island, N.W.T., continued. These focussed on aspects of the chemistry of the ice and the lakes.

FLOODING DUE TO ICE CONSTRICTION
(S.L. Fenety, EC/Dartmouth; Fenco Nfld. Ltd)
Flooding in the Badger and Rushy Pond areas is largely caused by a backup of water as a result of an ice constriction. Three approaches were examined for determining the 1:20, 1:100-year return period flood levels. These were:
(1) The perception stage approach, which makes maximum use of the historical data on ice levels to determine the frequency of occurrence of particular levels.
(2) The ice progression modelling approach, which identifies factors relating to ice conditions and uses the frequency of the occurrence of these factors in historical observations to determine the return period of a particular flood level.
(3) Backwater modelling with ice, which generates ice level based on flow and ice stability criteria, and determines the frequency of a particular level based on analysis of the full set of levels.

BREAK-UP OF SMALL STREAMS
(M.-K. Woo, GEOG/McM)
The effects of snow and ice upon spring floods in small subarctic streams have been studied. These processes typically involve the clearance of snow and ice in the channels and frequent exchanges of water flow between the streams and their adjacent wetlands during the break-up.

HEAT FLUX TO THE BASE OF RIVER ICE COVERS
(P. Marsh, SWD/NHRI/EC)
A study to determine the convective heat flux from the river to the overlying ice cover during the spring break-up period has been conducted near the confluence of the Liard and Mackenzie rivers. Field measurements have included water temperature beneath solid and fractured ice, water velocity, river discharge and ice roughness. Three techniques for calculating the heat flux have been compared and tested against field measurements.

WATER TEMPERATURE BENEATH RIVER ICE COVERS
(P. Marsh, SWD/NHRI/EC)
Detailed measurements of water temperature have been made in the ice-covered Liard River, N.W.T. The energy sources controlling water temperature, radiation penetration of the ice, internal friction heat, and bed heat flux have been measured or simulated. A model predicting water temperature, both across the channel and with time, has been developed.

RIVER ICE BREAK-UP AND ICE JAMMING, MACKENZIE BASIN, N.W.T.
(T.D. Prowse, SWD/NHRI/EC)
Intensive field studies of river ice jams near the confluence of the Liard and Mackenzie rivers were continued. During the spring of 1985, ice jams formed at the mouth of the Liard River and on the Mackenzie River just

downstream of the island of Fort Simpson. The latter jam caused some backwater flooding of the town of Fort Simpson. Detailed field measurements were made of: water and ice slopes through the jams, water velocities upstream of and within the jams, ice jam thickness, shear wall heights and hydrothermal heat flow. A report has been completed which details the Liard River break-up processes and the character of ice jam formation, growth and effect on water levels over the period 1978-1984. "Guidelines for River Ice Data Collection Programs" have been prepared for the NRC Working Group on River Ice Jams.

RIVER ICE STUDIES
(B. Michel, J.P. Nadreau, J. Lachance, J.M. Tanguy and F. Picard, CIVIL/LAVAL)
A computer model has been developed to compute backwater curves in rivers in winter. It includes the formation, growth and decay of river ice covers.

An aerial survey is being continued on the movement of river ice in the restricted converging-diverging section of the St. Lawrence river at the Québec bridge in order to study the dynamics of moving ice.

ICE JAMS ON BULKLEY RIVER AT QUICK, B.C.
(P.M. Brady, BC Ministry of Env./Victoria)
Antecedent conditions, including extremely cold temperatures, extensive anchor ice, the rapid production of frazil ice and 8 km of ice cover downstream, caused an increase of about 3 m in the height of the ice surface at Quick between December 22 and 25, 1984. Local residents had to be evacuated due to the resulting ice jam and flooding, with subsequent re-evacuation on December 27 after an intervening recession and increase of the ice surface. Surveys of river cross sections and ice scars on trees in the area, obtained in 1985, indicated that the ice has generally been contained by existing vegetation near the edge of the banks. However, near Quick the vegetation has been cleared and the top of the bank is locally depressed by approximately 1 m. The construction of an "ice anchor" in the vicinity is not feasible due to sensitive environmental constraints and therefore an ice deflection/flood protection berm is being investigated as a means of reducing the possibility of future damage.

TRANSPORT OVER FLOATING ICE SHEETS
(M.J. Hinchey, ENG/MUN)
When something is moving over an ice sheet, large amplitude fluxural gravity waves can be generated at a certain critical speed. An explanation for the phenomenon based on energy considerations was recently developed. With help from C-CORE an array of sensors capable of measuring the complex deflection patterns generated by transport over the ice sheet will be set up.

RIVER ICE JAM STUDIES
(S. Beltaos, NWRI/CCIW/EC)
Field documentation of the ice jams on the Thames and Grand rivers has continued. In the laboratory, studies have been carried out on the toe of ice jams and the surge effects of jam release. A non-dimensional stage-discharge relationship has been established for Canadian rivers.

FRAZIL AND ANCHOR ICE
(G. Tsang, NWRI/CCIW/EC)
An instrument has been developed for point measurement of frazil ice concentration. Work has continued on the formation, thermodynamics and crystallographic evolution of frazil formed in water of different salinities and at different supercoolings. The frazil and anchor ice and their hydraulic effects have been studied at the Lachine Rapids in the St. Lawrence River.

Floating Ice - Icebergs

DYNAMIC ANALYSIS OF CAPSIZING ICEBERGS
(D.W. Bass and G.R. Peters, ENG/MUN)
Icebergs can increase their draft on being perturbed from an orientation of near unstable equilibrium. In the present study, the authors consider the likely perturbations leading to capsize, and subsequently, by simulating the dynamics of capsize, calculate the maximum draft increase, the final draft increase at the new equilibrium orientation and the maximum roll velocity for a number of hypothetical iceberg models. The parameters are of some significance in assessing the likely damage to sea-bed structures caused by a capsizing iceberg.

CURRENT DYNAMICS OF HOPEDALE SADDLE, OFFSHORE LABRADOR
(J. Bobbitt and D.B. Muggeridge, ENG/MUN)
A theoretical study of extensive field data obtained from a number of current meter strings deployed for Petro Canada Exploration Ltd. has been initiated. Particular attention is being given to iceberg drift and the implications for design of offshore structures on the Labrador Shelf.

ICEBERG SCOURING OF SEAFLOOR
(T.R. Chari, ENG/MUN)
A mathematical model was developed to explain the phenomenon of pits on the seabed caused by icebergs. Further laboratory tests were done with model iceberg keels of different shapes.

The range of variation in the computed scour size due to different keel shapes was evaluated and normalized with respect to an idealized iceberg having a vertical keel.

ICEBERG DIMENSIONS AND SHAPE
(R.J. Robbins, Petro-Can/Calgary)
Data collected off the east coast of Newfoundland in the spring of 1985 were used to determine the above- and below-water characteristics of icebergs. The study used an underwater acoustic array in conjunction with a scanning sonar system so that all digitized profile data for a given iceberg were referenced to a coordinate system for that iceberg. It provides detailed analyses of both two- and three-dimensional iceberg underwater shape as well as corresponding above-water information.

Data collected through various programs were assembled to define dimensions typical of icebergs near the Terra Nova field on the northeastern Grand Banks. The study provides a statistical description of the iceberg dimensional and shape parameters according to method of data collection and water depth.

ICEBERG DETERIORATION STUDIES
(D. Diemand, C-CORE/MUN)
Several icebergs were observed over periods up to five days in order to determine the principal mechanisms of mass loss in large icebergs. Two examples of ram loss and iceberg splitting were documented. The implications of these poorly documented phenomena in iceberg drift and deterioration modelling are being considered.

ICEBERG STRESSES & FRAGMENTATION
(D. Diemand, C-CORE/MUN)
Work is continuing on developing practical methods of iceberg fragmentation. Starting with the premise that an efficient means of subdividing an iceberg must take advantage of existing weaknesses in the ice mass, a theoretical study on iceberg stress state has been undertaken. It is hoped that further work will include field measurement of *in situ* stresses in icebergs in cooperation with other research groups.

MEASUREMENT OF ICEBERG MOTIONS
(J. Lever, C-CORE/MUN)
The motions of several grounded icebergs in Northern Labrador were monitored during the Dynamics of Iceberg Grounding and Scouring (DIGS '85) project. Motions of a number of bergy bits and growlers in various sea states were also measured. The basic design for the six degrees-of-freedom accelerometer package was developed in 1984, and improvements incorporated for the 1985 program. This work is expected to continue on the Grand Banks in the spring of 1986.

ICEBERG SPEED EVALUATION
(R.J. Robbins, Petro-Can/Calgary)
Iceberg trajectory information, collected as part of offshore drilling operations, was analysed to assess iceberg speed on the northeastern Grand Banks. The study provides a comprehensive data bank of iceberg speed characteristics near the Terra Nova field.

Remote Sensing

AIRBORNE MICROWAVE REMOTE SENSING TECHNIQUES
(C.E. Livingstone, A.L. Gray and R.K. Hawkins, CCRS/EMR)
The Data Acquisition Division of CCRS used airborne microwave remote sensing techniques for sea-ice mapping and reconnaissance in various Arctic and East Coast regions and in various seasons. Ice imagery, radar backscatter and emissivity data have been collected and studied using synthetic aperture radars at X-, C- and L- band, a Ku-band scatterometer and a K-band radiometer. Some seasonal dependence of sea-ice signatures have been investigated. CCRS has also participated in experiments on the detection of icebergs, bergy bits and other floating ice hazards, using synthetic aperture radars. C-band SAR imagery of sea ice and icebergs may be acquired during 1986 using IRIS, the new airborne SAR system, developed in conjunction with the RADARSAT programme.

SPECTRAL REFLECTANCE AND ATTENUATION OF SOLAR RADIATION BY THE SNOW COVER
(H.B. Granberg & A.Kulkarni, GEOG/ McG)
A probe has been developed for use with a Li-Cor 1800 spectro-radiometer to measure the penetration of solar radiation into the snow cover. A measurement program is underway to determine spatial and temporal variations in the spectral reflectance and attenuation of solar radiation by snow in the Schefferville area.

PHOTOGRAMMETRY OF RIVER ICE JAMS
(T.D. Prowse, SWD/NHRI/EC and S. Watson, GEOG/TRENT)
A stereo-photogrammetric study of river ice jams continues. The data base includes six years of large format photography of ice jams at the confluence of the Liard and Mackenzie rivers. Field surveys were completed of surrounding topography to allow for rectification of the images. In addition to obtaining information about surface characteristics, it is hoped that some measurements of accumulation thickness and water/ice slopes through the jams can also be made.

Snow and Avalanches

SNOWMELT ANALYSIS
(A.M. Melone and M.C. Quick, CIVIL/UBC)
Data have been assembled for various mountainous coastal watersheds and are being compared with watershed model predictions in an analysis of snow-melt floods with special emphasis on rain-on-snow events.

NET RADIATION OVER SNOW
(H.B. Granberg & A. Nadeau, GEOG/McG)
A net radiometer has been developed for detailed study of radiation over snow. A set of 44 such radiometers, connected to a

CSI/CR7 datalogger, is used intermittently to monitor spatial and temporal variations in net radiation at a forest edge near Schefferville throughout the 1985-86 winter.

SNOWPACK GRAINSIZE DISTRIBUTION PROFILES
(H.B. Granberg and R. Wener, GEOG/McG)
An investigation of temporal variations in snowpack grainsize distribution profiles is being undertaken during the 1985-86 winter. Sieve analyses with micro-photographs of sieve contents are made of snow from sites in different environments near Schefferville during the winter.

SNOW MANAGEMENT STUDY
(W. Nicholaichuk, Agriculture Canada/Swift Current)
Based on snow management studies conducted since 1973 at Swift Current, Saskatchewan, approximately half of the snowfall received can be trapped by agronomic practices such as the use of grass barriers, strips of tall standing stubble and by swathing at alternate heights. On the average, half of the water from the trapped snow is stored in the soil and is available for crop use. The amount of water that infiltrates is highly variable, depending on climatic conditions. The spring runoff was inversely proportional to infiltration. As more snow was trapped, the potential for runoff increased. Hence the impact of agronomic snow management practices would not adversely affect surface runoff and subsequent surface water supplies.

NUMERICAL SIMULATION OF SNOW DEPTH
(M.-K. Woo, GEOG/McM)
The numerical simulation of snow depth has been undertaken for subarctic spruce forests, to derive probablility distributions of depths given different densities and sizes of trees. The results will yield a better estimate of snow storage in northern forests than is available using conventional snow survey methods.

SNOW PROPERTIES
(R. Perla, SWD/NHRI/EC)
A cold lab technique for rapid microtoming, etching, polishing, and photomicrography of serial sections through snow specimens produced micrographs at the rate of about 10/hour. The micrographs were converted to video images and digitized automatically. Contrast was high enough to permit reliable discrimination of ice and pore phases. Algorithms are being developed to find those stereological and topological measures of the interconnected ice network that best model the electromagnetic, mechanical and thermodynamic properties of snow.

CHANGES IN CHEMICAL COMPOSITION OF SEASONAL SNOW COVERS
(H.G. Jones, INRS/Québec/Ste-Foy)
Studies to develop models of the physical, chemical and microbiological processes within snowpacks during pre-melt and melt periods are being made at boreal forest sites in the Laurentian Park, Québec. One, for the leaching of atmospheric pollutants from the snowcovers, has been validated and subsequently integrated into a physical model for meltwater discharge. Work is presently being carried out on interactions of organic matter with snow and snow-melt discharges from the pack.

SNOW AND AVALANCHES
(D.M. McClung & P.A. Schaerer, DBR/NRC)
In spite of a winter with lower than average snow and relatively few avalanches, impact and speed information were obtained for a good number of avalanches. In collaboration with the Norwegian Geotechnical Institute, theoretical work and data analysis were completed for specification of runout distances for avalanche paths in a maritime climate regime and a geometrical model of avalanche terrain was developed. The factors that determine the total mass of avalanche snow at a given site were analysed and a predictive equation was developed. Supplementary observations of avalanche mass were carried out at Rogers Pass. Small-scale tests are underway to determine avalanche flow heights, speeds and runout characteristics under controlled conditions. Experiments were carried out at Rogers Pass, Banff, and with helicopter ski operations to evaluate the techniques of the shovel shear test and to develop guidelines for applications. Temporal and spatial distribution of pressures on an avalanche defence structure were modelled. A pilot study was started to determine the acoustic emissions in alpine snow shear failure.

KAGHAN VALLEY, PAKISTAN, WESTERN HIMALAYA
(F. de Scalley and J. Gardner, GEOG/Waterloo)
Preliminary surveys were made of avalanche paths in the vicinity of Naran, Kaghan Valley, to estimate the hydrological role of snow avalanches in this rugged Himalayan front range area. This research will continue in 1986 and is a collaborative project between IDRC (Canada), Wilfrid Laurier University and the Water and Power Development Authority (Pakistan).

Ice Physics/Engineering

CONSTITUTIVE MODELLING OF ICE
(I. Jordaan and M. Maes, DnV/Calgary)
The Cold Climate Technology group of Det norske Veritas (Canada) Ltd. (DnV) has been active in the constitutive modelling of freshwater and sea ice. The need for new theories results from an in-depth analysis of different ice-structure interaction laboratory tests. Damage theories and extensions thereof are found to effectively model the degradation of ice under various loading conditions.

Continuing damage results in powdery, pulverized material, the confined state of which can be adequately described by the constitutive equations of frictional, non-inertial flow. Considerable attention has also been focussed on the use of fracture mechanics and on the use of finite-element modelling.

ICE-STRUCTURE INTERACTIONS
(I. Jordaan and M. Maes, DnV/Calgary)
Comprehensive modelling of Arctic ice conditions and the development of a probabilistic model to describe global ice loads on a fixed offshore structure are the objectives of a Joint Industry Project managed by DnV. The model combines ice parameter distributions with ice-structure interaction systems in a statistical extreme value analysis to produce maximum loads and their likelihoods.

THE BROKEN ICE/STRUCTURE INTERACTION PROBLEM
(O.G. Vinogradov, CALG)
A simulation methodology and mathematical model of the broken ice-structure interaction problem have been completed. Graph theory was used to derive differential equations governing the behaviour of a cluster of floes with a variable number of floes having variable geometrical arrangements.

SPRAY ICE ISLAND
(D.M. Masterson, Geotech Ltd./Calgary)
In the winter 1984/85, GEOTECH constructed a 100-m diameter spray ice island near Prudhoe Bay, Alaska, in 10 m of water. Invaluable information was gathered for the design of future spray ice islands to support Arctic offshore petroleum drilling operations. Two mobile skid-mounted high-pressure pumps were used. The island was completed in 28 days, at an average build up of 0.5 m/d. An exensive testing program was carried out during and after construction.

JOINT INDUSTRY MULTI-YEAR ICE IMPACT TESTING PROGRAM
(D.M. Masterson, Geotech Ltd./Calgary)
Valuable information on ice impact mechanics, including the ice forces and pressures developed on impact, was obtained from a multi-year ice floe in the Arctic Islands region of Canada. An impact machine, designed and built by GEOTECH and capable of exerting a maximum force of 13.5 MN (3 million pounds), was used with three different indentors to test the ice. The largest indentor had a spherical contact area of 2.5 m^2 and weighed 835 kg. Three 3-m deep trenches were excavated. The impact apparatus was positioned crosswise in the trench, the trench walls acting as the test frame. The results of this project will be useful in engineering applications, such as ship, ice-breaker and petroleum exploration/development structure design.

MULTI-YEAR RIDGE ICE TESTING
(D.M. Masterson, Geotech Ltd./Calgary)
Through its Cold Environment Test Laboratory, GEOTECH recently completed an extensive research program on the strength and material properties of multi-year ridge ice. Uniaxial and triaxial tests were done at a range of strain rates and temperatures and using strain rate control, stress rate control and proportional loading control at specified stress ratios. Index properties of the ice, such as density, porosity, salinity and crystallography were determined and analysed with respect to the mechanical test results.

ARCTIC HOVERCRAFT DESIGN
(D.F. Dickins Assoc. Ltd., Vancouver)
The overall power requirements of 14 designs propelled by 21-feet diameter propellors have been evaluated. Variables such as skirt resistance over ice, number of engines, transmission systems and rotating bow thrusters were considered.

BEAUFORT SEA SHIPPING ROUTES
(D.F. Dickins Assoc. Ltd., Vancouver)
The most viable form of year-round transport between East Amauligak (roughly 30 miles offshore) and various shore locations is being determined. Ridge frequency, ridge height, water depth and distance from shore were compared in a series of graphs. Gaps between ridge features were evaluated for the possibility of air cushion vehicle transport. All data was derived from stereo photograph analyses.

ICE INTERACTION WITH A GRAVITY BASE STRUCTURE
(M. Wishaby & D.B. Muggeridge, ENG/MUN)
A combined theoretical and experimental study is in progress to determine the hydrodynamic interaction between a number of idealized rigid body iceberg models and a large cylindrical platform while under the influence of steep waves of known group characteristics. Initial tests, using a scale of 1:100, have been reported.

ICEBREAKING BOW DESIGNS
(B. Paterson & D.B. Muggeridge, ENG/MUN)
An experimental program to determine the resistance in level and broken ice is underway with a number of segmented bow models attached to a model of the M.V. Arctic (1:50 scale). The tests are being run in the new IMD/NRC ice tank.

RESISTANCE OF SHIPS IN PACK ICE
(A. Aboul-Azm and D.B. Muggeridge, ENG/MUN)
The added resistance for four models of different lines in broken pack ice is being studied. The mathematical model is under development and resistance tests for two of the models (M.V. Arctic and C.C.G.S. Franklin at scales 1:50 and 1:40, respectively), in ice covers up to 9/10 coverage with various size distributions, have been completed.

ICE FORCES ON CONICAL STRUCTURES
(M. Lau and D.B. Muggeridge, ENG/MUN)
The efficiency of fixed and oscillating downward breaking cones is being investigated. The program is an extension of the work of Frederking and Schwarz and looks at the icebreaking performance of cones in rafted ice. A tank has been constructed to conduct calibration tests in our own cold rooms before conducting further tests in the ice tank at IMD/NRC.

DYNAMIC ANALYSIS OF THE MOLIPAQ
(J.P. Nadreau, C-CORE/MUN)
A dynamic analysis at the Gulf Mobile Arctic Caisson, used in the Beaufort Sea, is being performed. The study will analyse the response of the structure when subjected to ice forces. Spectral analysis of various transducers is being conducted.

From the results of this study, a major NSERC university-industry program will address the analysis of the ice/structure/seabed interaction in a modelling perspective.

INSTRUMENTED ICE AUGER
(C-CORE/MUN)
The initial design of an instrumented auger has been developed by C-CORE. Further development of this tool, which can help in characterizing the ice by determining its relative "hardness" during field investigations, is considered a useful contribution to ice research in general. Funding for its development is being sought. The study will include the design of the auger, the construction and development of the tool, and a field trial.

A NEW TYPE OF MODEL ICE
(G.W. Timco, MECH/NRC)
A new type of model ice has been developed for use in refrigerated towing tanks. It is grown from an aqueous solution containing ethylene glycol, aliphatic detergent and sugar. This new model ice - termed EG/AD/S ice - accurately models the mechanical properties of sea ice and is a significant improvement over other existing types of model ice.

ICE FORCES ON MULTI-LEGGED STRUCTURES
(G.W. Timco and B.D. Pratte, MECH/NRC)
A series of tests were performed in the Hydraulics Laboratory ice tank at NRC/Ottawa to look at the interference effects when an ice sheet interacts with a multi-legged structure. The results indicated that if the distance between the legs is less than six leg diameters, strong interference effects occur influencing the direction of loading and failure mechanisms of the ice.

MODEL TESTS OF THE RIDGE-BUILDING PROCESS
(G.W. Timco, MECH/NRC; M. Sayed, DBR/NRC
The forces involved in the formation of pressure ridges were measured in model tests in the ice tank at NRC/Ottawa. Throughout the formation process, the forces and the sail and keel profiles were measured continually.

ICE PHYSICS AND ENGINEERING
(R. Frederking, L.E. Goodrich, N.K. Sinha, V.R. Parameswaran and M. Sayed, DBR/NRC)
The rate sensitivity of confined and unconfined compressive strength, deformation and Poisson's ratio of anisotropic columnar-grained ice and congealed frazil ice have been determined at $-10\,^{\circ}C$, $-20\,^{\circ}C$ and $-30\,^{\circ}C$ at the field station of Mould Bay. Methods have been developed to examine the intra-subgranular slip processes in sea ice. The response and usefulness of a borehole jack test system under operational conditions in the High Arctic were evaluated, and a new system has been designed and constructed. A series of confined compression tests was conducted on zero-salinity second-year sea ice and iceberg ice up to a closed-loop controlled strain rate of $10^{-2}\ s^{-1}$. Uniaxial and biaxial compressive strength tests on multi-year ridge sea ice have been carried out over a closed-loop controlled constant strain rate range of 10^{-6} to $10^{-2}\ s^{-1}$ and at temperatures of $-2\,^{\circ}C$, $-10\,^{\circ}C$ and $-20\,^{\circ}C$.

Field measurements were carried out at Esso's caisson retained island Amerk 0-09, in collaboration with Public Works Canada and K.R. Croasdale and Associates. Ice rubble stresses and movements were measured from February to May, 1985. Three site visits to Adams Island were made over the winter 1984-85 from November to May. Horizontal ice movements, ice stresses and strains, and meteorological and oceanographic factors were measured during this period. These measurements, plus the analysis done under contract by the University of Waterloo, support the hypothesis that tidal jacking from the shore is a prime factor in controlling ice movement adjacent to Adams Island. Maximum ice stress averaged through the ice cover was about 200 kPa within 100 m of the island. DBR collaborated in field trials by CRREL to determine the dynamic response characteristics of a MOT pier in Lac St. Pierre, Quebec. These results have been analysed and the model characteristics of the pier determined. The maximum ice load on the pier in 1985 was 300 kN, compared to 500 kN the previous year. Two sets of accelerometers were installed on the pier and a tape recorder with a timer relay was also set up to record the vibrations due to ice impact. Stress panels were installed on a bridge pier in the Rideau River near its outlet to the Ottawa River. Pressures on the pier during break-up will be recorded. Ice pressure measurements are being conducted adjacent to the dock at Nanisivik. Ice cover movements and meteorological data are also recorded.

Adfreeze strength between wood piles and saline ice was measured at $-10\,^{\circ}C$ at different rates of displacement. Penetration tests were carried out in saline ice using a stainless steel

cone penetrometer. Results from these tests will be used for design of pile foundations in ice and frozen soils.

CHEMICAL ANALYSIS OF ICE CORES
(M.O. Jeffries, GPHYS/ALASKA; H.R. Krouse, PHYS/CALG)
In April and May 1985, fieldwork on the north coast of Ellesmere Island involved sea ice coring and stratified lake sampling. Ice cores were drilled in adjacent ridges and troughs in multi-year landfast sea ice at the front of Ward Hunt Ice Shelf, Milne Ice Shelf and in Ayles Fiord. Ice salinity has been measured and O^{18} and tritium analysis is being undertaken to study the processes of thermo- dynamic sea ice growth and ice shelf regeneration. Stratified Lake "C" has remained stratified since it was last investigated in 1969. A second stratified lake was discovered 3 km south of Lake "C". Isotopic investigations of these lakes are in progress to assess their palaeoclimatological significance and study microbiological sulphate reduction and oxidation of organic matter at high latitudes.

ICE ENGINEERING
(B. Michel, J.P. Nadreau, J. Lachance, J.M. Tanguy and F. Picard, CIVIL/LAVAL)
Tests are being made on breaking ice with flat, inclined indentors at various angles in the upwards and downwards breaking modes, with S_2 controlled ice in a laboratory tank (4 m x 5 m). Tests are completed for failure in the brittle range and in progress at very low rates of loading. Creep tests in simple tension and compression and triaxial compression tests have been completed on simulated pressure ridge ice. A new failure envelope has been proposed for this type of ice. Studies are being made on crack nucleation and propagation in S_2 ice, under various conditions of loading in the brittle range.

ICE I, ORIGIN OF HIGH INFRARED ABSORPTION INTENSITY
(E. Whalley and D.D. Klug, CHEM/NRC)
The integrated absorption intensity of the ν_1 vibration of a water molecule increases by the factor 227 when it is transferred from the vapor to the crystal. The origin of this large increase is both the symmetry of the crystal, which requires the dipole moment to be zero, when all hydrogen atoms are half-way along their 0–0 lines, and the large electric field of neighbouring molecules, which further increases the dipole moment, and so increases the dipole-moment derivative.

ICE I, DIPOLE MOMENT DERIVATIVES
(E. Whalley and D.D. Klug, CHEM/NRC)
The dipole moment induced by stretching an O-H bond in a molecule of water in the vapor is known to be directed 25.2° outside the molecule. The same quantity for a molecule in ice I has been obtained from the ratio of intensities of the ν_1 and ν_3 vibrations of a D_2O molecule isolated in ice Ic or amorphous ice, and is along the bond. This change of direction is a newly-recognized effect of hydrogen bonding.

ELASTIC CONSTANTS OF ICE UNDER PRESSURE
(R. Gagnon, H. Kiefte and M.J. Clouter, PHYS/MUN; E. Whalley, CHEM/NRC)
The adiabatic elastic constants of single crystals of ice I in various directions have been measured up to 2 kbar by Brillouin spectroscopy. The elastic constants of polycrystalline ice III, V, and VI have been measured at −28° in their regions of stability.

NEUTRON AND X-RAY DIFFRACTION BY HIGH-DENSITY AMORPHOUS ICE
(A. Floriano and E. Whalley, CHEM/NRC)
An apparatus has been made for measuring the neutron and X-ray diffraction of high-density amorphous ice in order to determine its structure.

ICE, ORDERED FORMS
(Y.P. Handa, D.D. Klug and E. Whalley, CHEM/NRC)
Orientational ordering and disordering transitions in ice V and VI are being followed by scanning calorimetry.

Permafrost/Ground Ice/Gas Hydrates

FIELD TESTING METHODS FOR RHEOLOGICAL PROPERTIES OF FROZEN SOILS AND ICE
(B. Ladanyi and J.R. Murat, CINEP)
Two different test methods have been investigated in several friield and laboratory studies in the last ten years: (a) The Borehole Dilatometer (or Pressuremeter) Test, and (b) The Static Cone Deep Penetration Test. During the last two years, the performance of dilatometer creep tests in ice and frozen soils was studied both theoretically and by the finite-element method, to assess the length of stress redistribution time after a load application, the knowledge of which is essential for a proper interpretation of such tests. The study resulted in developing a correction algorithm.

Further theoretical developments have enabled the results of the Static Cone Penetration Test to be used either for the determination of creep properties of frozen soils and ice, or for a direct design of piles embedded in permafrost.

BEHAVIOUR OF FROZEN SOILS
(B. Ladanyi, J. Bourbonnais and J. Landva, CINEP)
This study, to measure the thermal and mechanical properties of frozen soils and ice at very low temperatures, down to −165°C, in connection with the underground storage of liquefied natural gas (LNG), started several years ago. It involved two different materials, a uniform sand and an undisturbed clay, and included a series of tests with polycrystalline

ice. An additional study of the thermal expansion behaviour of several clays down to cryogenic temperatures, made in 1984/85, revealed that considerable differences exist between those containing large quantities of active clay minerals and those composed mainly of inactive ones.

BEARING CAPACITY OF PILES IN FROZEN SOILS
(B. Ladanyi and G. Guichaoua, CINEP)
The behaviour under axial load of three different types of piles embedded in frozen soil by a slurrying method was studied experimentally under cold room conditions and analyzed theoretically for design purposes. The tests revealed that, under comparable conditions, a corrugated pile had a much better performance than a smooth pile, its ultimate bearing capacity being several times higher and its post-peak behaviour much less brittle than that of a smooth pile. On the other hand, the tapered piles (with a 3° taper) showed a continuous increase in their bearing strength up to large settlements, without reaching failure conditions. Direct shear and model pile tests, for studying the healing capacity of adfreeze bond, are presently underway.

FROZEN SOILS
(T.H.W. Baker and V.R. Parameswaran, DBR/NRC)
The effect of dynamic stress on the creep of frozen sand and clays was studied. Measurements of electrical potentials developed in various soils during freezing and thawing of the ground in Inuvik, N.W.T., were continued. Work continued on the section "Classification and Index Testing" of the Permafrost Testing Manual. Procedures for classification, salinity and bulk density were approved. An outline of procedures for the determination of water content (total and unfrozen) and organic content was prepared. The chapter on Dynamic Properties for the Testing Manual has been completed. Wet rodding and dry pluviation methods for preparing sand specimens were compared. Preparation of frozen specimens at various densities allowed for the determination of the effect of dry density on the compressive strength. This has led to the formulation of a model of the physical mechanisms contributing to the strength of frozen sand.

SCHEFFERVILLE PERMAFROST DATA
(H.B. Granberg, D.T. Destrochers, L. Houston, J.E. Lewis, T.R. Moore, P. Steer and R.K. Wright, GEOG/McG)
Materials relating to permafrost research over the years during which the Iron Ore Company of Canada operated mines at Schefferville have been gathered into two reports (EPB/EMR) totalling some 42 volumes. The reports contain ground temperature data from 214 thermocables, some 20 000 active layer depth soundings, geologic information in the form of drill logs, profiles and maps, detailed topographic information in the form of maps of scale 1:2 500 and 1:10 000 and stereo models of scale 1:30 000 using air photos flown prior to disturbance of the ground by mining. The report also contains papers, theses, reports, memoranda and other correspondence dealing with permafrost research at Schefferville.

PERMAFROST ACTIVE LAYER DEVELOPMENT
(D. Halliwell, GEOG/McM)
Measurements of the surface energy balance, ground thermal and moisture properties and active layer development have been made at a site near Churchill and at a site 80 km south of Churchill. These will be used to develop and test a numerical simulation model which uses standard meteorological data.

COMPUTER MODELLING OF PERMAFROST
(M.-K. Woo and J. Drake, GEOG/McMaster)
A computer model has been developed to simulate the hydrological and thermal behaviour of permafrost, wetland environments of the low arctic region. Field studies have been completed and all the requisite equations for the model have been obtained. The model is expected to be finished in 1-2 years.

PERMAFROST GEOPHYSICS
(M.K. Seguin, GEOL/LAVAL)
Research has been carried out on the formation and extent of permafrost in northern Quebec using various techniques. In the Kangiqsualvjjuaq area south-east of Ungava Bay, the thickness, spatial and temporal distribution of the discontinuous permafrost were determined using electrical resistivity measurements, induced polarization, EM techniques, geothermal techniques, etc.

PERMAFROST AND FROST ACTION
(T.H.W. Baker, L.E. Goodrich, G.H. Johnston, J.-M. Konrad, V.R. Parameswaran and O.J. Svec, DBR/NRC)
Regular ground temperature observations were continued in the western Cordillera and at Alert, NWT, to determine the distribution and characteristics of permafrost in Canada. Ground temperature measurements were continued at the Inuvik airstrip to monitor its performance and evaluate its design and construction. Ground and air temperature observations were made at test sections on the Mackenzie and Dempster Highways, NWT, Thompson, Manitoba and Eagle River Bridge, Y.T. Static and dynamic tests using model piles in frozen soils (sand and clays) were continued in the laboratory. Equipment to carry out penetration tests in frozen soils in the laboratory has been assembled. Experiments to study the feasibility of drilling and slotting of frozen sand and clay using high-pressure water jet cutting technique were carried out in collaboration with DME/NRC. The material could easily be cut by the water jet and potential use for this technique in permafrost areas will be in drilling for

placement of piles and cutting trenches for utilities. A third season's data was gathered including soil and wall temperatures and movements, along with moisture and thermal property information. Freezing tests were conducted on silty clay samples using the ramping and step-freezing techniques. New computer-assisted freezing was also investigated in order to achieve a prescribed ice lens pattern. The first set of tests to evaluate frost lens growth was completed successfully. Low-temperature gradient was achieved with exceptionally low horizontal heat flow. Density scanning of the X-ray images proved to be an asset to analysis.

PERMAFROST AND PIPELINES - CANADA - FRANCE PROJECT
(P.J. Williams, M.W. Smith et al, Geotech. Sci. Labs (GSL)/GEOG/CARL; CINEP; Lab Central des Pont et Chaussés, CNRS, Paris and Caen)
A chilled 16 m pipeline, in a controlled environment facility, is being deformed by frost-heave. Observations include temperature and stress distributions in freezing soil annulus and in pipe. Internal stresses and secondary frost-heave are being analysed and a predictive model for heave and deformation has been developed.

INTERNAL STRESSES - FROZEN GROUND
(P.J. Williams, GSL/GEOG/CARL)
The freezing of water in soils is governed by thermodynamic conditions imposed by the pore of the soil. In particular, water freezes at temperatures substantially below 0 °C under pressures limited by mechanical properties of the soil. Stresses developed on a near-microscopic scale in soils at different temperatures are being investigated experimentally and models combining thermodynamics and mechanics have been developed for prediction of the externally effective frost heave pressures.

FIELD STUDIES OF GROUND ICE, MAYO
(C.R. Burn, GSL/GEOG/CARL)
The water balance of the surface layers of permafrost terrain has been examined at nine sites near Mayo, Yukon Territory, and has been related to the thermal conditions present at each site. On an annual basis, permafrost appears as a net sink for water derived from the atmosphere.

Examination of the ground ice stratigraphy in the study area has indicated that permafrost has been aggrading over the past 8 000 years in central Yukon and incorporating water at between 1 and 0.1 mm/a. Confirmation of recent movement of atmospherically-derived water into permafrost has been provided by the presence of tritium-enriched ice below 9 cm of segregated ice at the base of the active layer.

NEEDLE ICE
(W.C. Mahaney, GEOG/York; M.G. Boyer, Biology/York)
Experimental work has been carried out on the needle ice forms in paleosols on Mount Kenya. Field experiments were also performed to study the formation of mud polygons by freeze thaw and wetting and drying on Mount Kenya.

MOISTURE TRANSFER AND FROST HEAVING
(M.W. Smith, GSL/GEOG/CARL)
Investigations have been continuing into the precise nature of moisture transfer in freezing soils and the details of frost heaving, both in the field (at Inuvik, N.W.T. and Mayo, Y.T.) and in the large-scale experiment in Caen, France. Attention has been focussing on the movement of water in soil at temperatures below −1 °C.

PERMAFROST SENSITIVITY TO CLIMATE CHANGE
(M.W. Smith, GSL/GEOG/CARL)
A network of seven stations has been established near Mayo, Y.T. for continuous, long-term observations of ground temperatures down to 5 m, with a view to determining the response of permafrost to climatic variation over the next ten to twenty years. A study was completed on how climate influences ground thermal conditions at a boreal forest site, near Mayo, in order to assess the degree to which such sites would be buffered from the effects of climatic change. Observations have been continued on the rate of development of contemporary thermokarst features in the Stewart River Valley, near Mayo, and the relationship of this, if any, to climatic conditions. Computer modelling has been used to explore the significance of variations in thermal properties to geothermal calculations.

SNOW/GROUND INTERFACE TEMPERATURE MONITORING
(H.B. Granberg and D.T. Desrochers, GEOG/McG)
Detailed monitoring of snow/ground interface temperatures, shallow ground temperature profiles and snow form part of a project to further elucidate the role of the seasonal snow cover in controlling the spatial distribution of permafrost in the Schefferville area. One forest and one tundra site will be fully instrumented in the 1986-87 winter season. A datalogger at each site will monitor some 250 sensors.

CLATHRATE HYDRATES
(D.W. Davidson et al., CHEM/NRC)
The ice-like gas hydrates formed by such small molecules as argon, krypton, and oxygen are type II, not type I, as previously assumed. The hydrocarbons in naturally-occurring gas hydrates recovered from sub-oceanic deposits have been identified by nmr techniques.

G.W. Timco

UNITED KINGDOM

ANALYSIS OF SEASAT RADAR ALTIMETRY OVER SEA ICE
(S. Laxon, C. Rapley and N. McIntyre, Mullard Space Science Laboratory, University College, London [MSSL/UC]
An automated retracking algorithm has been developed to remove the range jitter due to radar altimeter tracker response to sea ice surfaces. This enables definition of the geoid in regions of sea ice cover as precisely as over the ocean. Investigations of alterations in waveform shape and strength are leading to a better understanding of altimeter response to changes in ice concentration, floe size distribution and ice type.

ANALYSIS OF SEASAT RADAR ALTIMETRY OVER THE ANTARCTIC ICE SHEET
(K. Partington, W. Cudlip, N. McIntyre and C. Rapley, MSSL/UC)
Analyses of sequences of waveform data over the ice sheet and ice shelves are providing indications of instrument response to a range of topographies. In particular, attention is being focussed on repeat ground-track coverage and instances of loss of lock. Techniques for the standard processing and archiving of data are also being investigated as part of a programme aimed at generating detailed topographic maps of the ice sheet surface.

RADAR ALTIMETRY DURING MIZEX
(MSSL/UC, SPRI & Rutherford Appleton Lab.)
Data are being analyzed from a 13.7 GHz airborne radar altimeter flown during the Marginal Ice Zone Experiment. Altimetry from interior pack ice and marginal ice zones in the Greenland and Bering Seas and from terrestrial ice in Svalbard and Greenland is being compared with coincident surfaces, airborne and satellite measurements from a range of sensors. Initial results suggest algorithms for extracting sea ice concentration and other glaciological parameters will be developed.

ALTIMETER PERFORMANCE SIMULATION
(MSSL/UC, SPRI & Rutherford Appleton Lab.)
Modular software coding has been developed which enables simulation of the performance of radar altimeters over a range of surfaces. Components already completed include ice sheet and sea ice surfaces, a waveform generator and a range of tracking systems. This provides support for the interpretation of existing satellite and aircraft radar altimeter data, development of algorithms for the extraction of glaciological parameters from future systems and testing of concepts for technical improvements in radar altimeters themselves.

J.G. Paren

U.S.A. - ALASKAN REGION

Last report of U.S.A. - Eastern region: see ICE, No. 76, 1984, p. 7-11
Last report of U.S.A. - Western region: see ICE, Nos 78 & 79, 1985, p. 16-34

ROLE OF GLACIERIZED BASINS
(C. Benson, W. Harrison, J. Gosink and S. Bowling, Geophysical Institute, University of Alaska (GPHYS/AK); L.Mayo & D.Trabant, Glaciology Project Office/USGS/ Fairbanks)
An international *Workshop on Alaskan Hydrology: Problems Related to Glacierized Basins*, was held in Eagle River, Alaska during April, 1985. Hydrology in Alaska is strongly influenced by problems associated with snow, ice and permafrost which will become increasingly important as economic development proceeds. The Scandinavian countries, Switzerland and Canada have preceded Alaska in developing hydrological resources that depend on glaciers for their sources and Alaska can learn from their experience. The international workshop sought to capitalize on this expertise and experience from abroad and to bridge the communication gap between scientific and engineering/ management groups, by having both groups participate. The subjects considered were: runoff from glacierized basins, sediments in glacial streams, hazards associated with glaciers, ice problems on rivers and reservoirs, and selected aspects of permafrost hydrology in glacierized basins. Two days of the workshop were devoted to presentations by the participants, followed by intensive meetings of five subgroups. The conclusions and recommendations of the subgroups will be published by the Geophysical Institute, University of Alaska- Fairbanks, Fairbanks, AK 99775-0800.

STREAM ICINGS
(K. Dean, GPHYS/AK)
Stream-icing zones (aufeis or naleds) in mainland Alaska were mapped from multi-date Landsat imagery at a scale of 1:250 000. Mapped features include late winter overflow, residual ice-sheets and braided streams possibly susceptible to icings. Results were generalized and the regional distribution of icings displayed.

Stream icings are common throughout Alaska and usually recur near the same locality annually. Their areal extent may vary each year. The highest frequency and greatest density of icings occur in the Brooks Range, the northeast coastal plain and foothills. The largest icings also develop in this area. Few icings occur in the western coastal plain and foothills. Generally, the number and size of icings steadily decrease southward, except in the Alaska Range, where there are numerous stream icings. In interior Alaska, icings are numerous, but relatively small and are

restricted to tributary stream valleys. Almost all large icings occur within or near upland or mountainous regions and often along finely braided streams.

NORTHERN LAKE & RESERVOIR MODELS

(J. Gosink, GPHYS/AK)

The assessment and prediction of water temperature and quality in lakes and reservoirs located in high latitudes and possibly fed by glacier streams calls for a number of improvements or modifications to existing reservoir models. They include changes to the thermodynamics expressions in the surface heat balance and changes to simulation of dynamic processes involved in the deepening of the thermocline. Thermodynamic factors which must be considered include ice formation, albedo changes, short-wave attenuation in snow and ice, the coupled relations between snow and ice surface temperatures and net surface heat flux, and heat conduction through the snow and ice. The ice cover also reduces the effective wind stress to a negligible intensity or to zero. In addition, there is some indication that Coriolis effects in high-latitude lakes and reservoirs may not be negligible, contrasting with lakes of the same size in more temperature zones. This is due to the simultaneous decrease in Coriolis time scale with increasing latitude, and increase in internal wave period for northern lakes with weak stratification.

The appropriate modifications were added to the one-dimensional reservoir model DYRESM, yielding an all-season version designated as DYRSMICE. Predictions of temperature profiles from DYRSMICE were compared with measured temperatures obtained for a hydro-electric project study at Eklutna Lake near Anchorage, Alaska. The comparisons indicated very good overall agreement.

BLACK RAPIDS GLACIER

(L.R. Mayo, D.C. Trabant and R.S. March, CRHPO/USGS); T.S. Clarke, GPHYS/AK)

Glaciers in the Alaska Range have been receding for decades, which if continued, suggests that periodic surging of Black Rapids and other famous glaciers of the area could terminate. From 1973 to 1977, the surge storage reservoir was, in fact, not filling. Since then, the reservoir has resumed filling, and the lower edge of the filling area has propagated 16 km down glacier. Comparison of 1949 mapped altitudes with 1985 surveys shows that the ice reservoir has filled 50 m and the glacier volume has increased, resulting in an average glacier thickness increase of 10 m. Glacier speed is increasing steadily, but not enough to dissipate the ice accumulation, so a surge is imminent. The date of the next surge is unknown.

BLACK RAPIDS GLACIER - MOULINS

(B. Buchanan and M. Wumkes, Glacier Data Ltd., Fairbanks)

Three moulins in the upper part of the Black Rapids Glacier were explored to a depth of 90 m during the winter of 1984-85. One included a relatively horizontal water course (open channel) extending more than 65 m. Basic morphological data were collected. Pegs were imbedded in the moulin walls to measure erosion and deformation. Periodic fluctuations in erosion rates were evidenced by squiggums (horizontal, water flow lines eroded into ice walls). Deformation was apparent from the squeezing together of passageway walls over a five-month period. Almost continuous, high-pitched sounds were audible at lower depths during late winter. Sediment samples of organic matter were collected. It is anticipated that lower depths and greater distances will be reached during continuing studies.

GLACIER RUNOFF ESTIMATION

(L.R. Mayo, CRHPO/USGS)

Average glacier and alpine runoff rates are related inversely to equilibrium line altitude, or ELA, in Alaska. IHD data for McCall Glacier (studied by Univ., Alaska) and Gulkana and Wolverine Glacier (USGS) provide information for a simple model by which average runoff rates for basins in Alaska with glaciers can be estimated using ELAs interpreted from topographic maps. A test at Knik Glacier predicted 2.0 m/a runoff; measured is 2.03 m/a The ELA Runoff Model indicates that Bering Glacier produces 26 km^3/a, or 4.2% of the total runoff from Alaska and 1.2% of that from the nation.

COLUMBIA GLACIER

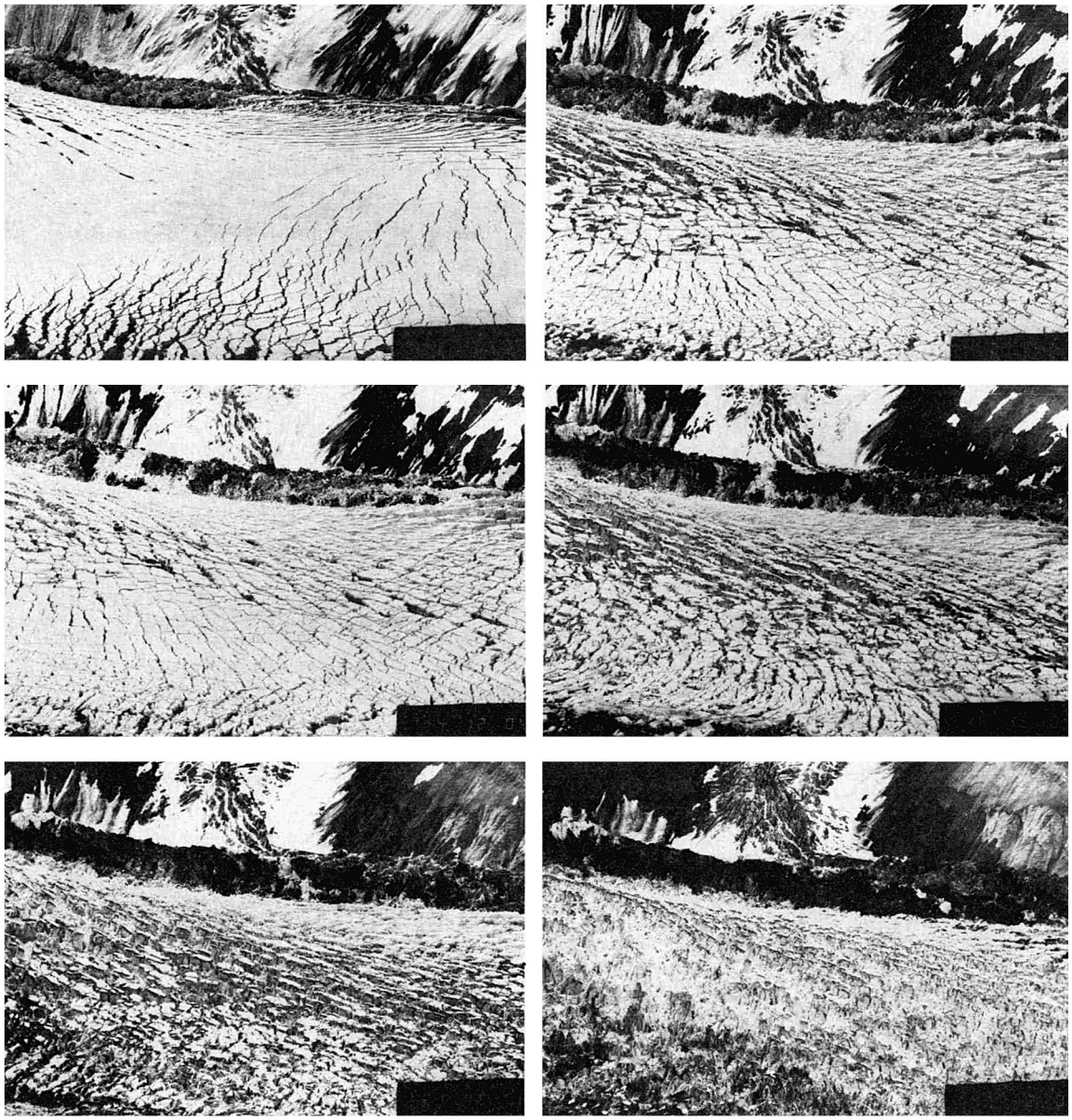
(L.R. Mayo, D.C. Trabant and R.S. March, CRHPO/USGS)

Columbia Glacier has receded 2 km from the protection of the sub-sea moraine since 1980. Icebergs are now compacted between the foward-moving ice front and the moraine crest, which is undoubtedly being abraded by the passage of shoved, grounded icebergs. Because of the steeper glacier surface gradient, the glacier speed (primarily sliding) has increased from 800 m/a in 1980 to 3000 m/a at a point about 5 km above the snout. The speed increase diminishes up-glacier. The central 'ice jet' shears past much slower tributaries and is lubricated at its bed more in winter than in summer. The lubrication may be due to disruption by sliding of the basal drainage conduit system when liquid input in minimal. Draw-down of ice extends to about the equilibrium line.

The lower part of the glacier has become severely crevassed, so motion/balance stakes cannot survive. Furthermore, snow depths of 10-20 m in the upper accumulation zone preclude stake survival there. Motion and glacier temperature in both of these difficult areas are now measured with animal radio collars. We hope to be able to measure snow depth above the transmitters. At 2600 m altitude, the glacier at 10-m depth is $-10\,^{\circ}C$.

SURGE OF VARIEGATED GLACIER

(Taken from Geophysical Institute Biennial Report 1983/84, University of Alaska-Fairbanks)



Sequence of photos showing the surge of Variegated Glacier in SE Alaska. The top left photo was taken on 14 May 1984, well after the glacier had started to surge. Subsequent photos (top right to bottom left) were taken on 4, 8, 16 and 24 June. The last photo (bottom right) was taken on 14 July, ten days after the glacier stopped its surge. (Photos by Will Harrison.)

GULKANA GLACIER GROWTH AND RUNOFF

(L.R. Mayo, D.C. Trabant and R.S. March, CRHPO/USGS)

The upper part of Gulkana Glacier began thickening in 1976. Since then, thickening has extended to lower atitudes. By 1980, the volume of the glacier began increasing. River discharge from the Alaska Range is increasing also. In general, runoff, temperature, and precipitation tend to vary in-phase with glacier mass balance.

GROWTH OF WOLVERINE GLACIER

(L.R. Mayo, R.S. March and D.C. Trabant, Cold Regions Hydrology Project Office, U.S.G.S., Fairbanks (CRHPO/USGS))

Since 1976, Alaska has experienced warmer and wetter weather than earlier. Wolverine Glacier is growing steadily because the increase in winter snowfall has been larger than the increase in summer ablation. In June 1985, we resurveyed three 1974 transverse and one longitudinal profile. The upper 70% of the glacier thickened uniformly about 5 m and the terminus area thinned with 30 m of loss near the snout. Even though the glacier is receding, it thickened an average of 3 m. An advance is anticipated.

McCALL GLACIER MASS BALANCE

(D.C. Trabant, CRHPO/USGS; C.S. Benson, GPHYS/AK)

Internal accumulation and superimposed ice amounted to approximately 40% of the net accumulation on McCall during four years of analysis on this Arctic glacier in Alaska. During the 1969-72 study, reliable measurement of volume changes of the ice glands, layers, and lenses formed by internal accumulation proved to be impossible. The amount of internal accumulation formed each year was evaluated indirectly by estimating the amount of water available for percolation which rarely approached the potential capacity for internal accumulation due to the negative temperature of the firn. The annual balances of McCall from 1969 to 1972 were −0.42, −0.08, −0.14 and −0.19 m H_2O.

ICE ISLANDS

(W.M. Sackinger, M.O. Jeffries, M. Yan and H. Tippens, GPHYS/AK)

In September 1985, a 42-m ice core was drilled through an ice island that calved from eastern Ward Hunt Ice Shelf, Ellesmere Island, Canada during the interval 1982-83. Subsequent analysis has shown that the entire ice column is composed of non-saline ice. This is quite unlike western Ward Hunt Ice Shelf where there is a large body of old sea ice in the shelf.

Ice island drift is being monitored by satellite telemetry. Selected ice island trajectories are being related to meteorological data. In addition, a computer model of ice island movement is being developed.

SURGE OF VARIEGATED GLACIER

(C.F. Raymond, Univ. Washington; W.D. Harrison and K.A. Echelmeyer, GPHYS/AK); B. Kamb, Caltech; H. Engelhardt, Univ. Münster)

The 1982/83 surge of Variegated Glacier is one of the most carefully studied surges in the world; measurements included ice temperature, depth, bed morphology, hydrology, motion, short-period motion, seismicity and strain, mass balance, surface topography, subglacial water pressure, and the evolution of most of these with time. At its peak, the surge speed approached 70 m/day for short periods and almost the entire glacier was affected. Surface altitude change in the course of the surge exceeded 100 m at some sites. (see photographs, page 17).

Although interpretation of the results is likely to continue for some time, it is clear that the cause of the surge was water. The speed was erratic in time (but coherent in space) during the surge. Each sudden drop in speed was accompanied by a burst of water appearing at the terminus from under the glacier, and the final cessation of the surge was marked by a particularly large flood. Several observations, some quite direct, indicated high water pressure under the glacier during most of the surge. Dye tracing experiments indicated very poor drainage during the surge, but efficient drainage immediately after; a critical change in the glacier "plumbing" is therefore evident. Under consideration now are questions of the mechanics of "plumbing" changes and whether they can lead to an understanding of why some glaciers surge and others do not.

SUMMERTIME FLOE SIZE DISTRIBUTION

(W.J. Stringer, GPHYS/AK)

The areal extent of ice floes has been measured from Landsat imagery of the summertime Beaufort Sea, spanning the five months between break-up and freeze-up. In general, the distribution of floe sizes was found to obey a power law: $N(S) = N_1 S^{\lambda}$, where the number of floes per unit floe size interval (in area), N(S), is related to N_1, the number of floes in the particular distribution at unit floe size; S, the floe size interval; and λ, a number found to range between −1.33 and −2.06 (see Figure 1). When these data are grouped by time interval, the value of λ is found to decrease from −1.33 in May to −1.8 in August and then increase to nearly −1.6 in September. In addition, an exponential relationship with λ was found among the values of N_1 of the various distributions: $N_1 = N_0 e^{-15.14\lambda^1}$ (see Figure 2). This relationship appears to hold regardless of the seasonal variation of λ. Thus, floe size distributions were found to obey $N(S) = N_0(e^{-15.4}S)^{\lambda}$, with a value $N_0 = 1.23 \times 10^{-6}$ where N_0 is the number of floes per unit floe size at unit floe size for $\lambda = 0$.

A value of $\lambda = -1$ was found to produce a

floe size distribution, in which the apparent distribution of floe size is the same regardless of the scale at which it is viewed. A value of $\lambda = 0$, although not observed, would describe a floe field where all floe sizes are found in equal numbers.

Gunter Weller

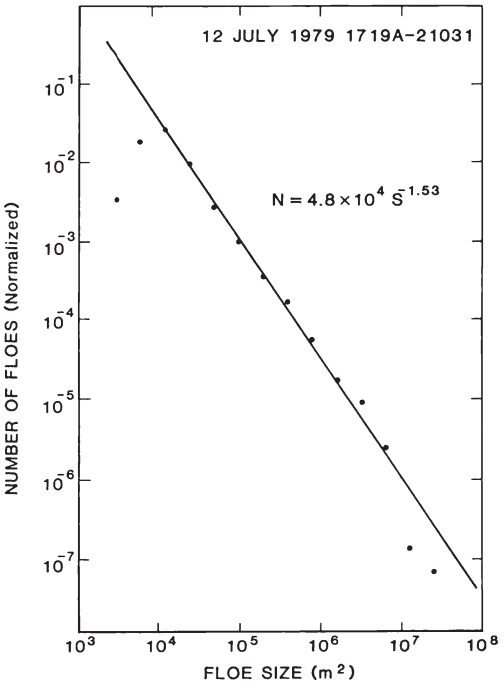


Fig.1. Typical floe size distribution data from July 12, 1979 are displayed on log-log coordinates. Best linear fit and resulting power law are shown.

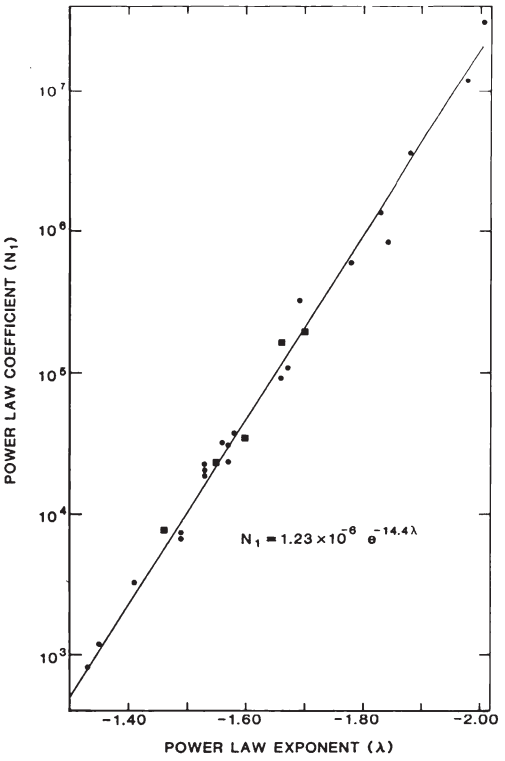


Fig.2. Plot of power law coefficients N_1 against power law coefficient λ. Data are displayed on semi-log coordinates. Best linear fit and resulting exponential law are shown.

U.S.A - WESTERN REGION

SEA ICE REMOTE SENSING

(D. Rothrock, Polar Science Center, Applied Physics Laboratory, University of Washington, Seattle, WA, [PSL/APL/WASH]

The sea ice velocity field is being observed from SAR images with spatial sampling density of one point every several kilometers. These dense observations show rigid pieces more than 100 km across drifting in response to the wind. Between the pieces are zones of intense deformation, whose production or destruction of open water is being related to the mean deformation over a scene (100 km^2).

Efficient techniques for measuring deformation and concentration change with digital image processing are being developed. Kinematic data are extracted by cross-correlation of two sequential images. The method does well on rigid floes with small rotations, and is being extended to more general motions occurring near the ice edge and in summer.

ARCTIC INTERNAL WAVE EXPERIMENT

(J. Morison, PSL/APL/WASH)

In March and April of 1985, oceanographers for Oregon State University, Scripps Institution of Oceanography and the University of Washington participated in the Arctic Internal Wave Experiment. The program was carried out on the sea ice at 74°N 143°W, approximately 250 nm northeast of Deadhorse, Alaska. The objective was to obtain detailed measurements of the internal wave spectrum in the Arctic Ocean. Horizontal and vertical arrays of temperature, conductivity and velocity sensors were suspended below the ice. Velocity profiles were obtained using acoustic doppler current profilers and a profiling current meter - CTD. Expendable velocity probes were used in a large-scale helicopter survey. Additional programs included an acoustic transmission experiment, boundary layer studies, meteorological and magnetics measurements.

Initial results indicate internal wave energy in the Arctic is much lower than in temperate oceans and shows more temporal variability. In addition to internal wave measurements a great deal of data was obtained on the mesoscale eddies which are commonly found in the Beaufort Sea.

ARCTIC SEA ICE

(R. Moritz, PSL/APL/WASH)

Current research studies include: observational estimates of the ice budget of the Greenland Sea; validation and sensitivity studies comparing kinematic and ice concentration outputs of the Hibler/Bryan ocean model with measurements; and a climatological study of the sea ice velocity, geostrophic winds and ocean currents in the region between Fram Strait and the North Pole.

The main data sets used include ice trajectories measured by buoys and manned camps, geostrophic winds estimated by the Arctic Basin Buoy Program, and ice concentration estimates from Walsh and Johnson (1979) and from the NASA SMMR. The first two projects are directed towards understanding the role of sea ice in the quasi-stationary climate and its variability, as stated in the World Climate Research Program Plan and in the Arctic Ocean Sciences Board Greenland Sea Project Plan.

ARCTIC BUOY PROGRAM

(R. Colony, PSL/APL/WASH)

The primary objective of the Arctic Buoy Program is to monitor the fields of surface atmospheric pressure, surface temperature and sea ice motion in the Arctic Basin. This is accomplished by maintaining a network of automatic data buoys which sit atop the drifting ice pack. The data (pressure, temperature, and position) are distributed in three ways: 1) In real time the data are collected by Local User Terminals in Edmonton and Oslo; here the data are entered onto GTS and made available to the international meteorological community; 2) With a delay of about four hours, the data are processed by Service Argos and entered onto the TIMENET system. These data are available to a wide following; 3) With a delay of one year an annual data report is published and the archived data are available through the World Data Center A: Glaciology. The program began in 1979 and is presently funded through 1990.

Data collected by the Arctic Buoy Program serve a number of areas: basic science; applied research; environmental monitoring and guidelines; arctic climate; and operational weather and ice forecasting. At the university, the focus has been on basic science. The data have been central to the study of sea ice kinematics, sea ice budgets, sea ice transport, large-scale circulation, and sea ice deformation.

ARCTIC SOFAR AND ALS DEVELOPMENT

(R. Colony and R. Moritz, PSL/APL/WASH)

Technology to support an arctic SOFAR (Sound Fixing and Ranging) is under development and field testing. In a joint program, Woods Hole Oceanographic Institute, Laboratoire d'Oceanographie Physique and the Polar Science Center are developing an 80 Hz transponder suitable for an arctic SOFAR drifter. In April 1986, the transponder will be installed near 90°N. Two ALSs (Autonomous Listening System) will be attached to ice buoys at distances of 300 km and 400 km from the transponder. A successful test would demonstrate the feasibility of a long-term program to monitor the low-frequency ocean currents in the Arctic Basin.

PHYSICAL OCEANOGRAPHY INVESTIGATIONS IN THE MIZ

(R.D.Muench, Sci.App.Int.Corp., Bellevue, WA)

The general, long-term objectives of this program are to describe and analyze the dynamics of dominant physical oceanographic processes in the northern hemisphere marginal ice zones (MIZs). Work carried out to date has addressed, through collection and analyses of field data, processes in the Bering and Greenland sea MIZs and has focussed on phenomena typical for both melting and freezing conditions. In both regions, the stress has been on frontal and circulation features which are associated with the ice edges. Work to date has resulted in a complete description and analysis of the front associated with the Bering Sea ice edge, and a preliminary description of the currents associated with the Greenland Sea ice edge. This information serves as input for tuning of numerical models which address oceanic and sea ice processes in the MIZs, and will help to characterize the acoustic propagation environments association with ice edges. This program is funded by the Arctic Sciences program, Office of Naval Research.

Andrew Fountain

INTERNATIONAL GLACIOLOGICAL SOCIETY

JOURNAL OF GLACIOLOGY

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

L.A. Rasmussen:
Refraction correction for radio echo-sounding of ice overlain by firn.

B. Kamb:
Stress-gradient coupling in glacier flow:
I: Longitudinal averaging of the influence of ice thickness and surface slope.

K. Echelmeyer and B. Kamb:
Stress-gradient coupling in glacier flow:
II: Longitudinal averaging in the flow response to small perturbutations in ice thickness and surface slope.

B. Kamb:
Stress-gradient coupling in glacier flow:
III: Exact longitudinal equilibrium equation.

B. Kamb and K. Echelmeyer:
Stress-gradient coupling in glacier flow:
IV: Effects of the T term.

T. Dowd and R.L. Brown:
A new instrument for determining strength profiles in snow cover.

C.C. Smart:
Some observations on subglacial groundwater flow.

L.B. Mead, H. Nakamura, T.E. Lang and J.D. Dent:
Comparison of experimental and computer modeling of snow-block impact on structures.

C.F. Raymond and S. Malone:
Propagating strain anomalies during minisurges of Variegated Glacier, Alaska, U.S.A.

N. Humphrey, C.F. Raymond and W.D. Harrison:
Discharges of turbid water during minisurges of Variegated Glacier, Alaska, U.S.A.

R.J. Rogerson:
Mass balance of four cirque glaciers in the Torngat Mountains of northern Labrador, Canada.

J.E. Beget:
Modeling the influences of till rheology on the flow and profile of the Lake Michigan lobe, southern Laurentide ice sheets, U.S.A.

ANNALS OF GLACIOLOGY

The following papers have been published in Volume 8, Proceedings of the Symposium on Glacier Mapping and Surveying, Iceland 1985.

H TOMASSON:
The history of mapping in Iceland, with special reference to glaciers.

M ANIYA, R NARUSE:
Mapping structure and morphology of Soler Glacier, Chile, using vertical aerial photographs.

H BJORNSSON:
Surface and bedrock topography of icecaps in Iceland mapped by radio echo-sounding.

H BJORNSSON:
Delineation of glacier drainage basins on Hofsjökull and Western Vatnajökull.

H H BRECHER:
Surface velocity determination on large polar glaciers by aerial photogrammetry.

A C CHAMPOUX, C S L OMMANNEY:
Photo-interpretation, digital mapping and the evolution of glaciers in Glacier National Park, B.C.

A C CHAMPOUX, C S L OMMANNEY:
Evolution of the Illecillewaet Glacier, Glacier National Park, B.C., using historical data, aerial photography and satellite image analysis.

CHEN JIANMING:
Map of the Mount Gongga Glacier: a combination of terrestrial and aerial photogrammetry.

R D CRABTREE, C S M DOAKE:
Radio-echo investigations of Ronne Ice Shelf.

D DAHL-JENSEN, J-P STEFFENSEN, S J JOHNSEN:
Least squares method used in reduction of data from theodolite measurements on fast moving glaciers.

J A DOWDESWELL, A P R COOPER:
Digital mapping in polar regions from Landsat photographic products: a case study.

J A DOWDESWELL, A P R COOPER, M R GORMAN, O LIESTOL, O ORHEIM:
Digital mapping of the Nordaustlandet ice caps from airborne geophysical investigations.

C DRIEDGER, P KENNARD:
Glacier volume estimation on Cascade volcanoes – an analysis and comparison with other methods.

J G FERRIGNO:
Recession of Grasshopper Glacier, Montana since 1898.

N S GUNDESTRUP, R A BINDSCHADLER, H J ZWALLY:
Seasat range measurements verified on a 3-D ice sheet.

N HAAKENSEN:
Glacier mapping to confirm results from mass-balance measurements.

W HAEBERLI, F EPIFANI:
Mapping the distribution of buried glacier ice – an example from Lago Delle Locce, Monte Rosa, Italian Alps.

W D HARRISON, C F RAYMOND, P MACKEITH:
Short period motion events on Variegated Glacier as observed by automatic photography and seismic methods.

P J HOWARTH, C S L OMMANNEY:
The use of Landsat digital data in glacier inventory.

H ITO, K SCHROFF, H-J FREI:
High-precision distance measurement with an unmanned moving target.

M O JEFFRIES, H V SERSON:
Ground survey and mapping of ice edge changes and multi-year sea ice growth along the north coast of Ellesmere Island, N.W.T.

T JOHANNESSON:
The response time of glaciers in Iceland to changes in climate.

W J KICK:
Glacier mapping for an inventory of the Indus drainage basin: current state and future possibilities.

N T KNUDSEN:
Recent changes of Nordbogletscher and Nordgletscher, Johan Dahl Land, South Greenland.

V M KOTLYAKOV, N N DREYER, V L KRAVTSOVA:
The main results of mapping glacio-nival systems for the World Atlas of Snow and Ice Resources.

R M KRIMMEL, L A RASMUSSEN:
Using sequential photography to estimate ice velocity at the terminus of Columbia Glacier, Alaska.

N MCINTYRE:
Antarctic ice sheet topography and surface bedrock relationships.

M NAKAWO, S IWATA, O WATANABE, M YOSHIDA:
Processes for distribution of supraglacial debris on the Khumbu Glacier, Nepal Himalaya.

C S L OMMANNEY:
Mapping Canada's glaciers.

G ØSTREM:
Repeated glacier mapping for hydrological purposes: water power planning.

K C PARTINGTON, K RICHARDSON, C G RAPLEY:
Simulation and analysis of altimeter performance for production of ice sheet topographic maps.

N REEH, O B OLESEN:
Velocity measurements on Daugaard-Jensen Glacier, Scoresbysund, East Greenland.

W REINHARDT, H RENTSCH:
Determination of changes in volume and elevation of glaciers, using digital elevation models for the Vernagtferner, Ötztal Alps, Austria.

A C SAETRANG, B WOLD:
Radio echo-sounding on Jostedalsbreen, Norway.

C W M SWITHINBANK, B K LUCCHITA:
Multispectral digital mapping of Antarctic ice features.

H H THOMSEN:
Photogrammetric and satellite mapping of the margin of the inland ice, West Greenland.

P L VORNBERGER, I M WHILLANS:
Surface features of Ice Stream 'B', Marie Byrd Land, West Antarctica.

E D WADDINGTON, D A FISHER, R M KOERNER, W S B PATERSON:
Flow near an ice divide: analysis problems and data requirements.

E D WADDINGTON, R MARRIOTT:
Ice divide at Blue Glacier, U.S.A.

O WATANABE, S IWATA, H FUSHIMI:
Topographic characteristics in the ablation area of the Khumbu Glacier, Nepal, Himalaya.

W B WHALLEY, H E MARTIN, A F GELLATLY:
Rock glaciers, ice-cored moraines and the problem of "hidden" ice in glacier mapping.

R S WILLIAMS JR:
Glacier fluctuations and glacier inventories of Iceland: evaluation and use of sources of data.

YIN SHICONG, CHEN JIANMING:
Cartographic methods for large-scale glacier maps.

BRITISH BRANCH MEETING

12-13 September 1985, University of Manchester

The Annual Conference of the British Branch took place in the Geography Department of the University of Manchester on 12-13 September 1985. Dr David Collins organised the meeting. The Annual Dinner took place in the splendidly preserved Britannia Hotel, and included a presentation to Dr Hal Lister prior to his retirement. Hal has entertained and inspired the British Branch in all the years of its existence.

The Branch Meeting covered many aspects of research in glaciology, and individual scientists can be contacted for further details of their work. The following papers were presented in the four sessions of the meeting.

ICE SHELVES AND ICE SHEETS

Julian Paren:
George VI Ice Shelf, a temperate ice shelf?

John Potter:
George VI Ice Shelf, on the edge of existence?

John Reynold and Michael Hambrey:
Structural glaciology of George VI Ice Shelf, Antarctica.

Mark Pedley:
Modification of ocean tides by ice shelf dynamics.

Eric Wolff and Chris Doake:
Implications of the form of the flow law for vertical velocity and age-depth profiles in polar ice.

Andrew Smith:
Preliminary investigations of Antarctic ice rumples.

Charles Swithinbank:
What we should be doing with satellite imagery of ice sheets.

Chris Doake:
Flow line analysis on Ronne Ice Shelf, Antarctica.

Richard Frolich:
Present work on the Rutford Ice Stream, Antarctica.

David Mantripp:
Stability of ice masses grounded below sea level.

MELTWATER RIVERS

Hal Lister:
Resistance to proglacial flow.

John Threlfall:
The relationship between discharge and suspended sediment in a small nival Subarctic catchment.

Roger Stonehouse:
Suspended sediment concentration in a proglacial meltwater river, Switzerland.

ALPINE GLACIERS

Andrew Fountain:
Hydrology of the firn, South Cascade Glacier, U.S.A.

Campbell Gemmell:
The basal ice of a temperate glacier - material content and implications for the study of entrainment.

David Collins:
Climatic variations and run-off from Alpine glaciers.

SNOW CHEMISTRY

Acid Rain Group (Trevor Davies, Martyn Tranter et al):
Is preferential elution a major process in the chemical evolution of snow?

John Moore:
A rapid method for the dielectric profiling of ice cores.

Eric Wolff and David Peel:
New measurements of heavy metal concentrations in Greenland surface snow.

Martin Sharp:
Tectonic processes in surging glaciers as analogues for the evaluation of falling thrust belts.

The 1986 Branch meeting will be held at Homerton College, Cambridge on September 11-12 1986. Dr Julian Dowdeswell, at the Scott Polar Research Institute, is organising the meeting.

At the Annual General Meeting of the British Branch, Dr David Collins assumed the post of President, taking over from Dr Dougal Goodman who had held the post for two years.

Dr Julian Paren was elected to the post of Vice President, and Dr Julian Dowdeswell to the post of Secretary/Treasurer. Retiring office bearers were thanked for their contributions to the life of the British Branch.

J.G. Paren

SYMPOSIUM ON ICE-CORE ANALYSIS

Bern, Switzerland, 30 March - 4 April 1987

The Society will hold a symposium on ice-core analysis in Bern, Switzerland in 1987. Registration will take place on Sunday 29 March and sessions will be from Monday 30 March to Friday 4 April in the Physics Institute, University of Bern.

TOPICS
The symposium will be concerned with analytical techniques, results and interpretations related to studies on ice cores from polar areas and from mid-latitude glaciers.

1. PARTICIPATION This circular includes a booking form, which should be sent to the Secretary General before 1 January 1987. Payments should be made in £ sterling, as indicated on the booking form.

Participants (IGS members)..... £90
*Participants who are not members..... £120
Accompanying persons (aged 18 and over) £40
There is no fee for those under the age of 18, unless they wish to attend the Banquet. Tickets for them may be purchased upon registration on 29 March.
* There is an administration surcharge for participants who are not members of I.G.S.

Participants' registration fees cover organization costs, distribution of preprints of summaries, Icebreaker, Banquet, and a copy of the Proceedings Volume.
Accompanying persons' registration fees include organization costs, Icebreaker and Banquet.

2. ACCOMMODATION
Accommodation will be arranged by the official Tourist Office and Convention Bureau of the City of Bern, in three categories of hotel. When completing the booking form, you should indicate which category you prefer.
Approximate prices per night for room and breakfast, with service charge and taxes included, are as follows (in Swiss francs):

	Single	Double
Cat. A (bath or shower)	80	110
Cat. B (bath or shower)	69	94
Cat. C (without bath/shower)	42	70

(Rates for 1987 may be slightly higher.)
(One Swiss franc is about US$0.50, or £0.30.)
Payments will be made direct to the hotel by the participants.

3. PAPERS
(i) SUBMISSION OF PAPERS
Those participants who would like to contribute to the Symposium should first submit a summary of their proposed paper in English; this summary should contain sufficient detail to enable the Papers Committee to form a judgement on the likely merit of the proposed paper, but should not exceed two pages of typescript, on international size paper A4 (210 x 297 mm).

Summaries should be sent to:
Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, England.

LAST DATE FOR SUBMISSION OF SUMMARIES – 14 JULY 1986

(ii) SELECTION OF PAPERS
Each summary will be assessed by the members of the Papers Committee, acting independently of each other, taking into account scientific quality and relevance to the topics of the Symposium. The Papers Committee will then invite a strictly limited number of papers for presentation and thorough discussion at the Symposium (not necessarily confining themselves to authors who have submitted summaries). It is hoped to notify authors of papers during October 1986.

(iii) DISTRIBUTION OF SUMMARIES
The summaries of the accepted papers will be distributed to all participants before the Symposium.

(iv) SUBMISSION OF FINAL PAPERS AND PUBLICATION
The Proceedings will be published by the International Glaciological Society in the *Annals of Glaciology*. Papers presented at the Symposium will be considered for publication in these proceedings, provided they have not been submitted for publication elsewhere. Final typescripts of these papers should be submitted to the Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, England, by 1 January 1987. They should be written in English and prepared in accordance with the instructions that will be sent to authors when they are notified about acceptance of papers for the Symposium. Authors will be told the maximum length for their papers when they receive notice of acceptance of their summaries. The papers will be refereed according to the usual standards of the Society before being accepted for publication. Speedy publication of the proceedings will depend upon strict adherence to deadlines.

LAST DATE FOR SUBMISSION OF FINAL PAPERS: 1 JANUARY 1987

PAYMENT SHOULD BE SENT IN £ STERLING

By cheque payable to

INTERNATIONAL GLACIOLOGICAL SOCIETY
and sent to:
Secretary General
International Glaciological Society
Lensfield Road,
Cambridge CB2 1ER
England

BOOKING FORM – REGISTRATION

SYMPOSIUM ON ICE-CORE ANALYSIS

30 March – 4 April 1987

Mail to: Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, England

BEFORE 1 JANUARY 1987

PLEASE PRINT OR TYPE

REGISTRATION

...../ .....
(family name) (initials)

Address .....

.....

.....

Accompanied by

Name .....

Participants (IGS members) .....£ .....

Participants (non-members).....£ .....

Accompanying person .....£ .....

PAYMENT SENT £ .....

DATE .....

BOOKING FORM – HOTELS

SYMPOSIUM ON ICE-CORE ANALYSIS

30 March – 4 April 1987

Mail to: Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, England.

BEFORE 1 JANUARY 1987

PLEASE PRINT OR TYPE

HOTELS

The undersigned reserves:

	Single room	Double room
Category A: (approx. 80 SF)	[ ]	(110 SF) [ ]
Category B: (approx. 69 SF)	[ ]	(94 SF) [ ]
Category C: (approx. 42 SF)	[ ]	(70 SF) [ ]

Date of ARRIVAL .....

Date of DEPARTURE .....

Number of nights .....

Arriving by CAR.....[ ]

Arriving by TRAIN/ BUS.....[ ]

The bill has to be paid by the participants directly to the hotel.

Signature
.....

Date .....

SYMPOSIUM ON ICE DYNAMICS

Hobart, Australia, 14 - 20 February 1988

The Society will hold a symposium on ice dynamics in Hobart, Tasmania, Australia in 1988. Registration will take place on Sunday 14 February and sessions will be from Monday 15 February to Friday 19 February in the University of Tasmania. Tours to Hawaii and New Zealand will take place in association with this event.

TOPICS

1. Derivation of flow law parameters from field and laboratory studies. 2. Results of field survey of ice sheet and glacier dynamics. 3. Modelling of the dynamics of ice masses. 4. The stability of marine ice sheets. 5. The flow of ice shelves. 6. Interaction of ice shelves and icebergs with the ocean. 7. The dynamics of sea ice.

PAPERS

The Papers Committee will be happy to consider papers on these topics. Further information about the topics, summaries and final papers will be given in the Second Circular, to be published in January 1987. Dates for submissions are firm ones and must be adhered to. The Committee may decide to invite review papers on some of the topics if submitted contributions do not give sufficient coverage.

PUBLICATION

The Proceedings of the symposium will be published by the Society in the *Annals of Glaciology*. Papers will be refereed according to the Society's usual standards before being accepted for publication.

SESSIONS

Sessions will be held on four full days. A full day excursion will be held during the week. Details will be given in the Second Circular.

ACCOMMODATION

Accommodation has been booked in Jane Franklin Hall of the University of Tasmania: details will be given in the Second Circular.

TOURS

HAWAII – HOBART – NEW ZEALAND

Package tours for members of I.G.S. and their accompanying persons will be arranged from Europe, North America and Japan. Details will be given in the Second Circular.

(a) *symposium only*, in Hobart;
(b) *symposium plus a 6-day pre-symposium tour* of Hawaii to study with University of Hawaii specialists the earth, life and atmospheric sciences and the history and culture of the state;
(c) *symposium plus a 6-day post-symposium tour* of the glaciers of New Zealand;
(d) *symposium plus Hawaii and New Zealand*

Please indicate below which of those 4 package tours will be of interest to you. Traveller's World, who handled the travel arrangements for the I.G.S. events in Japan and China in 1984, has been appointed by the Council to be our travel agent for the February 1988 events.
The local carrier within Australia will be TAA (Trans Australian Airlines).

SYMPOSIUM and TOUR ORGANIZATION
H. Richardson (Secretary General, I.G.S.)
LOCAL ARRANGEMENTS COMMITTEE
T.H. Jacka (Chairman)
I. Allison (Deputy Chairman)
W.F. Budd
P. Schwerdtfeger

INTERNATIONAL GLACIOLOGICAL SOCIETY
SYMPOSIUM ON ICE DYNAMICS, 1988

Family Name/s .....

First Name/s .....

Address .....

.....

Number of people [ ]
*I expect to submit a summary of a proposed paper
* I am/we are interested in joining a package tour from Europe/N. America/Japan for.....
(a) symposium only [ ]
(b) symposium plus Hawaii [ ]
(c) symposium plus New Zealand [ ]
(d) symposium plus Hawaii and New Zealand [ ]
* *without obligation*

TO BE SENT AS SOON AS POSSIBLE TO:
Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, England.

NORTHWEST GLACIOLOGISTS' MEETING

5-6 December 1985, University of British Columbia, Vancouver, B.C., Canada

The annual meeting of Northwest Glaciologists was convened by Garry Clarke at the University of British Columbia. As usual, it was very well attended and attracted participants not just from the Northwest but from elsewhere in the U.S. and from other countries. A list of the papers presented is given below.

J. Walder:
Penetration of ice into till.
R. Hooke:
Swedish glaciology.
K. Brugger:
Nonsynchronous behavior of Storglaciaren and Rabots Glaciers.
R. Jacobel:
Time variations of ice radar echos from Variegated Glacier.
S. Hodge:
Crete II site selection.
D. Jones:
Backpack portable ice radar with on-site computer processing and unattended data acquisition.
B. Hanson:
Mass balance boundary condition for a 2D ice sheet-model for the Barnes Ice Cap.
L. Mayo:
Internal accumulation in glaciers.
A. Letreguilly:
Statistical analysis of glacier mass balances in North America.
E. Waddington:
Is there basal ice melt at Crete?
G. Holdsworth:
Ice cores from Mt. Logan, YT, Canada.
R. Armstrong:
Mass balance history of Blue Glacier.
B. Vaughn:
Columbia Glacier - vertical motions near the terminus.
B. Dunlap:
Columbia Glacier - statistical analysis of velocity variations near the terminus.
R. Walters:
Proglacial oceanography of tidewater glaciers.
T. Pfeffer:
Finite element modelling of the lower part of Variegated Glacier during its surge.
T. Pfeffer:
Structures in the lower surge region of Variegated Glacier.
G. Clarke:
Probability analysis of surging glaciers in Canada.
B. Kamb:
Longitudinal stress coupling theory.
K. Hutter:
Solution strategies in numerical ice sheet flow modelling.
M. Fahnestock:
Water pressure variation during minisurges.
T. Pfeffer:
Radiation absorption by a crevassed surface.
C. Lingle:
Modelling Ice Stream B.
C. Driedger:
Ice volumes estimation on volcanoes in the Northwest.
J. Schmok:
Outburst floods of Lowell Glacier, YT in the geological record.
M. Maxwell:
Debris layers and isotopes.
L. Merliat:
Paleoclimatic and paleoenvironmental information from Antarctic ice cores.
P. Grootes:
Isotopes from Ross Ice Shelf cores.
E. Waddington:
Blue Glacier ice divide migration.
M. Balise:
Impulse radio soundings of the Blue Glacier ice divide.

FUTURE MEETINGS (of other organizations)

GLACIER FLUCTUATIONS AND CLIMATIC CHANGE

1–5 June 1987, Amsterdam, The Netherlands

The symposium will be organized by the Institute of Meteorology and Oceanography, University of Utrecht. The registration fee will probably be about hfl. 150 ($60). There is a limited budget for funding of participants (costs of travel and registration, not accommodation), on a competitive basis. Deadline for abstracts is 1 February 1987.

TOPICS include:
Records of glacier fluctuations on various time scales.
Inventory of the world's present glaciers
Mass-balance studies
Processes at the glacier/atmosphere interface.
Mathematical models of glaciers.
Modelling the response of glaciers to climatic change.
Long-term evolution of glacier/valley systems.
Glaciers and the carbon dioxide problem.

There may be a Workshop on a future data base of glacier distribution and fluctuations.

Sponsors: The University of Utrecht
The Dutch Ministry of Housing, Physical Planning and Environment
Koninklijke Nederlandse Akademie van Wetenschappen, through the Dutch section of the INQUA Commission.

Program committee:
J. Oerlemans (Chairman).
W. Haeberli
M. Kuhn
L. Reynaud
D. Sugden

For further information contact:
Local Organizer:
J. Oerlemans
Princetonplein 5
3508 TA Utrecht,
The Netherlands.

INTERNATIONAL SYMPOSIUM ON COLD REGIONS HEAT TRANSFER

4-6 June 1987, University of Alberta, Edmonton, Alberta, Canada

First Announcement and Call for Papers

OBJECTIVES AND TOPICS

During the past twenty-five years, considerable progress has been made in cold regions (Arctic) engineering due mainly to natural resources development in the Arctic regions. The subject of heat and mass transfer is of basic importance to cold regions engineering and is characterized by a multi-disciplinary approach.

The purpose of this conference is to provide a forum for the review and dissemination of recent scientific and technical information related to all aspects of heat transfer in cold climates. A general review of progress during the past quarter century should be of considerable value as furnishing a point of departure from which progress during coming decades may be measured.

The symposium is co-sponsored by:
- American Society of Mechanical Engineers (Heat Transfer Division)
- Japan Society of Mechanical Engineers
- Institute for Research in Construction, National Research Council Canada
- Centre for Frontier Engineering Research (University of Alberta)
- Centre for Cold Ocean Resources Engineering (Memorial University)
- Scott Polar Research Institute
- **International Glaciological Society**
- Boreal Institute for Northern Studies
- Canadian Society for Mechanical Engineering

Invited lectures on historical review and state of the art reviews in cold regions heat transfer will precede each technical session. The conference will be organized in conjunction with the Canadian Congress of Applied Mechanics, May 31 - June 4 1987.

The Topics will include:
Numerical and analytical methods for freezing and thawing.
Heat transfer problems relating to permafrost and soils.
Thermal engineering of structures in cold regions.
Natural and artificial heat transfer phenomena for ice in water, air, earth and life.
Heat transfer problems in engineering construction.
Human response to extreme conditions.
Energy utilization and conservation in cold regions.
Other heat transfer phenomena in cold regions.

TIME SCHEDULE AND PUBLICATION

Three copies of a 500-word abstract due.....October 15, 1986
Notification of abstract acceptance.....October 25, 1986
Five copies of complete manuscript.....December 5, 1986
Reviews returned to author/s.....January 10, 1986
Final manuscript, typed on mats, due.....February 10, 1987

The papers will be reviewed in accordance with ASME policies and published in a bound volume by ASME. Enquiries, abstracts, and manuscripts should be sent to either -

V.J. Lunardini, US Army Cold Regions Research and Engineering Laboratory, 72 Lyme Road, Hanover, NH 03755-1290, USA.
or -
K.C. Cheng, Dept. of Mechanical Engineering, University of Alberta, Edmonton, Alberta, Canada T6G 2G8.
or -
N. Seki, Dept. of Mechanical Engineering, Hokkaido University, Sapporo 060, Japan.

SYMPOSIUM ADVISORY COMMITTEE
K.C. Cheng, Edmonton
L.E. Goodrich, Ottawa,
G.S.H. Lock, Edmonton
V.J. Lunardini, Hanover
N. Seki, Sapporo
J.P. Zarling, Fairbanks

SPECIAL SESSION ON HOLOCENE GLACIER FLUCTUATIONS

August 1987, XII INQUA Congress, Ottawa, Canada

A day-long session on Holocene Glacier Fluctuations will be held at the 1987 INQUA Congress. It will consist of 2 parts: (1) eight invited review papers covering the Canadian Cordillera, American Cordillera, Alaska, Antarctica/South America, Africa, New Zealand, Scandinavia, and Alps/Himalayas; (2) poster presentations covering any aspect of Holocene or latest Pleistocene glacial history. The ultimate goal is to compare chronologies for glacial deposits throughout the world in an attempt to improve the proxy data base for understanding of Holocene climate change.
If you have any new information or are planning any new field work in the next year that you would like to present in a poster session at the Special Session, please contact either of the co-chairmen:

P. Thompson Davis,
Dept. of Geology
Mount Holyoke College
South Hadley,
MA 01075
U.S.A.

G. Osborn
Dept. of Geology
University Calgary
Calgary
Alberta T2N 1N4
Canada

A circular detailing poster format, publication plans, and abstract requirements will be sent to interested parties in Autumn 1986.

Scientific Committee on Antarctic Research (SCAR)

FOURTH INTERNATIONAL SYMPOSIUM ON ANTARCTIC GLACIOLOGY

7-11 September 1987, Bremerhaven, Federal Republic of Germany

The Fourth SCAR Symposium on Antarctic Glaciology (FISAG) will be held in Bremerhaven, Federal Republic of Germany. Sessions will take place in the Weserforum (City Conference Center) as well as in the Conference area of the new building of the Alfred-Wegener-Institute for Polar Research.
It is co-sponsored by the Alfred-Wegener-Institute for Polar Research, Bremerhaven, the Deutsche Forschungsgemeinschaft, Bonn, and the International Glaciological Society, Cambridge.
The topic of the Symposium will be *Surface Processes and Evolution of the Ice Sheet.* (Subjects such as Sea Ice and Applied Glaciology are excluded as they are covered by other symposia.)
The Proceedings of the Symposium will be published as a volume of the *Annals of Glaciology* of the International Glaciological Society. Papers will have to meet the standards of the Annals in order to be acceptable for publication.
Further information concerning the Symposium can be obtained from:

Dr H. Kohnen
Chairman, Local Organizing Committee
c/o Alfred-Wegener-Institute for Polar Research
Columbus-Center
2850 Bremerhaven
Federal Republic of Germany

NOTES FROM THE U.S.A. WESTERN REGION

A new book, *A Visitor's Guide to Mount Rainier's Glaciers*, by Carolyn Driedger, is due for publication in June 1986. This book was commissioned by Mt. Rainier National Park and is a layman's guide to the glacial features of Mt. Rainier. Much of the book is a synopsis of previous U.S.G.S. studies; however it does include previously unpublished terminus variations and other glacier observations. The Pacific Northwest Parks and Forests Association is subsidizing the cost of publication. The author, Carolyn Driedger, is employed with the Project Office - Glaciology, U.S. Geological Survey in Tacoma, Washington.

The Avalanche Research Project of the U.S. Forest Service, Fort Collins, Colorado, has been disbanded after many years of very successful service to snow research. The Project Chief, Dr M. "Pete" Martinelli, and Dr A. Judson have retired. Dr R.A. Schmidt joined the Blowing Snow Project, U.S. Forest Service in Laramie, WY, and Dr R. Sommerfeld joined the Mountain Meteorology Project, U.S. Forest Service in Ft. Collins, CO.

Dr Ronald Tabler, Project Chief of the Blowing Snow Project, U.S. Forest Service, Laramie, WY, has retired effective January 3, 1986, after 25 years with the Forest Service. He plans to continue his work in snow as a consultant and hopes to keep active in research. The new Project Chief is Dr D. Sturges.

WORLD GLACIER MONITORING SERVICE

The tasks of two exisiting ICSI services - the Permanent Service on the Fluctuations of Glaciers (PSFG) and the Temporary Technical Secretariat for the World Glacier Inventory (TTS) - have been combined into a new service - the World Glacier Monitoring Service (WGMS). It will concentrate its efforts on: (1) The establishment of an annual or bi-annual publication series containing selected mass balance results (running time series); (2) The investigation of ways of summarizing glacier fluctuation data (classification of glaciers, intercomparison of glacier length variations); (3) A feasibility study and the use of satellite observations in selected remote areas; (4) The continuation of the publication of general fluctuation data at 5-yearly intervals; (5) The completion and updating of regional preliminary glacier inventories.

Further information can be obtained from;

Dr Wilfried Haeberli,
Director of the WGMS,
Section of Glaciology, VAW/ETHZ,
ETH-Zentrum
8092 Zürich, Switzerland

RECENT PUBLICATIONS

Dating Methods of Pleistocene Deposits and Their Problems, edited by N.W. Rutter, ISBN 0-919216-15-3, was published in 1985 as Geoscience Canada Reprint Series 2. It contains chapters on the following aspects: thermoluminescence dating, uranium-series disequilibrium dating, the promise of atom counting, amino acid racemization dating, tephrochronology and fission-track dating, paleomagnetism, paleosols, weathering, and electron spin resonance. It may be ordered from Geological Association of Canada, GAC Publications, Business and Economic Service Ltd., 111 Peter Street, Suite 509, Toronto, Ontario M5V 2H1, Canada for Can$12 plus $3 postage and handling.

Glyatsiologicheskiy Slovar': Glossary of Glaciology A/Z, edited by V.M. Kotlyakov, 1984, Leningrad Gidrometeoizdat, U.S.S.R. This is a first attempt at compiling a comprehensive glossary of glaciology and related earth sciences. It covers all types of snow and natural ice: snowcover, avalanches, sea, river and lake ice, ground ice and aufeis, as well as such phenomena as glacial mudflows. The entries contain definitions, in Russian only, of 2200 terms with explicit references to related processes and phenomena. The glossary is illustrated with line drawings and photographs and includes 316 references.

Field and Theory - Lectures in Geocryology edited by M. Church and O. Slaymaker, ISBN 0-7748-0204-9, University of British Columbia Press, Vancouver, 1985, 213 pp. This collection of papers was originally presented as a series of lectures at the University of British Columbia in 1980-81 in honour of J. Ross Mackay. Together they illustrate the central dilemma in a science where fieldwork must be undertaken in the harsh periglacial environment and where, consequently, it is difficult to test theory rigorously. The papers provide an overview of the current status of international research in a wide area of the field - permafrost, patterned ground, and cold climate pheomena and processes. The treatment varies from anecdotal, historical. and descriptive to mathematical. Papers have been contributed by W.H. Mathews, A. Jahn, A. Rapp, B.B. Fitzharris, L.W. Gold, M.W. Smith, S.I. Outcalt, N.R. Morgenstern, N.N. Romanovskij and A.L. Washburn.

The studies on soil freezing, ice formation and thaw are relatively sophisticated treatments that are physically sound, theoretically based, and quantitatively precise, as are the computational methods and the extension of results to engineering site evaluations given in other contributions. The regional accounts of geocryological and nival phenomena, on the

other hand, remain entirely empirical and, for the most part, qualitative. This critical mismatch of understanding between microscale and regional scale is emphasized in the review of the status of periglacial studies. Ross Mackay's most valuable contribution to science has been his consistent demonstration of how to occupy the middle ground by applying simple physical concepts to explain variations in the landscape.

GLACIOLOGICAL DIARY

** IGS Symposia
* Co-sponsored by IGS

1986

2-10 July
I.A.H.S. 2nd Scientific Assembly, Symposium on Modelling Snowmelt Induced Processes. Budapest, Hungary. (A. Szöllösi-Nagy, VITUKI, H-1453 Budapest, Pf 27, Hungary)

13-27 July
Chemical Dynamics of Seasonal Snowcovers, NATO Advanced Study Institute, Savoy, France. (H.G. Jones, INRS-Eau, CP 7500, Sainte-Foy, Québec, G1V 4C7, Canada)

22-25 July
Cold Regions Hydrology Symposium, American Water Resources Association. Fairbanks, Alaska, U.S.A. (Douglas L. Kane, Inst. of Water Resources, Engineering Experiment Station, Univ. of Alaska, Fairbanks, AK 99701, U.S.A.)

18-22 August
* 8th Symposium of the I.A.H.R. Section on Ice Problems. Iowa City, U.S.A. (R. Ettema, Inst. of Hydraulic Research, Univ. of Iowa, Iowa City, IA 52242, U.S.A.)

30 August - 5 September
* VII Symposium on Physics and Chemistry of Ice. Grenoble, France. (VII Symposium on Physics and Chemistry of Ice, Laboratoire de Glaciologie, BP 68, 38402 St. Martin d'Hères cedex, France)

6-12 September
** Symposium on Remote Sensing in Glaciology and 50th Anniversary of the IGS. Cambridge, England. (Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, U.K.)

11-12 September
** British Branch meeting, International Glaciological Society. Homerton College, Cambridge, England. (J.Dowdeswell, Scott Polar Research Institute, Lensfield Road, Cambridge)

14-19 September
* International Symposium on Avalanche Formation, Movement and Effects. Davos, Switzerland. (C.Jaccard, Symposium 1986, EISLF, Weissfluhjoch, CH-7260 Davos-Dorf, Switzerland)

27-30 October
Polar Tech '86, Inter. Offshore and Navigation Conf. Helsinki, Finland. (Technical Research Centre of Finland, Lab. of Structural Engin. Betonimiehenkuja 3, 02150 Espoo, Finland)

28-30 October
3rd Annual Arctic Offshore Technology Conference, Calgary, Alberta, Canada. (AOTC Head Office, #101–3009–23 Avenue S.W., Calgary, Alberta, T3E 0J3, Canada)

1987

March
** North East North American Branch meeting, International Glaciological Society. Location to be announced. (S. Ackley, US Army CRREL, 72 Lyme Road, Hanover, New Hampshire 03755, U.S.A.)

30 March - 4 April
** Symposium on Ice-Core Analysis. Bern, Switzerland. (Secretary General, IGS, Lensfield Road, Cambridge CB2 1ER, U.K.)

1-5 June
Symposium on Glacier Fluctuations and Climatic Change. Amsterdam, Netherlands. (J. Oerlemans, Princetonplein 5, 3508 TA Utrecht, The Netherlands)

4-6 June
International Symposium on Cold Regions Heat Transfer. Edmonton, Alberta, Canada. (V.J. Lunardini, CRREL, 72 Lyme Road, Hanover, NH 03755, U.S.A., or K.C. Cheng, Dept. Mechanical Engineering, University of Alberta, Edmonton, Alberta, Canada T6G 2G8, or N. Seki, Dept. Mechanical Engineering, Hokkaido University, Sapporo 060, Japan)

31 July - 9 August
12th Congress of the International Union for Quaternary Research. Ottawa, Ontario, Canada. (L. Baignée, Secretariat, XII INQUA Congress, c/o National Research Council of Canada, Ottawa, Ontario K1A 0R6, Canada)

31 July - 9 August
Holocene Glacier Fluctuations, 12th INQUA Congress. Ottawa, Ontario, Canada. (P.T. Davis, Dept. Geology, Mount Holyoke College, South Hadley, MA 01075, U.S.A. or G. Osborn, Dept. Geology, University of Calgary, Calgary, Alberta, T2N 1N4, Canada)

9-22 August
Symposium on the Physical Bases of Ice-sheet Modelling, IUGG General Assembly. Vancouver, BC, Canada. (E. Waddington, Geophysics Program AK-50, University of Washington, Seattle, WA 98195, U.S.A.)

9-22 August
Symposium on Marginal Ice Zone Processes. IUGG General Assembly. Vancouver, BC, Canada. (R.D. Muench, Science Applications Inc., 13400 B Northrup Way, Suite 36, Bellevue, Washington 98005, USA or K. Davidson, Dept. Meteorology, Naval Postgraduate School. Monterey, CA, U.S.A.)

9-22 August
Symposium on Large Scale Effects of Snow Cover, IUGG General Assembly, Vancouver. BC, Canada. (B.E. Goodison, Atmos. Environ. Service, Environment Canada, 4905 Dufferin St., Downsview, Ontario M3H 5T4, Canada)

9-22 August
Workshop on River Ice, IUGG General Assembly. Vancouver, BC, Canada. (K.S. Davar, Dept. Civil Eng., Univ. New Brunswick, Fredericton, NB E3B 5A3, Canada)

7-12 September
* Fourth SCAR International Symposium on Antarctic Glaciology. Bremerhaven. FRG. (H. Kohnen, Alfred-Wegener Inst. for Polar Research, Columbus Center, D-2580 Bremerhaven, FRG)

1988

14-19 February
** Symposium on Ice Dynamics. Hobart. Australia. (Secretary General, IGS, Lensfield Road, Cambridge CB2 1ER, UK)

September
** Symposium on Applied Glaciology. Norway. (Secretary General, IGS, Lensfield Road, Cambridge CB2 1ER, UK)

1989

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

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

NEW MEMBERS

S.J. Bolsenga, Great Lakes Environment Research Institute, 2300 Washtenaw Avenue, Ann Arbor, MI 48104, U.S.A.

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Founded by G. Seligman

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