NUMBER 84 2nd ISSUE 1987

ICE

NEWS BULLETIN OF THE INTERNATIONAL GLACIOLOGICAL SOCIETY

INTERNATIONAL GLACIOLOGICAL SOCIETY

ISLANDS SAFARI 1988

The Ice Dynamics symposium in Hobart, Tasmania, 14-20 February 1988, will be the Society's first-ever meeting in the southern hemisphere. Registration for the symposium should be made with the Society using the form in the Second Circular previously mailed to you.

A post-symposium tour to New Zealand, 20-26 February, will take us to the glaciers of South Island. The five days are organized by our New Zealand members, who are experienced in creating tours that are as memorable for the magnificent scenery as for the efficiency of the organization.

An added treat, 6-12 February, to be experienced en route to these southern hemisphere events, will be the visit to a very different island environment: Hawaii, just north of the Equator. Six days will be spent visiting these islands: Oahu, Maui and Hawaii (the Big Island). Faculty members from the University of Hawaii and other professional groups have created a unique programme for us, encompassing earth, life and atmospheric sciences and Polynesian history and culture.

The long-haul travel and land arrangements are in the capable hands of Traveller's World, who looked after us for our 1984 visits to Japan and China. It is greatly to the benefit of the Society for us to use the package tours described in the brochure that Traveller's World will mail to members in May.

The tours are based on two departure points (London for European members, Los Angeles for North American members) and use Continental Airlines on a westwards routing London-Los Angeles-Honolulu-Sydney. Japanese and Chinese members may join the tours in Honolulu. Internal travel in Australia is by Australian Airlines, who will fly us from Sydney/Melbourne to Hobart and back.

JOIN THE ISLANDS SAFARI!

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COVER PICTURE: Etching of Mer de Glace, France.
Photograph contributed by Robert Vivian.

FRANCE

ICE CORE STUDIES – ICE SHEETS

STABLE ISOTOPE STUDIES

(C. Lorius, J.R. Petit, Laboratoire de Glaciologie et Géophysique de l'Environnement (LGGE/CNRS) BP 96 38402 St Martin d'Hères Cedex, France)

Potential reconstruction of paleotemperatures from isotopic profiles is supported by empirical and atmospheric modelling studies (LGGE/CNRS, Laboratoire de Géochemie Isotopique (LGI, Saclay), Laboratoire de Météorologie Dynamique (LMD, Paris)).

A 2083 m-deep ice core obtained at Vostok (East Antarctica) by Arctic and Antarctic Research Institute, Leningrad, USSR (AARI), allowed them to obtain the first complete and unambiguous climatic record over the last climatic cycle (150,000 years), extending into the end of the previous glacial period. Results show that the present Holocene stage was preceded by a long glacial period marked by two relatively warm interstadials. The well-marked last interglacial was significantly warmer than the Holocene and the end of the previous glacial was quite similar to the last glacial maximum leading to an estimated temperature drift of about 10°C for surface temperature.

Current work indicates that most of the deduced paleotemperature changes could be explained by local insolation (with a well-marked 40 kyr cycle), northern hemisphere climate (as depicted also from ice volume changes obtained from marine records), and mainly by CO_2 atmospheric concentrations (LGGE, LGI, SAE and Institute of Geography, Moscow).

ICE CRYSTAL GROWTH IN POLAR AREA

(J.R. Petit, P. Duval and C. Lorius; LGGE/CNRS)

The growth rate of ice crystals in polar areas is believed to depend mainly on in-situ temperature, strain conditions, soluble and non-soluble impurities. In fact, the above mentioned parameters cannot explain the observed variations in the growth rate that we observe in Dome C and Vostok ice.

We suggest that the crystal growth rate is mainly driven by a "built-in" memory of the temperature at the time of deposition. We have, thus, besides the isotopic composition of the ice, a new tool for estimating paleo-temperatures. The proposed semi-quantitative model gives a Last Glacial Holocene temperature shift of ≈ 10°C which is in agreement with estimations based on the isotope measurements. Nevertheless, for other ice cores, the model suffers limitations since the climatic signal could be marked by strain conditions.

GAS STUDIES ON ICE CORES

(D. Raynaud, J.M. Barnola, D. Mazaudier, C. Lorius; LGGE/CNRS)

Studies in progress are related to the measurements of the total gas content of ice and the composition of the air trapped in ice cores, including CO_2, other radiatively active trace gases (N_2O, CH_4, in collaboration with the Fraunhofer Institut in Garmish), isotopic composition of O_2 and CO_2 (with the University of Rhode Island and Centre des Faibles Radioactivités in Gif sur Yvette).

These studies are worked out on different ice cores including the Vostok core in collaboration with the Soviet Antarctic Expedition (SAE), the Dome C and D 57 cores, the Mt Logan core (collaboration with G. Holdsworth, NHRI, Canada), the Mizuho and Yamato cores (collaboration with F Nishio, NIPR, Japan).

One of the most recent striking results concerns the 160 kyr atmospheric CO_2 record contained in the Vostok core. Available data indicate a high correlation between CO_2 and Antarctic climate, with CO_2 concentrations similar to the "pre-industrial" level during the two interglacials and much lower during the glacial periods (LGGE/CNRS, SAE).

CHEMICAL COMPOSITION OF ANTARCTIC PRECIPITATION

(R. Delmas, M. Legrand, S. Kirchner, F. Zanolini; LGGE/CNRS and A. Aristarain, IANIGLA, Mendoza, Argentina)

The chemical composition of Antarctic precipitation is now better understood. All major soluble ions (Na^+, k^+, NH_4^+, Mg^{++}, Ca^{++}, SO_4^{--}, NO_3^-, Cl^- and H^+) have been determined by ion chromatography (except H^+ which is obtained by titration). The measurements necessitate the use of contamination-free techniques for sample collection, transport and analysis. A very close balance between anion and cation concentration has been obtained for more than 1000 snow and ice samples. The study locations have been Terre Adélie sites, Dome C, South Pole, Vostok, James Ross Island (Antarctic Peninsula), and Byrd Station. Except in most coastal areas, where the sea salt contribution is important, the dominant soluble impurities are the 3 mineral acids H_2SO_4, HNO_3 and HCl (the latter is not always present). This composition can be considered as representative of a global atmospheric background. Most of the sulphuric acid is contributed by marine biogenic activity whereas nitric acid is most likely produced by lightning at mid-latitudes. Hydrochloric acid is formed by the interaction of H_2SO_4 with sea salt particles. An additional and sporadic source of H_2SO_4 is provided by the

very large volcanic eruptions of global concern.

During the last glacial age, the atmospheric impurities were mostly crustal dust and sea salt particles, produced at this time in great amounts. On the other hand, the strength of the mineral acid sources was not changed significantly during this time period.

All these results are relevant for atmospheric chemistry studies, in particular for the understanding of biochemical cycles.

MICROPARTICLES OVER THE LAST CLIMATIC CYCLE

(J.R. Petit, L. Mounier, M. de Angelis and C. Lorius; LGGE/CNRS and N. Barkov and Petrov; AARI/Leningrad)

From the Vostok ice core covering the last 150 kyr, non-soluble microparticle profiles are now completed. Profiles of particles with radius >0.4 μm are obtained by Coulter Counter measurements for concentration and size distribution. Data are compared with countings obtained with an optical microscope and with aluminium concentration obtained by Instrumental Neutron Activation. Mineralogy of individual microparticles is studied with a microprobe mounted on a transmission electron microscope (with Gaudichet LEPI/Paris, R. Lefevre LMAAST/Univ, Paris XII/Créteil). Major changes observed in concentration are linked with glacial-interglacial climatic transitions.

COSMIC DUST IN POLAR AREAS

(M. Maurette, Laboratoire Réné Bernas, BP1, Bt 108, 91406 Orsay, Campus, France; M. de Angelis, LGGE/CNRS; M. Pourchet, LGGE)

Studies of micrometeorites (cosmic material smaller than a few hundreds of micrometers) are important for the knowledge of the primitive solar system. Until 1985, most of the available data concerned particles which had been found in marine sediments and were therefore highly corroded. A natural concentration process occurring in the melt zone of the Greenland ice cap allowed M. Maurette and C. Hammer (Geophysical Isotope Laboratory, Copenhagen, Denmark) to collect in 1985 very large quantities of much better preserved extraterrestrial particles. However, due to the fact that during a few months each year they lie in a liquid medium, those particles were coated with a calcareous cocoon whose elimination induced the destruction of the most brittle dusts. So, in aiming to find well-preserved micrometeorites we intend to collect them directly in snow areas where no summer melting occurs. The sampling programme will be realised in 1987-88 in coastal areas of Adélie Land, where blue ice from central areas (where the annual snow accumulation rate and terrestrial background are very low) outcrops. Melting a few thousands of litres of ice should allow us to get a population of particles quite representative of the cosmic dust flux over the earth.

RECONSTRUCTION OF THE PAST ATMOSPHERIC COMPOSITION THROUGH ANTARCTIC DEEP ICE CORES ANALYSIS

(M. de Angelis, LGGE/CNRS; N.I. Barkov, V.N. Petrov, Arctic and Antarctic Research Institute, Leningrad, USSR)

Due to removal processes occurring over Antarctica, the chemical composition of the snow layers is well correlated to the atmospheric aerosol content. Decontaminated ice samples have been studied by thermal neutron activation and flameless atomic absorption analysis. The concentrations of continental (i.e. Al, Ca, Mg and marine (i.e. Cl, Na)) indicators have been measured over time periods varying from 30 to 160 kyrs and then including glacial periods. (The $\sigma^{18}O$ concentrations in the same samples provide climatic information.) Marine and continental aerosol contents over Antarctica were respectively ≃30 times higher during the coldest periods of glacial stages than during the penultimate interglacial and the Holocene periods. We consider that it was a consequence of the glacial climatic conditions and was driven by stronger atmospheric circulation, enhanced aridity and faster aerosol transport towards Antarctica.

Presently attempts are being made to get further information concerning the potential sources areas of continental aerosol during the glacial age, mainly by analysing the insoluble and soluble parts of each continental indicator and by studying the temporal variations of their relative abundance.

LEAD IN ANTARCTIC ICE DURING THE LAST 155,000 YEARS

(C.F. Boutron, LGGE/CNRS; C.C. Patterson, Division of Geological and Planetary Sciences 170-25, California Institute of Technology, Pasadena, California, 91125, USA)

As part of a collaboration between the LGGE and the California Institute of Technology, concentrations of lead have been measured by ultraclean Isotope Dilution Mass Spectrometry in numerous sections of the Antarctic Dome C deep ice core which integrates the last 32,000 years and of the Antarctic Vostok deep ice core which integrates the last 155,000 years.

For each section, series of veneer layers were mechanically chiselled in sequence from the outside to the inside of the core. Lead concentrations were shown to decrease abruptly along a radius from the outside to the centre of the cores. For most sections, a clear plateau of concentrations was obtained in the inner parts of the cores, thus establishing that the lead concentrations measured in the centre of the cores do represent the original ones in the Antarctic ice.

Lead concentrations are found to have varied widely in Antarctic ice during the last 155,000 years: they were high, up to 35 pg Pb/g, during the end of the ice age (Illinois) which preceeded the last interglacial, and during the Last Glacial Maximum. They

were on the other hand low, down to about 0.3 pg Pb/g, during the last interglacial, the first two-thirds of the last ice age (Wisconsin), and the Holocene.

Soils dust appears to be the major source of natural lead, but the volcanic contribution is found to be significant during low lead time periods.

SPECTRAL ANALYSES OF CLIMATIC DATA FROM ICE DEPOSED AT DOME C (ANTARCTICA)

(J.P. Benoist, LGGE/CNRS).

Two isotopic and one crystal growth series from two different cores taken at Dome C (Antarctica) were studied. Because of the natural variability of accumulation in this area, it is assumed that these cores are randomly sampled. Theoretical considerations and simulations have shown that such sampling limits the risk for detection of allied frequencies. When the signal is noisy, simple linear interpolation and low-pass filtering are convenient for obtaining regular sampling. The window filtering method and the adjustment splines of order two are studied. Splines seem to be suited to remove the low frequencies whose energy is about 97% of the energy of the climatic signal: an empirical relation between the smoothing factor of splines and the low-pass equivalent filter gives results identical to those of the window method. With the evolutive spectral analysis by Maximum Entropy, various datations of these series are discussed. The study of a 2,000-year core shows the perturbations generated by a bad transformation from real depth to water equivalent depth; smoothing of density data by Reinsch's method to estimate spline function gives very satisfactory results. Evolutive spectral analysis suggests that the bottom of the 905 m-deep core could be 38,500 ± 2,500 years old. Very low frequencies represent about 97% of the total energy; the remainder is shared between periodicities: 3,600 ± 300 years, 2,500 ± 200 years, 1,700 ± 150 years, 1,400 ± 150 years, 1,200 ± 100 years and 350 ± 30 years. Part of the results could be generated by the sampling process or by computing artifices.

MECHANICAL BEHAVIOUR OF POLAR ICE

(P. Duval, L. Lliboutry, P. Pimienta, LGGE/CNRS)

Recent work has focussed on the mechanical behaviour of polar ices. Laboratory tests were carried out in order to study the flow behaviour of small-grained ices at low stresses. A Newtonian viscosity is expected with dislocation glide accommodated by grain boundary migration linked with grain growth. Strain-induced grain boundary migration is an efficient mechanism to accommodate the incompatible plastic deformation between grains of different lattice orientation. It is also shown that most fabrics of polar ices result from the rotation of c-axes by dislocation glide. The flow behaviour of anisotropic ice has also been analyzed. These findings should help to describe more accurately the flow of ice sheets.

TEMPERATURE FIELD IN AN ICE SHEET

(C. Ritz, LGGE/CNRS)

A bidimensional model for solving a time-dependent heat equation is developed. The surface temperature, accumulation rate and ice sheet thickness are prescribed with time. The calculation is made both in ice and rock. A sensitivity study shows that a rock thickness of 2 km is sufficient to take into account the influence of the temperature perturbations in rock. This model is used to interpret the temperature profile measured in the Vostok hole. First results indicate that the geothermal heat flux in the Vostok area should be higher than 45 mW/m^2.

NUMERICAL SIMULATION OF ICE FLOW

(J. Meyssonnier, LGGE/CNRS)

Slow flows of ice considered as a non-linear viscous material are modelled using the finite element method. Special attention is given to basal sliding boundary conditions of temperature glaciers. Now a finite element model of ice caps in the short scale range, which is to be incorporated in a simpler global flow one, is being developed.

ICE CORE DRILLING

(D. Donnou, LGGE/CNRS)

After the 905 m deep drilling made in 40 days at Dome C (Antarctica) using a thermal core drill in a dry hole, the laboratory is developing a thermal drill working in a fluid. This equipment will be set up and tested during the next years in Adélie Land. This drill should reach the bedrock in the central regions of Antarctica and recover ice cores of 8 m long and 123 mm in diameter.

With this system of drilling we hope to perform a complete coring during a summer field season.

At the same time, an electromechnical drill (200 m) has been used during the summer seasons on different sites:

Dome C	: 140 m 180 m
Adélie Land	: D15 150 m D57 203 m
James Ross Is	: 150 m
South Pole	: 143 m 127 m and other
Mont Blanc (Col du Dôme, 4,250 m)	: 70 m

This drill uses round cutters which give good results and allow us to perform on the 100 m ϕ cores all the scientific observations planned.

An ultra-light electro-mechanical drill (50 m) has been developed (weight 60 kg including the generator). This equipment can be used by a single operator during traverses and is set up quickly. It can collect 75 mm-diameter cores in runs of 150 cm length.

FLUCTUATIONS OF ALPINE GLACIERS

(L. Reynaud, M. Vallon LGGE/CNRS)

In the French Alps, the annual survey programme of glacier fluctuations concerns mainly 10 glaciers selected for the length of existing measurements and for their easy access.

The aim of this systematic survey consists of establishing a data set indispensable for understanding glacier fluctuation mechanisms, their modelling and finally their climatic significance. The systematic survey deals with changes in mass balance, velocity, mean altitude of fixed cross-profiles and length of glaciers. The surveyed glaciers lie in the Mont Blanc range (4), Vanoise (1), Grandes Rousses (2) and Ecrins (3).

Following their morphology these glaciers are more suited to mass balance survey (Saint Sorlin and Sarennes glaciers: Grandes Rousses) or to dynamics (Argentières and Mer de Glace glaciers: Mont Blanc). Whereas the Sarennes glacier gives the oldest direct mass balance series (since 1948, surveyed by F. Valla, CEMAGREF). Saint Sorlin will be in its thirtieth year in September 1987.

The last 10 years, since 1976, have been characterized by 5 years of very good alimentation, followed by 5 years of heavy melting (especially the last two years).

Such balance variation deeply modified the glacier dynamics, causing particularly a well-marked kinematic wave on the Mer de Glace tongue.

This recent period caused various problems to the users of glaciers (water intake near the snout or under the glacier on the bed, cable car near the glacier or skiing stations . . .). In this case, glaciologists are faced with the interesting but delicate forecasting of snow variations, changes in altitude of the glacier surface or management of the firn layer.

Finally this programme deals also with methodology of data acquisition as well as their interpretation. This is the reason we developed tools to bore balance stakes (15 m) or to bore holes of small diameter (Rado et al., *Journal of Glaciology*, in press), and on the other hand are trying to find alternative methods to determine mass balance variations (Reynaud et al., *Journal of Glaciology*, in press).

GLACIER SURVEY

(R. Burnet, F. Valla, Centre National du Machinisme Agricole, du Génie Rural, des Eaux et Forêts, (CEMAGREF), BP 76 38402 St Martin d'Hères Cedex, France)

In 1986, the photogrammetrical survey of the glaciers located in Savoie was achieved. The terrestrial measurement of snow depth on the glacier of Sarennes (Oisans) was carried out.

OPTICAL MEASUREMENTS

(C. Sergent, Centre d'Etude de la Neige (C.E.N.), BP 44, 38402 St Martin d'Hères Cedex, France)

Diffuse light extinction has been measured for visible and near infrared wavelengths through various snow types, among which were depth hoar, fine grains and melt-freeze particles. Empirical relationships were derived giving the asymptotic extinction coefficient versus grain size and relative density for wavelengths from 400 nm to to 1000 nm.

THERMAL CONVECTION IN SNOW

(E. Brun, C.E.N.)

Several experiments conducted on snow samples from 150 to 440 Kg/m^3 revealed that the effective thermal conductivity was not dependent on heat flow, giving evidence that no thermal convection occurred in the snow samples even in extreme conditions. The reliability of the experiment was checked by the consistency of measured thermal conductivity data in steady-state and in transient state with Yen's formula. The conclusion of this experiment is that thermal convection is unlikely in natural alpine snowpack.

SNOW MORPHOLOGY

(E. Brun, C.E.N.)

By digitizing the output of a video camera, numerical analysis was performed on pictures of scattered snow grains. This convenient technique was developed and used for a quantitative study of weak gradient metamorphism.

AVALANCHE FORECASTING

COMPUTER-AIDED AVALANCHE FORECASTING

(J.L. Dumas, C. Genre, C.E.N.)

Daily avalanche hazard forecasting is now operated in France in every mountain region with the help of computer processing of snow and weather data. Storage, display, basic processing are done on a network of 9 micro computers connected to a central processing centre in real time in Centre de la Neige (Grenoble). Available statistical models and thermodynamic simulation of the snowpack are to be integrated in this application.

An expert system for avalanche risk forecasting is also being developed.

SKILL EVALUATION

(G. Giraud, E. Pahaut, C.E.N.)

A skill evaluation method was studied for avalanche forecasting, relying on the comparison of the eight-level hazard scale index to a regional avalanche activity index.

STATISTICAL FORECASTING
(J.P. Navarre, G. Guyomarc'H, C.E.N.)
A statistical model for local avalanche warning on ski areas was set up for operational use by the safety office of the ski resort. It is based both on nearest neighbour selection and on discriminant analysis.

SNOWDRIFT MODELLING
(P. Beghin, T. Castelle, CEMAGREF)
Using quartz particles in a water flume, studies of buildings and snow fences were conducted. The results are of qualitative interest but the behaviour of sand in water and snow in air are difficult to match, especially from the fact that quartz is cohesive whereas snow is not.

AVALANCHE LIMITS
(B. Berthier, CEMAGREF)
Applying a Norwegian method, statistical studies were conducted to assess the extreme limit of avalanches from topographical data, the model being calibrated from a file of well- known avalanche zones. The model gives satisfactory results in the Haute-Savoie département (Chamonix and other places).

AVALANCHE DYNAMICS
(J.P. Vila, CEMAGREF)
The numerical simulation of dense avalanches was improved due to the use of new explicit shock-fitted models. These models allow a better simulation of singularity than clasical implicit models. The model was also applied to the movements of water caused by an avalanche flowing into a lake. Simultaneously, some physical modelling was performed to calibrate the mathematical model.

POWDER SNOW AVALANCHE
(G. Brugnot, F. Rapin, CEMAGREF)
A code was written as an application of the physical simulation conducted from 1974 to 1982. This code can be used to assess the potential damages of a powder snow avalanche. The results are very sensitive to the value chosen for the depth of snow collected by the avalanche.

EXPERT SYSTEMS AND AVALANCHE ZONING
(P. Audfray, C. Charlier, CEMAGREF)
The feasibility of an expert system applied to avalanche zoning was tested. It appeared that the elaboration of an actual expert system providing a substantial help in avalanche zoning is remote but some tools of artificial intelligence may be useful provided they are combined with 3D representation method.

ATMOSPHERIC ICE

ATMOSPHERIC ICING
(P. Personne, Laboratoire Associé de Météorologie Physique (LAMP) BP 45 63170 Aubière, France)
One objective of the "Physics of Precipitation Group" at the LAMP concerns the study of the atmospheric icing. More precisely, the main topics are the following:

Extensive *in situ* measurements of the microphysical parameters in different types of icing clouds.

Statistical studies and collaboration with the Federal Aviation Administration of the U.S.A. for the establishment of a data base on the characteristics of icing clouds.

Research on the icing processes. Role of the meteorological parameters on the ice growth and effects on ice density and crystallographic structure.

Modelling of the icing growth for aircraft and ground structure (power lines) applications.

Collaboration with aeronautical industries for the certification in icing conditions of the new French and European helicopters and aircraft.

For these researches, the LAMP operates a specific microphysical instrumentation mounted on research aircraft and has conducted several experiments in France, Spain and Ivory Coast.

The Laboratory is also operating an instrument icing wind tunnel (air speed from 5 to 60 m s^{-1}) located at the summit of the Puy de Dome mountain (1500 m MSL). Computing systems are used to process the data and to provide numerical simulations.

APPLIED RESEARCH ON SNOW AND ICE
(P. Admirat, M. Maccagnan, Association pour les Applications Atmosphériques, 96, chemin des Sept Laux, 38330 St Ismier, France)
A3 is a new group of people who have a scientific and professional interest in industrial problems linked to atmospheric phenomena (snow, wind, evaporation or condensation ...). They have a background in the field of snow, cloud physics, hail, atmospheric ice, meteorology and sea ice.

During the year 1985-86 most of the work was connected to the study of wet snow, especially in relation to overhead power lines. Other research included the prevention of icing in chimneys, the making of submillimetric ice pellets, and the processing of remote sensing data on sea ice.

ICE PHYSICS – ICE MECHANICS

ICE PHYSICS
(J. Perez, J. Tatibouet, R. Vassoille, Groupe d'Etudes de Métallurgie Physique et de Physique des Matériaux (GEMPPM), INSA de Lyon, Bvd Einstein, 69 Villeurbanne, France)
Two types of research topics have been developed in the laboratory concerning the study of ice properties:

a) Study of the vitreous state stability obtained after quenching of glycerol or 1-2 propanediol aqueous solution such as those used in cryobiology ice crystallization conditions have been studied by means both

of internal friction measurements and X-ray diffraction experiments.

b) Micromechanical properties of ice are investigated essentially by very low frequencies internal friction measurements and microcreep experiments. Internal friction is now measured between 10^{-4} and 1 Hz in the temperature range 90-273 K. Recent results on bi- and polycrystals show a specific high temperature relaxation peak associated with grain boundary dislocations movement. Characteristics of this peak (relaxation intensity, activation energy . . .) are being examined in correlation with grain boundary structure.

EXTRATERRESTRIAL ICES

(J. Klinger, S. Espinasse, B. Schmitt, LGGE B. Schmitt (now at Huygens Laboratory, Leiden University, Netherlands))

Surface properties of different forms of ice are studied. Special attention is given to the behaviour of amorphous ice that has been obtained by condensation of water vapour at liquid nitrogen temperature. It has been found that this amorphous ice has an important surface area and a high microporosity. Clathrate hydrates have been produced when ice powders have been exposed to a sufficient pressure of a clathrate-forming gas. The kinetics of formation and of decomposition of hydrates formed in this way has been investigated. Special attention has been given to CO_2 clathrate. The purpose of this work is to obtain relevant physical parameters that can be used in the development of models of comet nuclei that is in progress in our laboratory and, perhaps, later on in the investigation of other ice-bearing bodies in the solar system.

ICE STRUCTURE INTERACTION

(P. Duval, J. Meyssonnier, LGGE/CNRS)

The new LGGE research programme on ice-structure interaction consists of the study of ice under indentation in the high strain-rate range ($10^{-3}s^{-1} < \dot{\varepsilon} < 10^{-1}s^{-1}$).

The main objectives of this study are to determine how the speed of the indentor influences the strength of ice, and how the boundary conditions influence the confining pressure which is an essential parameter in multiaxial stress-state situations.

High strain rate experiments will be performed using a 5 x 10^5 N instrumented hydraulic press which will allow the effects of the various parameters to be detected more precisely.

In order to achieve the behavioural laws of ice, the indentation tests will be modelled numerically. In a first stage the phenomenon of crushing at the ice-indentor interface will be studied.

This programme is a part of the France-Canada co-operation programme (participants: Institute for Marine Dynamics, Memorial University of Newfoundland, Centre for Cold Ocean Resources Engineering (Canada) – Institut Français du Pétrole – LGGE (France).

VERY SLOW FLOWS OF SOLIDS

(L. Lliboutry, LGGE/CNRS)

L. Lliboutry has sent the manuscript of his book *Very slow flows of solids, basics of modelling in geodynamics and glaciology* to the publisher Martinus Nijhoff. Together with basics of continuum mechanics at zero Reynolds number and of numerical computation, it exposes the microscopic processes of creep, the classical theories in glacial-isostasy and mantle convection in glacier and ice-sheet flow, stressing the many problems still open.

NEW ZEALAND

GLACIER SNOWLINES ANNUAL PHOTOGRAPHIC SURVEY

The annual end-of-summer glacier snowline survey was made on April 10 and 11, 1986. The coverage of snowline positions was incomplete due to a light covering of snow from a fresh fall in the eastern alps. In addition to annual variations in snowline attitudes, this survey provides data for the glacier inventory and provides an opportunity to record numerous other alpine glacial, erosional and structural features.

TASMAN GLACIER

A research student, Martin Kirkbride (Geology Department, University of Canterbury) is carrying out field work for a PhD dissertation on the sediment transport of the Tasman Glacier system. Essential measurements on the glacier include ablation, ice flow rates, and thickness and movement of the supraglacial debris cover.

DART GLACIER

Dr Graham Bishop (Geological Survey, Department of Scientific and Industrial Research) continued intermittent glaciological measurements on the Dart Glacier, although this programme is being wound down. On the névé and at the equilibrium line measurements of ablation and ice movement were continued, while on the tongue, subglacial bedrock profiles and ice surface profiles were investigated by seismic, gravity and resistivity measurements. Comparative photographs were also taken to monitor ice levels.

ANTARCTICA

During the 1985-86 summer season, a monitoring programme of hydrology and glaciology in the Dry Valleys region was continued. Mass balance measurements were continued on one glacier while ablation measurements were continued on the snouts of

the three glaciers. The equilibrium of Wright Valley glaciers is being investigated by measurements of frontal cliff positions. The positions of the fronts of eight glaciers were measured during the season.

In co-operation with a scientist from Sweden and a scientist from West Germany, a reconnaissance survey was made of the glaciers of Cape Bird, Ross Island, and a radio-echo sounding traverse was made of the Erebus Glacier ice tongue, from the snout to the névé area. In addition a 5 km radio-echo sounding traverse was made across the tongue of Wright Lower Glacier.

Trevor Chinn

NORWAY

Snow and glacier research in Norway is mainly carried out at three agencies: the Norwegian Polar Institute (NPI), the Norwegian Electricity and Water Resources Board (NVE) and the Norwegian Geotechnical Institute (NGI).

NPI is a governmental institute, responsible for research both in Arctic and Antarctic regions. NVE is the governmental department for the administration of water resources and the development of hydropower plants. Within the NVE is an office for glacier research working on surveying domestic glaciers and predicting the run-off of the glaciers. The NGI is a private research and consulting company, concentrating on snow research of avalanches and snow pressures on constructions. The main research financing sources are governmental research funding and research and development contracts from governmental agencies.

NORWEGIAN GEOTECHNICAL INSTITUTE

SNOW GLIDING

Snow pressures on constructions

(J.O. Larsen, NGI and D. McClung, National Research Council of Canada)

At the snow research station in Grasdalen, Western Norway, a retaining wall, two cylindrical pipes and the base of a high-voltage transmission tower have been erected on a 25° slope, exposed to both snowgliding and creeping. The installations are instrumented for calculating the resulting snow pressures.

The projects are related to different theories for plastic deformation and for recording snow material properties such as density, temperature and ram hardness.

Publications:

D.M. McClung, J.O. Larsen and S.B. Hansen (1984). Comparison of snow pressure measurements and theoretical predictions. *Canadian Geotechnical Journal*, vol 21(2): 250-58.

J.O. Larsen, D.M. McClung and S.B. Hansen (1985). The temporal and spatial variation of snow pressure on structures. *Canadian Geotechnical Journal*, vol 22(2): 166-71.

AVALANCHES

Run-out distances of avalanches based on topographical parameters

(K. Lied, S. Bakkehøi and U. Domaas, NGI and D.M. McClung, NRC)

The purpose of the project is to develop a model for the run-out of avalanches based on objective topographical parameters. 210 avalanches, having a return period of 50-300 years, are recorded from different regions of the country, and the most important topographical parameters are identified.

The investigation indicates that the angle of run-out, measured from the starting zone, can be estimated by a standard deviation of approximately 1-2.0° using regression analysis. The most important topographical parameters are the gradient from the starting point to the section with 10° inclination, the vertical drop, the second derivative of best fit parabola to the avalanche path and the slope in the starting zone.

Publications:

Lied, K. and Bakkehøi, S. (1980). Empirical calculations of snow avalanche run-out based on topographic parameters. *Journal of Glaciology*, 26(94): 165-77.

Bakkehøi, S., Domaas, U, and Lied, K. (1983). Calculation of snow avalanche runout distance. *Annals of Glaciology*, 4: 24-29.

McClung, D.M. and Lied, K. (1984). Statistical avalanche zoning. *Proceedings of the International Snow Science workshop Aspen, Colorado Oct 24-27 1984*: 95-98.

McClung, D.M. and Lied, K. (1986). Statistical and geotechnical definition of snow avalanche runout. (In press).

Avalanche release related to meteorological parameters

(S. Bakkehøi)

NGI has a research station in Grasdalen, Western Norway, where both meteorological parameters and avalanche occurrence have been recorded for the last 12 years. The data obtained give valuable information for the meteorological parameters that are most important for avalanche release in that area and for different avalanche paths.

The analysing of the data has been

concentrated on a probabilistic evaluation of the avalanche hazard, giving the probability for an avalanche with a certain climate for the last 72 hrs.

Publications:

Bakkehøi, S. (1986). Snow avalanche predictions using a probabilistic method. *International Symposium on Snow Avalanche Formation, Davos 1986.*

Avalanche dynamics, the Ryggfonn project

(H. Norem, K. Tronstad and K. Kristensen)

Full-scale experiments are carried out in the Ryggfonn avalanche path, Western Norway, recording impact pressures and behaviour of the avalanche flow on the following installations: (1) a 15 m high dam, (2) a 4.5 m high concrete structure, (3) three cables crossing the path 8, 12 and 16 m above the ground, and a 25 m tubular tower.

As part of the Ryggfonn project theoretical analyses of avalanche flow are made. The flowing snow is modelled as a visco-plastic fluid. The dynamic interaction between the flow and the structures will also be carried out.

Publications:

Kvisterøy, T. (1983). *NGI report* 58120-3. Description of instrumentation and data registration system.

Lied, K. (1984). *NGI report* 58120-4. Earth dams for protection against snow avalanches.

Norem, H., Kvisterøy, T. and Evensen, B.D. (1985). Measurement of avalanche speeds and forces: instrumentation and preliminary results of the Ryggfonn project. *Annals of Glaciology*, vol 6: 19-23.

Norem, H., Kristensen, K. and Tronstad, K. *NGI reports* 58120-6, 7 and 8. The Ryggfonn project. Avalanche data from the winter 1982/83-83/84 and 84/85.

Norem, H., Irgens, F. and Schieldrop, B. (1986). A continuum model for calculating snow avalanche velocities. *NGI report* 58120-9.

SLUSHFLOWS/SLUSH AVALANCHES

(E. Hestnes, F. Sandersen and S. Bakkehøi)

Slushflows, i.e. rapid mass-movement of water-saturated snow, have not received the emphasis given to snow avalanches. Objective criteria to identify areas subjected to slushflows and methods for their prediction and control are sought.

Basic inter-relationship between meteorological conditions, snowpack properties and geomorphic features of slushflow-terrain are established. Slushflows are primarily released in drainage channels. Basal accumulations of water are enhanced by an impermeable icy layer, a rock surface or frozen ground. Both rainfall and meltwater are normally essential contributors. Intense thaw in spring may also produce more meltwater than can infiltrate at the base. Slushflows occur when shear stress of snowpack exceeds shear strength. New snow and coarse grained snow are most liable to downward. It is possible to calculate the probability for specific slushflows to occur.

Publications:

Hestnes, E. (1985). A contribution to the prediction of slush avalanches. *Annals of Glaciology*, vol 6: 1-4.

Hestnes, E. (1985). Slush avalanche research at the Norwegian Geotechnical Institute. *NGI report* 58200-2.

Hestnes, E. and Sandersen, F. (1987). Slushflow activity in the Rana district, North Norway. (In press).

NORWEGIAN ELECTRICITY AND WATER RESOURCES BOARD

GLACIER MASS BALANCE STUDIES

(N. Haakensen, E. Roland, B. Wold, NVE)

Yearly mass balance studies continue on Ålfotbreen, Nigardsbreen, Hardangerjøkulen, Hellstugubreen and Gråsubreen in southern Norway, and on Engabreen in northern Norway. Storbreen in southern Norway is measured by the Norwegian Polar Research Institute (O. Liestøl).

RADIO ECHO-SOUNDINGS

(A. Chr. Sætrang, B. Wold, NVE)

Radio echo-soundings of parts of the ice cap Jostedalsbreen in southern Norway and of western Svartisen ice cap in northern Norway have been carried out by use of a 1-10 MHz sounder in 1985 and 1986.

The 1986 data from Jostedalsbreen are so far only published in a Norwegian special report, and the data from Svartisen are under reduction.

Publications:

Sætrang, A. Chr. and Wold, B. (1986). Results from the radio echo-sounding on parts of the Jostedalsbreen ice cap, Norway. *Annals of Glaciology*, vol 8: 156-58.

GLACIER MAPPING

(N. Haakensen, A. Tvede, G. Østrem, NVE)

New glacier maps have been constructed for the glaciers Folgefonni, Gråsubreen, Stupbreen during the last 3 years.

Publications:

Haakensen, N. (1986). Glacier mapping to confirm results from mass balance measurements. *Annals of Glaciology*, vol 8: 73-77.

Østrem, G. (1986). Repeated glacier mapping for hydrological purposes: water power planning. *Annals of Glaciology*, vol 8: 135-40.

Østrem, G. and Tvede, A. (1986). Comparison of glacier maps - A source of climatological information? *Geografiska Annaler*, vol 68A: 225-31.

SNOW HYDROLOGY

(N. Haakensen, M. Johnsrud, E. Roland, NVE)

A national computer data-base for all Norwegian snow measurements has been

established, including data as far back as 1920.

Studies on the application of satellite images to snow melt forecasting and studies on the snow distribution in high mountain areas are carried out.

Publications:

Andersen, T. and Haakensen, N. (1985). Remote sensing of snow in high mountain basins in Norway. *Annals of Glaciology*, vol 6: 250-51.

Johnsrud, M. (1985). The effect of snow distribution on gamma-ray survey of snow cover. *Annals of Glaciology*, vol 6: 211-14.

Østrem, G. (1986). Snow and ice - Remote sensing applications in civil engineering. *Proceedings of the postgraduate summer school at University of Dundee 1984.*

SEDIMENT TRANSPORT IN GLACIER-FED RIVERS

(J. Bogen, O. Kjeldsen, H.C. Olsen, NVE)

The continuous record of sediment transport from the Nigardsbreen glacier started in 1968 is still maintained. Extensive studies were carried out at several other locations around the Josteldalsbreen ice cap during the summer 1986.

Publications:

Bogen, J. (1986). Sampling of suspended sediments in streams. In: B. Hasholt. Soil and transport of sediment-associated nutrients and contaminants. *Nordic Hydrological Program report* no 14.

Bogen, J. (1987). Deltaic depositional process in a glacier-fed lake: A model for the fluvial/lacustrine interface. Society of Economic Paleontologists and Mineralogists. Special Publication no 39.

SEDIMENT TRANSPORT PROCESSES AND RIVER MANAGEMENT

(J. Bogen, B. Wold, NVE)

The significance of erosion and sediment transport processes for river management in Norway have been investigated. A monitoring programme of selected river basins is suggested.

Publications:

Bogen, J. (1986). Erosion and sediment transport in Norwegian rivers. River management: responsibilities, status and research requirements. [In Norwegian with an extended English abstract.] *Norwegian National Committee of Hydrology Report* no 20.

MODELLING GLACIER RESPONSE TO CLIMATE CHANGES

(T. Laumann, NVE)

The one-dimensional model developed by R. Bindschadler (1978) has been adjusted for Norwegian ice caps with valley glacier outlets, and will be operative during 1987.

SUBGLACIAL HYDROLOGY

(E. Roland, B. Wold, NVE)

Tracer studies are made to get a better understanding of water drainage within and under glaciers.

Data from the subglacial water intake at Bondhusbreen are reduced and published.

*Publication:*Hooke, R.L., Wold, B. and Hagen, J.O. (1985). Subglacial hydrology and sediment transport at Bondhusbreen, southwest Norway. *Geological Society of America Bulletin*, vol 96: 388-97.

NORWEGIAN POLAR RESEARCH INSTITUTE

NORWAY

Subglacial investigations at Bondhusbreen

(J.O. Hagan, O. Liestøl, J.L. Sollid, B. Wold, and G. Østrem)

A co-operative project between the Department of Geography at the University of Oslo, the Glacier Division at NVE and NPRI was carried out during the concentrated field period 1980 to 1982. Subglacial hydrology, sediment transport, sliding velocity, ice pressure and temperatures have been studied beneath approximately 160 m of ice at Bondhusbreen. Data have been published and presented at international symposia and workshops.

Mass balance investigations

(O. Liestøl, J.O. Hagen and O. Orheim)

Full mass balance measurements are carried out on Storbreen in Jotunheimen and on Hardangerjøkulen, and skeleton net balance measurements are made on Supphellebreen, a westerly outlet glacier from Jostedalsbreen. The measurements on Storbreen are one of the world's longest series with continuous measurements from 1948. The mean yearly net balance for all these years has been -0.3 m of water equivalents. The results are published each year in publications from NPRI.

Glacier fluctuations

(O. Liestøl and J.O. Hagen)

Front positions have been registered once a year at ten glaciers in Norway. The registrations give an indication of the long-term trend of the mass balance of these glaciers. During the period 1930-1960 most of the glaciers in Norway retreated rapidly. In the years after 1960 they still retreated, but more slowly and a few smaller outlet glaciers were almost stagnant or advanced slightly.

SVALBARD

Mass balance investigations

(O. Liestøl and J.O. Hagen)

Since 1966 mass balance investigations have been undertaken on Brøggerbreen and Lovenbreen close to Ny-Ålesund. The net balance has been negative every year since then and the mean net balance values have been about -0.4 m water equivalents. Glacier fluctuations and velocity measurements are also carried out on other glaciers in the

Ny-Ålsund area. Results are published each year in publications from NPRI.

Glacier atlas
(O. Liestøl)
A detailed glacier inventory has been carried out covering all the islands of Svalbard. The data cover all available data about glacier type, area, volume, surges and morphology, and have been collected in a glacier atlas that will be published in the near future.

Glacier surges
(J.O. Hagan and O. Liestøl)
Glacier surges have been registered through several years. Most of the glaciers in Svalbard are sub-polar and 90% of them seem to be of the surge type. More detailed investigations of glacier surges started in 1985 at Usherbreen on the east coast of Spitsbergen. Detailed maps have been made of Usherbreen before and after the surge. The processes of ridge formation in front of the surging glacier have been studied. Similar mapping before and after a surge has also been carried out on two small inland glaciers.

Temperature measurements
(J.O. Hagen)
In connection with the coal mines in Longyearbyen and Svea on the west coast of Spitsbergen there have been drillings through some glaciers down into the bedrock beneath. Thermistor strings will be placed in these boreholes.

Sea ice studies
(T. Vinje)
Sea ice studies have been carried out in the Arctic Ocean (and periodically in the Antarctic) since the 1960s. Most of the work of the sea ice group is concerned with obtaining data on the physical parameters of the sea ice, both by field measurements, remote sensing, and buoys. More than 100 of the latter have been deployed in the Arctic and Antarctic over the past 10 years, including in recent years numerous deployments from aircraft. Sea ice maps are published yearly in NPRI publications, and other results are published in NPRI's *Polar Research* and in other refereed journals.

JAN MAYEN
(O. Orheim)
Glaciological and glacial geologic research was conducted at Jan Mayen from 1972-77, with most work done at Sørbreen, one of the main glaciers on the side of Beerenberg. This glacier advanced 30 years ago, and suggestions were then made that this was caused by increased precipitation. Our research indicates that the apparent precipitation increase was caused by relocations of the meteorological station, and that temperature changes accounted for most of the glacier variations observed.

ANTARCTICA
(O. Orheim)
Various types of glaciological research have been done on all Norwegian expeditions to Antarctica. Three summer expeditions have been conducted in recent years, with studies concentrated on Riiser-Larsenisen, an ice shelf in western Dronning Maud Land. Work here includes flow and mass balance studies, radio echo-sounding and snow chemistry and isotopes. Work has also been done on icebergs, including eight instrumented by automatic stations, and establishment of an international co-operative programme of iceberg observations. More than 100,000 icebergs are now on file, and results indicate larger calving rates and larger iceberg volumes than previously used by most authors. Studies of Landsat MSS and TM scenes from Dronning Maud Land show that the latter are particularly useful for obtaining glaciological information, with the lower bands and TM and the MSS bands giving information on subtle variations in surface slopes, while the higher reflective infrared bands of TM reveal variations in snow properties.

Harald Norem

POLAND

PETUNIABUKTA EXPEDITION, SPITSBERGEN
The research workers of the Quaternary Research Institute of Adam Mickiewicz University of Poznan went under the leadership of A. Karczewski on a research expedition to the Petunia-bukta region, Billefjord. The main research problems included the marginal zone of the Hörbye Glacier, the influence of supraglacial mantles on the areal disappearance of the glacier, present-day sedimentation in proglacial basins, outwash levels versus drainage stages, phases of glacier recession, contributions from proglacial run-off and tides to the building up of tidal plains in the Petunia Bay.

HORNSUND, SPITSBERGEN - GEOMORPHOLOGY (1:75 000)
In 1986 a Polish-English map of the Hornsund fjord region with a commentary was published by the Institute of Geophysics of the Polish Academy of Sciences (printed in 1984). Its compilation was based on the field mapping of unglaciated areas in 1979 and 1980, on the interpretation of Norwegian air photos of glaciated areas, and on the research output of Polish expeditions in the last 25 years. Fourteen authors under the supervision of A. Karczewski, the Scientific Editor, participated in this compilation.

S. Kozarski

CENTRAL SIERRA SNOW LABORATORY FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE, SODA SPRINGS, CALIFORNIA, U.S.A.

In the period after World War II, the United States – particularly the Western States – faced an expanding population and consequent growing demand for hydroelectric power and irrigation and potable water. The three principal mountain ranges in the West – Sierra Nevada, Cascades, and Rockies – were prime sources of water supply to meet these rising demands.

Planners in the U.S. Army Corps of Engineers and the Weather Bureau forsaw the need for improved methods for designing spillways and for predicting streamflow. In 1945, the two agencies formed the Cooperative Snow Investigations Research Program with the aim of solving hydrologic problems in the West, and with these specific goals:

1) Determine a practical, reliable method of evaluating the maximum streamflow that may be produced by a watershed as a result of snowmelt or combined snowmelt and rain.

2) Develop a practical, reliable method of forecasting seasonal and short-term streamflow, including floods, resulting from snowmelt or combined snowmelt and rain.

3) Expand basic knowledge of the hydrodynamic and thermodynamic characteristics of snow through a program of fundamental scientific research.

To carry out the research program, the two agencies established three outdoor laboratories. Each laboratory represented a different environmental condition. To study rain and snow with snow predominating, the Central Sierra Snow Laboratory was established in northern California, 25 km northwest of Lake Tahoe, near Donner Summit. To study rain and snow with rain predominating, the Willamette Snow Laboratory was established in west central Oregon, in the Blue River drainage. To study snowfall, the Upper Columbia Snow Laboratory was set up in Montana, immediately west of the continental divide, near Flathead Lake. Major products from research at these three laboratories included publication of annual *Hydrometeorological Logs* and in 1956, the volume on *Snow Hydrology*, a benchmark on the subject that has become a standard reference.

Among the three facilities, only the Central Sierra Snow Laboratory still exists. The other two Laboratories were closed in the early 1950s when the field phase of the Cooperative Snow Investigations program was terminated. The Forest Service, U.S. Department of Agriculture, assumed sponsorship of the Central Sierra Snow Laboratory (CSSL) in 1954. And since then, it has been a part of the Pacific Southwest Forest and Range Experiment Station, headquartered in Berkeley, California.

Located near Soda Springs, about 290 km northeast of San Francisco, the CSSL lies at 2 100 m elevation on the west side of the Sierra Nevada. The surrounding 10 km^2 watershed extends from 2100 to 2775 m elevation in the lodgepole pine/true fir vegetation zone. This location is strongly influenced by a Mediterranean maritime climatic regime. Although snow is the predominant winter precipitation form, rainfall can be expected once or twice each winter up to the crest of the range.

EARLY STUDIES

In the 1950s primary financial support for the CSSL was shared between the Forest Service and the California Department of Water Resources. Henry W. Anderson, in charge of the CSSL as the Snow Research Leader for the newly-formed Cooperative Snow Management Research work unit, identified research objectives as "the development and testing of ways that forests in the snow zone of the State can be cut and forest land managed to the end that California's water supply can be maintained or improved".

Given the pace of development in California since the end of World War II, it was not surprising that this goal embodied many of the objectives set forth in the original charter of the CSSL. The Sierra Nevada snow zone, representing 12% of the State's land area, produces one-half of the runoff. The need for flood control and the often competing needs for water for irrigation, hydroelectric power, recreation, and fisheries places enormous demands on that water supply. California's system of interbasin water transfers is as complex as any in the world and even minor improvements in capabilities for predicting snowmelt runoff timing and magnitude can reap significant economic benefits.

By 1957, the Snow Management Research Unit has 16 studies underway. Its work centered on inventrying soils, geology, terrain, and meteorological characteristics of watersheds in California, and of forest conditions, soils, and vegetation at the CSSL; on developing research techniques, including the use of radio-isotopes in hydrology; and on relation of terrain to energy factors and their effects on the amount and timing of snow accumulation, snowmelt, and water yield.

Under Anderson's stewardship between 1956 and 1963, results were published in more than 90 papers in journals and proceedings. Not only was work done at the CSSL, but at two Forest Service Experimental Forests: the 1300 h Onion Creek Experimental Forest, 10 km south of the laboratory, and the 1300 h Teakettle Experimental Forest, 275 km south of the laboratory.

Research on increasing and delaying runoff from the snow zone predates the establishment of the CSSL by many years. In the early 1900s, James Church did pioneering research on snow hydrology. He proposed that streamflow amount and timing could be changed through snowpack management. Field observations in the 1950s and 1960s suggested that clear cutting the forest in east-west strips, varying in width dependent upon tree height and ground slope and aspect, might enhance snowpack accumulation and affect snowmelt rates. By this conceptual approach, shading from the south (for northern hemisphere sites) would be maximized and re-radiation from trees to the north would be minimized. A cutting cycle progressing southward would maintain a wall-and-step forest. Each cut would produce a wall of shade on the south, and the steps to the north would reduce back radiation. While numerous measurements were made in the 1960s of snow accumulation in the cut strips and surrounding forest, to this day little or no evidence exists for California sites that stream discharge has increased significantly or that flow peaks and timing at gauging stations has changed as the direct result of timber harvest.

Among the suggested alternatives to the strip cut design, the most promising one has historical roots in Church's proposal in 1912 that a "honeycomb forest" might improve water yield by harvesting a forest into a network of small openings less than a tree-height wide with each clearing isolated by uncut forest. Current thinking still has this method as the most effective treatment for delaying water yield in the mid-elevation Sierra Nevada west slope. Although increases of up to 40% in snow-water equivalent have been suggested, the potential for water-yield increases is probably much lower – less than 5% of current yields – because of the few openings that can by cut at one time, physical and management constraints, and guidelines on optimum use of other resources.

Between 1965 and 1975, the CSSL staff participated in numerous studies on various facets of snow hydrology. Among the findings are these:

1) Evaporation from the snow surface can be supressed in the Sierra Nevada by applying long-chain alcohol monolayers. But a new application is needed after every storm. Therefore, the treatment is not now economically feasible since evaporation rates are relatively low and the inter-storm period is often short.

2) Soil water movement rates – saturated flow velocity of fluid through Sierra Nevada mountain soil matrices – approximates 3 m/day [tracer velocity].

3) A method was developed for calculating the extent of boundary shading for any combination of date, slope and aspect in the contiguous United States by managing shadow sources for controlling solar light and heat.

SNOW ZONE HYDROLOGY RESEARCH

Much of this work was done under the auspices of Dr James L. Smith, who succeeded Anderson in 1964 and became Project Leader of the Environmental Hydrology of the California Snow Zone Research Unit at the Pacific Southwest Station. Smith completed development of the isotopic profiling snow gauge and applied it to various aspects of snow hydrology research. High density strata were identified in the snowpack and their role in directing water flowing through the pack was conceptualized. Smith continued research on forest management effects on snow accumulation and melt with the particular aim of developing practical guidelines for forest managers.

The CSSL continues to be the primary manned meterological observation station on the west slope of the Sierra Nevada. Numerous routine observations are recorded in a clearing adjacent to the main laboratory building. Measurements of the following properties are made at one-minute intervals 1 m above the ground or soil surface, and logged hourly: air, snow surface, and dew point temperatures, horizontal and vertical wind speed and direction (all at 11 m above the ground as well as 1 m above the snow surface), and radiation (incoming solar at several wavelengths plus diffused and reflected). Precipitation and snowpack runoff (basal outflow) are measured continuously. Soil and snow temperatures (at several depths in each medium), snow depth, snow density and water equivalent (at 1 cm increments within the snowpack), and the chemistry of precipitation and snowpack basal outflow are monitored several times daily or on an event basis. Weekly soil moisture observations are made at non-forested, forested, and partially forested sites. Wind, air and dew point temperature, and net radiation are logged hourly at a nearby forested site as well. Much of this comprehensive data base spans a 20-year period at CSSL. Less detailed hydrometeorological data are available from the 1950s and early 1960s and precipitation and air temperature records from nearby locations date back to the late 1800s.

The CSSL site is also part of the Soil Conservation Service, U.S. Department of Agriculture, snow telemetry network (SNOTEL) for monitoring snow water equivalent, precipitation, and air temperature. The data logging system at CSSL allows much more frequent interrogation of all the sensors than is typically available. Recent analysis of

the short term performance of the snow pillow sensor has identifed irregularities in the sensor energizing voltage and diurnal temperature effects. Results from this study have affected decisions by the Soil Conservation Survey in their actions to upgrade the entire SNOTEL network. This analysis concluded, nevertheless, that the snowpillow is a more reliable means of measuring snowfall than either a 20 or 30 cm orifice precipitation gauge. Post-storm loading, however, often delayed complete measurement of the storm water content.

The CSSL site is also part of the California Acid Deposition Monitoring Program, sponsored by the State Air Resources Board. The CSSL is the only snow zone station in the network where continuous monitoring of atmospheric deposition is effectively underway. Weekly precipitation samples are collected in a wet/dry collector and analyzed for pH, conductivity, and primary pollutants. In addition to these cooperative programs with the Air Resources Board and the Soil Conservation Service, data collected are used by several companies, including Southern Pacific Transportation Company and Pacific Gas and Electric Company in their daily winter operations. Numerous other agencies, commercial firms, the media, and the public request CSSL data frequently – sometimes several times daily.

THE SIERRA ECOLOGY PROJECT

In the early 1970s water resource planners in California recognized that long-range water needs in the State required exploration of all feasible future alternatives for providing adequate supplies. In response to this need, the Bureau of Reclamation, U.S. Department of Interior, launched the Sierra Cooperative Pilot Project (SCPP) in 1972 to study ways of augmenting the snowpack. The aim of SCPP is to explore the feasibility of enhancing California's water supply by cloud seeding. The Project currently seeds winter clouds by aerial applications of dry ice pellets. In 1975 the Bureau and the Pacific Southwest Station agreed to establish the Sierra Ecology Project to assess the effects of additional snowfall and meltwater on the forest ecosystem in the central Sierra Nevada. Dr Smith acted as coordinator of the Sierra Ecology Project until his untimely death in 1981, when Dr Neil Berg succeeded him.

Since 1976, the CSSL staff have been involved with numerous studies sponsored by the Sierra Ecology Project. The long-term CSSL data base allows us to estimate snowpack augmentation effectson forest diseases and insects, stream and lake biota, vegetation, deer and their habitat, and hydrologic pprocesses. As the primary meteorological station in the SCPP target area, the CSSL maintains climatology and snowpack data bases that form the baseline against which any long-term augmentation effects can be compared. A model has been developed for estimating snowpack water equivalent on a small basin (2-3 km^2) scale and to analyze snowpack water-holding capacity. This study identified the extreme spatial and temporal variability in water-holding capacity in the central Sierra Nevada snowpack. Saturated snow may exist adjacent to essentially dry snow. Typically, the snowpack at CSSL offer little delay or storage potential to midwinter rainfall. Water appears to move preferentially in the snowpack, often through flow fingers and macropores analogous in some ways to soil pipes.

More recently, research done under the auspices of the Sierra Ecology Project has dealt with potential effects of acidic deposition as well as traditional concerns with the disposition of "new" water produced by the cloud seeding. If acidic deposition is occurring in the SCPP target area, then additional snowfall could increase acid loadings to the forest ecosystem. Findings from Scandinavia and the northeastern United States suggest that the snowpack can act as a reservoir for contaminants, releasing high concentrations of pollutants over a short period of time during snow melt. Studies underway at the CSSL are investigating precipitation chemistry and the role of the snowpack in "concentrating" chemical inputs. Preliminary results suggest that snowfall chemistry is in the natural pH range (mean 5.25). No evidence has yet been found for a "pulse", "surge", or "spike" of acidity in streams in the study area during the main spring melt period. However, seasonal pH minima have been associated with rain-on-snow events, and an alkalinity "pulse" was observed during a mid-winter melt event.

What is the disposition of any "additional" snow resulting from cloud seeding? Assuming an extension of the snowmelt season, does the added runoff enter the streams or is it lost to evapotranspiration? To find out, we have a small basin study in which extension of the snowmelt season is being simulated by irrigating several hectares of land, and soil and ground water levels are monitored to compare with those on control plots. First-year results suggest that extension of snowmelt by 10 to 12 days causes a change in soil moisture that persists up to 2 months. But the evidence is less clear on the quantity of "added" water reaching the stream.

CURRENT RESEARCH

Research currently underway at CSSL centers on two primary problems:

1) Developing improved methods for estimating runoff in the California snow zone, particularly during and after rain-on-snow events.

2) Obtaining better information on snowpack chemistry and the role of the snowpack in the disposition of atmospheric pollutants in the California snow zone.

Much of the support for work on the

second problem – the "acid rain" question – comes from the Bureau of Reclamation studies described earlier. The primary objectives are (1) to identify the areal extent of acid deposition in the Sierra Nevada, and (2) to assess the role of the snowpack as a reservoir for deposited chemical constituents, particularly in terms of the chemical fractionation of snowmelt waters. Besides monitoring precipitation and stream water chemistry, researchers are studying the chemistry of water leaving the base of the snowpack. Such "basal outflow" is not modified by edaphic or biologic processes and should best signal evidence for a pulse or surge of contaminants leaving the pack.

The runoff estimation problem receives the bulk of the research effort. Studies are segmented into five compnents: (1) liquid water flow through the snowpack; (2) snow water holding capacity and measurement; (3) physics of ice lenses, crusts, and new snow; (4) snow accumulation and melt simulation; and (5) management effects on snow and stream hydrology and vegetation. Seventeen studies are planned; most of these are field efforts, and data have been collected for over half of the studies. Research on measurement of "liquid water" in the snowpack has received the most attention over the last 10 years. In the late 1970s and early 1980s the potential for using active microwave systems for liquid water measurement was explored. In spite of the promising theoretical possibilities of this technology, considerably more development is necessary before its potential can be realized. In 1985, research at CSSL led to the first known documentation of seasonal changes in snowpack porosity and permeability. Liquid water flow rates were more rapid early in the season than later. Researchers have hypothesized that early in the year the dominant flow mechanism is vertical flow channels ("flow fingers"), while later in the year the metamorphosed snow more closely follows flow through a homogenous matrix. The ultimate aim of these, and the other studies in this problem, is to formulate and validate runoff models and develop handbooks on snow management for use by land managers.

Since its inception, the Central Sierra Snow Laboratory has been the site of major pioneering snow research performed by several agencies. While research on snow accumulation and melt forecasting has been ongoing since 1946, unique and valuable findings continue to result from work done at the laboratory – the only manned, high-elevation snow research facility in the western United States.

Neil Berg

INTERNATIONAL GLACIOLOGICAL SOCIETY

JOURNAL OF GLACIOLOGY

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

C. Rado, C. Girard and J. Perrin:
Electrochaude: a self-flushing hot-water drilling apparatus for glaciers with debris.

H. Blatter:
On the thermal regime of an Arctic valley glacier: a study of White Glacier, Axel Heiberg Island, N.W.T., Canada.

M.O. Jeffries and H.R. Krouse:
Snowfall and oxygen-isotope variations off the north coast of Ellesmere Island, N.W.T., Canada.

R.S. Bradley and M.C. Serreze:
Topoclimatic studies of a High Arctic plateau ice cap.

M.C. Serreze and R.S. Bradley:
Radiation and cloud observations on a High Arctic plateau ice cap.

M.R. Banks, E.A. Colhoun and D. Hannan:
Early discoveries of the effects of ice action in Australia. [Early Discoverers]

V.G. Konovalov:
Methods of calculation and remote-sensing measurements for the spatial distribution of glacier annual mass balances.

M.E.R. Walford:
Radio and electrical measurements on glacial streams.

I. Hill, D.W. Roberts and M.E.R. Walford:
Optical measurements of water lenses in ice.

N. Reeh:
Steady-state three-dimensional ice flow over an undulating base; first-order theory with linear ice rheology.

J.D. Lyden and R.A. Shuchman:
A digital technique to estimate polynya characteristics from synthetic aperture radar sea-ice data.

W. Epprecht:
A major calving event of Jakobshavn Gletscher, West Greenland, on 9 August 1982.

ANNALS OF GLACIOLOGY

The following papers have been published in Volume 9, Proceedings of the Symposium on Remote Sensing in Glaciology, Cambridge, U.K., 1986.

R B ALLEY:
Texture of polar firn for remote sensing.

M S PELTO:
Mass balance of south-east Alaska and north-west British Columbia glaciers from 1976 to 1984: methods and results.

M R DRINKWATER AND J A DOWDESWELL:
A multi-sensor approach to the interpretation of radar altimeter wave forms from two Arctic ice caps.

U FELDMAN:
A method to estimate open pack-ice thicknesses from two-day sequences of side-lapping satellite images.

H H THOMSEN AND R J BRAITHWAITE:
Use of remote-sensing data in modelling run-off from the Greenland ice sheet.

R S WILLIAMS JR:
Satellite remote sensing of Vatnajökull, Iceland.

K STEFFEN:
Fractures in Arctic winter pack ice (North Water, Northern Baffin Bay).

W CUDLIP AND N F MCINTYRE:
SEASAT altimeter observations of an Antarctic "lake".

K C PARTINGTON, W CUDLIP, N F MCINTYRE AND S KING-HELE:
Mapping of Amery Ice Shelf, Antarctica, surface features by satellite altimetry.

C L PARKINSON, J C COMISO, H J ZWALLY, D J CAVALIERI, P GLOERSEN AND W J CAMPBELL:
Seasonal and regional variations of northern hemisphere sea ice as illustrated with satellite passive-microwave data for 1974.

MEEMONG LEE AND WEI-LIANG YANG:
Image-analysis techniques for determination of morphology and kinematics in Arctic sea ice.

G SCHARFEN, R G BARRY, D A ROBINSON, G KUKLA AND M C SERREZE:
Large-scale patterns of snow melt on Arctic sea ice mapped from meteorological satellite imagery.

S MAE AND M YOSHIDA:
Airborne radio echo-sounding in Shirase Glacier drainage basin, Antarctica.

A P R COOPER:
Interface tracking in digitally recorded glaciological data.

R A BINDSCHADLER, K C JEZEK AND J CRAWFORD:
Glaciological investigations using the synthetic aperture radar imaging system.

H ROTT AND C MATZLER:
Possibilities and limits of synthetic aperture radar for snow and glacier surveying.

H BLATTER:
Stagnant ice at the bed of White Glacier, Axel Heiberg Island, N.W.T., Canada.

W GOOD AND J MARTINEC:
Pattern recognition of air photographs for estimation of snow reserves.

M O JEFFRIES, W M SACKINGER AND H V SERSON:
Remote sensing of sea-ice growth and melt-pool evolution, Milne Ice Shelf, Ellesmere Island, Canada.

H J ZWALLY, S N STEPHENSEN, R A BINDSCHADLER AND R H THOMAS:
Antarctic ice-shelf boundaries and elevations from satellite radar altimetry.

H J ZWALLY AND J E WALSH:
Comparison of observed and modeled ice motion in the Arctic Ocean.

J MARTINEC AND A RANGO:
Interpretation and utilization of areal snow-cover data from satellites.

K YAMAMOTO AND M YOSHIDA:
Impulse radar sounding of fossil ice within the Kuranosuke perennial snow patch, central Japan.

M YOSHIDA, K YAMASHITA AND S MAE:
Bottom topography and internal layers in East Dronning Maud Land, East Antarctica, from 179 MHz radio echo-sounding.

Y FUJII, T YAMANOUCHI, K SUZUKI, AND S TANAKA:
Comparison of the surface conditions of the inland ice sheet, Dronning Maud Land, Antarctica, derived from NOAA AVHRR data with ground observation.

ZENG QUNZHI, ZHANG SHUNYING, CHEN XIANZHANG AND WANG JIAN:
Satellite snow-cover monitoring in the Qilian Mountains and an analysis for characteristics of stream snow-melt run-off in the Hexi region, Gansu, China.

A T C CHANG, J L FOSTER AND D K HALL:
Nimbus-7 SMMR derived global snow cover parameters.

J DOZIER AND D MARKS:
Snow mapping and classification from LANDSAT thematic mapper data.

J L BAMBER:
Internal reflecting horizons in Spitsbergen glaciers.

D G SCHULTZ, L A POWELL AND C R BENTLEY:
A digital radar system for echo studies on ice sheets.

D D BLANKENSHIP, S ANANDAKRISHNAN, J L KEMPF AND C R BENTLEY:
Microearthquakes under and alongside ice stream B, Antarctica, detected by a new passive seismic array.

C R BENTLEY, S SHABTAIE, D D BLANKENSHIP, S T ROONEY, D G SCHULTZ, S ANANDAKRISHNAN AND R B ALLEY:
Remote sensing of the Ross ice streams and adjacent Ross Ice Shelf, Antarctica.

O ORHEIM AND B K LUCCHITTA:
Snow and ice studies by thematic mapper and multispectral scanner LANDSAT images.

O ORHEIM:
Evolution of under-water sides of ice shelves and icebergs.

G J MUSIL AND C S M DOAKE:
Imaging subglacial topography by a synthetic aperture radar technique.

M J CLARK, A M GURNELL AND P J HANCOCK:
Ground data inputs to image processing for estimating terrain characteristics for glacio-hydrological analysis.

V M KOTLYAKOV AND Y Y MACHERET:
Radio echo-sounding of sub-polar glaciers in Svalbard: some problems and results of Soviet studies.

D K HALL, J P ORMSBY, R A BINDSCHADLER AND H SIDDALINGAIAH:
Characterization of the snow–ice density zones on glaciers using LANDSAT Thematic Mapper data.

M R GORMAN AND A P R COOPER:
A digital radio echo-sounding and navigation recording system.

T H JACKA, I ALLISON, R THWAITES AND J C WILSON:
Characteristics of the seasonal sea ice of East Antarctica and comparisons with satellite observations.

SYMPOSIUM ON ICE-CORE ANALYSIS 1987

The Symposium was held in Bern, Switzerland, 30 March - 3 April, and was organized by the Society. Ninety participants and accompanying persons enjoyed a stimulating programme of sessions and social events.

Sessions were held in the Institut für Exakte Wissenschaften of the University.

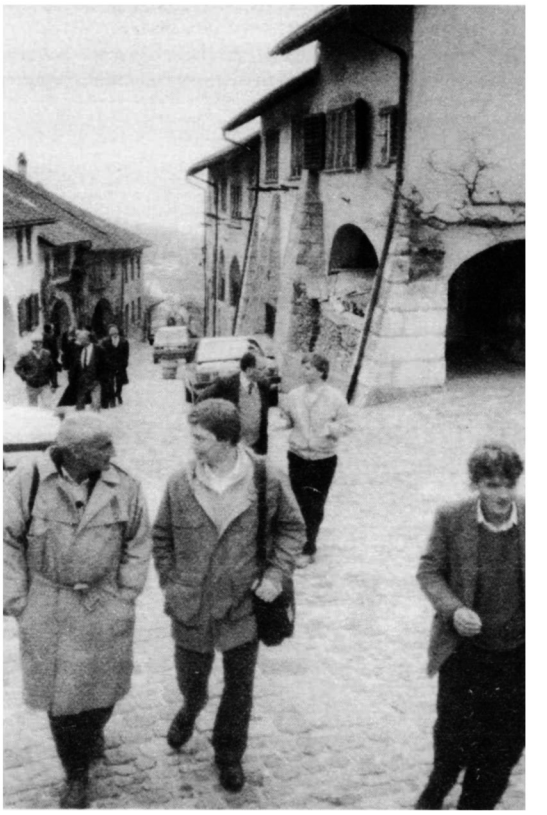
Papers presented in plenary sessions covered the following topics: stable isotopes; rheology, mechanics, stratigraphy; traces; gases; cosmic ray-produced isotopes, ice physics, miscellaneous. One afternoon was used for a Poster session, where 17 papers were presented.

The Chairman of the Local Arrangements Committee, Bernhard Stauffer, and his team gave efficient technical support to the sessions and social events.

Social events included an Icebreaker on Sunday evening, 29 March, a tram ride through old Bern on Tuesday, a half-day tour to Murten, an old Romanesque town, on Wednesday, and a Reception given by the State and City of Bern preceding the Banquet on the Thursday (which coincided with Hans Oeschger's 60th birthday, duly celebrated).

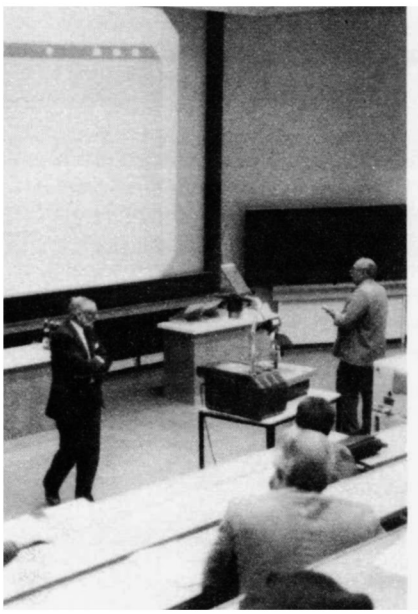
The Rektor of the University honoured us with his presence at the opening session, bidding us welcome, and at the Banquet.

The editors of the proceeding volume (*Annals of Glaciology*, volume 10, 1988) under the chairmanship of Hans Oeschger, worked hard with the authors during the week. We aim to publish the volume in January 1988.

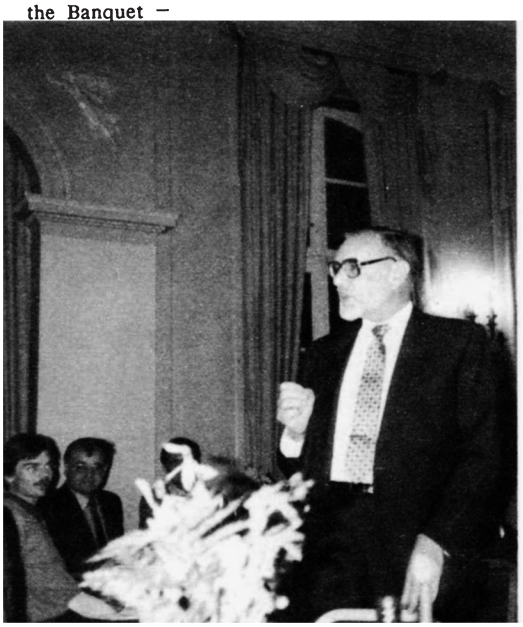


and a mid-week break was taken to visit the Romanesque town of Murten.

Session chairmen kept authors under control . . .



The President welcomed everyone at the Banquet –



– the wine flowed –

– Hans Oeschger cut his birthday cake –

– Bernhard Stauffer and T. Riesen relaxed after their hard work –

– and the Chinese and Japanese participants joined in the fun.

Photographs by Hilda Richardson

FUTURE MEETINGS (of other organizations)

The 6th International Conference on Numerical methods in geomechanics (ICONMIG 88) will be held on 11-15 April 1988 at Innsbruck, Austria. The sponsors are the University of Innsbruck, the Austrian Society for Geomechanics, the Austrian Federal Chamber of Engineers and the Austrian Society for Industrial Construction.

The objectives of the conference are to narrow the gap between theory and practice in the use of numerical methods to solve many non-linear problems in geomechanics.

The topics will include:

Constitutive laws of rock and soil
Modelling of joints and interfaces
Constitutive modelling of ice mechanics
Flow and consolidation
Rock hydraulics
Dynamics, earthquake problems, blasting loading
Modelling of infinite domains
Tunneling and underground openings
Dams
Soil/structure interaction
Mining
Interpretation of field measurements

Papers are invited on the topics outlined above and other topics within the general scope of the Conference. Abstracts should be of no more than 300 words. They should be sent *immediately* to the Conference chairman at the address given below. They should state clearly the purpose, results and conclusions of the final paper. Authors will be notified of preliminary acceptance within one week and this acceptance will depend upon review of the full-length paper.

G.A. Swoboda, University of Innsbruck, Technikerstr. 13, A-6020 Innsbruck, Austria.

GLACIOLOGICAL DIARY

** IGS Symposia
* Co-sponsored by IGS

1987

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

30 March - 3 April
Symposium on the Use of isotope techniques in water resources development. Vienna, Austria. (International Atomic Energy Agency, IAEA-SM-299, Vienna International Centre, P.O.Box 100, A 14400 Vienna, Austria.)

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)

** 13 July - 5 August
Western Alpine Branch. Tour to Greenland. (F. Valla, IGS Alpes Occidentales, c/o Nivologie ct-Gref, BP 114, 38402 St Martin d'Hères, France)

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)

12-14 August
Symposium on the Physical basis 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, Fed. Rep. Germany)

2-5 August
Fifth International Conference on Permafrost, Trondheim, Norway. (c/o The Norwegian Institute of Technology, Studies Administration, N-7034 Trondheim-NTH, Norway.)

2 August
(in conjunction with the above conference) Workshop on Permafrost data and information. (R.G. Barry, Director, WDC-A for Glaciology, Boulder, Colorado, U.S.A.)

4-9 September
** Symposium on Snow and glacier research relating to human living conditions. Lom, Norway. (Secretary General, IGS, Lensfield Road, Cambridge CB2 1ER, UK)

1988

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

11-15 April
Sixth International Congress on Numerical methods in geomechanics, Innsbruck, Austria. (G.A. Swoboda, University of Innsbruck, Technikerstr. 13, A-6020 Innsbruck, Austria)

4-8 July
Sixth International Congress on Protection of habitat from floods, debris flows and avalanches. Graz, Styria, Austria. (INTERPRAEVENT 1988, Postfach 43, A-8010 Graz, Austria)

1989

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

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

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

REVIEWS

A Visitor's Guide to Mount Rainier's Glaciers, by Carolyn Driedger. Pacific Northwest National Parks and Forests Association, Mt Rainier Branch, Longmire, WA 98397. 80pp.

Mt Rainier, rising to an altitude of approximately 4000 m, is the largest volcano in the northwest United States. It is a dormant stratovolcano and its most spectacular feature, aside from its height, is the 88 sq k mantle of pernennial snow and ice. Mt Rainier is a national park and attracts millions of visitors who come and enjoy the thick forests of fir trees and the easily accessible glaciers.

Ms Driedger's book focuses on the glaciers and is oriented towards the interested layman. The book is divided into two sections. The first section is organized into brief chapters, each no more than 4 pages long, which introduce basic concepts. These include glacial processes and their effect on the surrounding landscape, local glacial geology, and a historical summary of glaciological studies on the mountain. A separate chapter uses the geological evidence of former glacier positions to introduce the idea of climate change since the Pleistocene. The moraines at Mount Rainier clearly demonstrate this idea. The book also includes a glossary of geological and glaciological terms used. In summary, this first section is a good layman's version of Stan Paterson's *Physics of Ice* as applied to Mount Rainier.

The second section is devoted to the glaciers on the mountain. It begins with two

tables, one summarizing the orientation, area, and volume of each glacier and the other presenting the chronology of Mt Rainier glaciation. The twelve largest glaciers are described, starting with the south facing glacier and moving in a clockwise manner round the mountain. The description includes a historical account of observations or noteworthy glacier activity. Often a map of the major moraines, with dates shown, accompanies the text. Also, interesting glacial or geo-glacial features are mentioned and walking routes and view points are suggested. The amount of available historical and scientific information differs from glacier to glacier. A sampling of early 20th century photographs are included with some recent photographs from similar positions for comparison.

Because the book is short, only 80 pages, it cannot be used by itself unless the reader is already very familiar with Mt Rainier. Often places or routes are mentioned without accompanying maps, so another general guidebook to the area is required. Also, no index is included, which makes referral inconvenient.

In general, this book provides a good layman's introduction to glaciers. Professionals interested in Mt Rainier's glaciers will find it a fine resource as well. The book includes some data never before published and a reference section that lists most of the original material written about the glaciers of Mt Rainier. It has obvious interest to those of us who live here and take visitors to the mountain, but its regional appeal does not preclude a wider audience. Because of the wealth of information in maps, tables, and photos, I would recommend this book to anyone remotely interested in glaciers.

Andrew G. Fountain

Pipelines and permafrost: Science in a cold climate, by Peter J. Williams. Ottawa, Carleton University Press, 1986. 129pp, illus., maps.

Peter Williams of Carleton University has brought out a second edition of his popular book *Pipelines and permafrost*, first published by Longmans, New York, in 1979. It is an excellent and fully comprehensible exposition of the problems and the achievements. The new edition looks smaller, but contains more. The new material mostly concerns events since 1979; change of plans for the Alcan pipeline, Russian work, completion of the Norman Wells pipeline, experimental work in France, other megaprojects; and it makes a powerful plea for more research in Canada. Sadly, the bibliography has been dropped (though book titles are to be found in chapter end-notes). A curious detail: in the illustration of "thaw subsidence" on p.31, the man has used the time between the editions to go round to the other side of the pond.

Terence E. Armstrong

NEWS

AWARDS AND APPOINTMENTS

Louis Lliboutry (President of ICSI) and **Claude Lorius** (Past Vice-President of ICSI) have received the two main prizes in any discipline awarded by the French Academy of Sciences: "Prix du Rayonnement français pour les sciences physiques et mathématiques" to L. Lliboutry and "Grand prix de l'Académie des Sciences" to C.J. Lorius.

R.J. Adie has been awarded an honorary Doctor of Science degree by the University of Natal for his notable contributions to Antarctic science.

Barclay Kamb has been appointed Provost of California Institute of Technology with effect from mid-February 1987.

David Sugden has been appointed to the Chair of Geography, University of Edinburgh.

Geoffrey Boulton has been appointed to the Regius Chair of Geology at the University of Edinburgh.

NEW NAME FOR INSTITUTE OF POLAR STUDIES

A legacy from Admiral Byrd's estate has been received by I.P.S. in The Ohio State University. The Institute has now renamed itself the Byrd Polar Research Center.

NEW MEMBERS

E.W. Blake, Department of Geophysics & Astronomy, University of British Columbia, Vancouver, British Columbia V6T 1W5, Canada.

J.F. Bolzan, Byrd Polar Research Center, 125 South Oval Mall, Columbus, OH 43210, U.S.A.

P. Gregori, SVI-CAI, via Padova N. 3, 38100 Trento, Italy.

N.R.J. Hulton, Geography Department, University of Edinburgh, Drummond Street, Edinburgh, EH8 9XP, U.K.

J. Jouzel, LGI/DPC, CEN Saclay, F-91191 GIF/Yvette Cedex, France.

J. Pilling, College of Engineering, Department of Metallurgical Engineering, Michigan Technological University, Houghton, MI 49931, U.S.A.

H.F. Rohde, 1 Hosking Street, Balmain East, NSW 2041, Australia.

H. Rufli, Tonisbachstr. 26, CH-3510 Konolfingen, Switzerland.

Silvia M. Sartori, Dipartimento di Fisica "G. Galilei", via Marzolo 8, 35131 Padova, Italy.

U. Schotterer, Physikalisches Institut, Universität Bern, 3012 Bern, Sidlerstrasse 5, Switzerland.

Marylin P. Segall, 185 Castle Road, Columbia, SC 29210, U.S.A.

J.P. Steffensen, Geophysical Institute, Haraldsgade 6, DK-2200 Copenhagen N, Denmark.

Wu Xiaoling, Lanzhou Institute of Glaciology & Geocryology, Academia Sinica, Lanzhou, China.

THE GLACIER MARCH

(for performance by a mixed chorus of glaciers and ice sheets, to the tune of Onward Christian soldiers)

Onward grind the glaciers,
Surging o'er the land.
Ice sheets dream of ice falls
Where the cities stand.
Though we're now divided,
We'll together flow
Bringing snow and permafrost and
Raising albedo.

Onward yet the glaciers
Surge with pond'rous tread,
With the fimbulwinter
Going on ahead.

1985
Oranges freeze in Florida,
Phoenix reels in snow.
All the world is wond'ring
Where we next will go.
Shall we sink a tanker? *(Columbia Glacier, solo)*
Surge, and raise the sea? *(West Antarctic Ice Sheet, solo)*
Wrap the world from pole to pole in
Icy purity?

Onward yet the glaciers
Surge with pond'rous tread
With the fimbulwinter
Going on ahead.

1986
See the mighty Hubbard
Thrust into the sea,
Trapping seals and dolphins, what
Fools these mortals be!
Though the rise of Russell Lake
Swept away their pen,
Wait 'til next year and the Hubbard
Will be back again!

Onward yet the glaciers
Surge with pond'rous tread,
With the *fimbulwinter
Going on ahead!

*Any glaciologist not familiar with the meaning of "fimbulwinter" is invited to spend a weekend with a good book on Norse Mythology, especially the period known as the twilight of the gods.

Written by Sue Ann Bowling
Instigated by Carl S. Benson

INTERNATIONAL GLACIOLOGICAL SOCIETY

Founded by G. Seligman

c/o SCOTT POLAR RESEARCH INSTITUTE, University of Cambridge, Lensfield Road, Cambridge CB2 1ER, England

Secretary General: H. Richardson

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	* B. Wold	1985-88	1985
	* R. Hooke	1986-89	1986
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	* R. Perla	1986-89	1986
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	H. Oeschger	1986-87	1985

* first term of service on the Council

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		1986	G. de Q. Robin

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INTERNATIONAL GLACIOLOGICAL SOCIETY

Lensfield Road, Cambridge CB2 1ER, England

DETAILS OF MEMBERSHIP

Membership is open to all individuals who have scientific, practical or general interest in any aspect of snow and ice study. Payment covers purchase of the *Journal of Glaciology* and *Ice*. Forms for enrolment can be obtained from the Secretary General. No proposer or seconder is required.

ANNUAL PAYMENTS 1987

Private members	Sterling £25.00
Junior members	Sterling £12.50
Institutions, libraries	Sterling £70.00 for Volume 33 (Nos.113,114,115)

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

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

ICE

Editor: H. Richardson

This news bulletin is issued to members of the International Glaciological Society and is published three times a year. Contributions should be sent to the Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, England.

Annual cost for libraries, etc., and for individuals who are not members of the Society:

Sterling £9.00

All enquiries about the International Glaciological Society should be addressed to the Secretary General of the International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, England.