Number 122 *1st Issue 2000*

ICE

NEWS BULLETIN OF THE INTERNATIONAL GLACIOLOGICAL SOCIETY

ISSN 0019–1043

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COVER PICTURE: Bizarre ice structure on Lake Hoare, Taylor Valley, Antarctica, created by sublimation (Photograph by Konrad Steffen)

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

RECENT WORK

SWITZERLAND

(For abbreviations used see page 17)

GLACIERS AND ICE SHEETS

Glacier length variations in the Swiss Alps

(M. Hoelzle, D. Vonder Mühll, VAW/GK/SANW)

The annual surveys of glacier variations at 121 glacier snouts in the Swiss Alps are sponsored by the Glaciological Commission of the Swiss Academy of Sciences (GK/SANW) and the Laboratory of Hydraulics, Hydrology and Glaciology (VAW) at the Federal Institute of Technology in Zürich. The measurements have been made continuously since 1880.

The 118th to 120th surveys can be summarized as follows: the decreasing number of advancing glaciers and the prevailing number of retreating ones make it obvious that recession has continued steadily. The last three reports show that the general tendency of the last 150 years continues. In single cases, where rather small glaciers advanced, this was due either to particular mechanisms of glacier movement or to perennial snow deposited by avalanches on a glacier's snout.

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Swiss glacier inventory 2000

(F. Paul, A. Kääb, W. Haeberli, M. Maisch, T. Kellenberger, Geog/UZI)

In Switzerland, a complete glacier inventory was compiled from aerial photography taken in 1973. As part of National Research Programme (NRP) 31 (M. Maisch), this inventory was revised in detail and completed with a reconstruction of the glacierization in 1850. Now, a new glacier inventory for the Swiss Alps is being compiled using satellite imagery combined with digital terrain information. The project is closely linked to the GLIMS project (Global Land Ice Measurements from Space). Methodologies for efficiently compiling inventories from satellite imagery are being developed. Remote sensing at various scales (satellite imagery, aerophotogrammetry) and GIS technologies are combined with digital terrain information. This fusion and downscaling approach helps overcome the difficulties of earlier satellite-derived preliminary inventories (area determination only) and reduces the costs/time of compilation.

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Secular glacier-mass changes from cumulative glacier length changes

(M. Hoelzle Geog/UZI, VAW, GK/SANW; W. Haeberli, M. Dischl, Geog/UZI; W. Peschke, VAW)

The main problem with interpreting worldwide glacier-mass-balance evolution is representativity, i.e. the possibilities of comparing the small sample of values measured during a few decades with the evolution in unmeasured areas and during previous time periods. One key in dealing with such uncertainties and assessing the spatio-temporal representativity of the few available measurements is long-term change in cumulative glacier length. The data regularly collected and published by the World Glacier Monitoring Service are now analyzed using a continuity approach for time intervals, corresponding to the dynamic response time of mountain glaciers (a few decades to a century). Mean annual mass losses of the glaciers with long time-series of length-change measurements centers on a value of ~0.25 m w.e. a^{-1} since 1900. Such reconstructed secular mass losses are considerably higher in regions with abundant precipitation than in continental-type climates with polythermal and cold glaciers. In comparison, directly measured average annual mass loss (0.4 m w.e.) in 1996 and 1997 was remarkably higher than the mean from 1980–95 (0.3 m w.e.). 1998 appears to have resulted in an extreme, if not new, record mass loss.

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Glacier changes, 1850 – 1973 – 2000

(M. Maisch, F.Paul, Geog/UZI; R. Weingartner, UBern)

The main results of NRP 31 project (Glaciers of the Swiss Alps), published in 1999, will be summarized in the Hydrological Atlas of Switzerland (HADES project, R. Weingartner). One of the two planned atlas sheets will be dedicated to statistical analysis of the approximately 2000 glaciers of the Swiss Alps, their glaciological characteristics (i.e. glacier types) and their spatial distribution (i.e. ELA trend surfaces). A second series of maps and diagrams will illustrate the scale and dynamics of glacier recession since the middle of the 19th century with respect to area and volumetric changes, as well as to the observed shift of ELA. In addition, first results of the new Swiss Glacier Inventory 2000, using modern satellite imagery, will display selectively the recent trends in glacier behaviour.

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Reconstructing mass balance of Grubengletscher

(A. Kääb, Geog/UZI)

The kinematic boundary condition at the glacier surface is used to reconstruct past mass balances of Grubengletscher as a function of changes in the surface elevation and of the horizontal/vertical velocities. Vertical velocity can be estimated from basal slope, basal ice velocity and surface strain. The key input of the calculations, the area-wide surface-velocity field, is obtained by a newly developed photogrammetric technique. Ice thickness is derived from radio-echo soundings. Based on results from an earlier test on the tongue of Griesgletscher, the kinematic boundary condition was applied

to reconstruct a 20-year mass-balance curve for Grubengletscher. With respect to individual years, the mass-balance distribution on the glacier tongue was modelled with an accuracy of about ±0.9 m a^{-1}. Ice-mechanical assumptions and errors in glacier-bed geometry markedly affect discrete mass-balance patterns, but are eliminated to a major extent when calculating year-to-year mass-balance changes. The resulting curve for the tongue of Grubengletscher 1973–92 shows reasonable consistency with meteorological data and other glaciologically-derived mass-balance series.

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Firn temperature and energy-balance investigations in the European Alps

(S. Suter, M. Hoelzle, VAW)

In June 1998, firn temperatures were measured in 22 steam-drilled boreholes in the summit region of Mont Blanc (3800–4800 m a.s.l.). The boreholes were equipped with removable thermistor chains and the firn temperatures measured down to a maximum depth of 22 m. The firn temperatures ranged from near-temperate conditions in a firn basin below 4000 m a.s.l. to –15°C at the exposed firn and ice ridge of Les Bosses (4547 m a.s.l.). At the summit of Mont Blanc (4807 m a.s.l.), a surprisingly high 16-m firn temperature of –14°C was observed.

Similarly, 31 firn temperature profiles were measured in the Monte Rosa area in May/July 1999. The observed 16 m firn temperature range was between –14°C at the 4450 m high firn saddle of Colle Gnifetti and temperate conditions at about 3900 m a.s.l. 74 % (Mont Blanc area) or 80 % (Monte Rosa area) of the variability of the observed 16 m firn temperatures could be explained by the altitude and aspect. Wind-exposed saddles and crests with low accumulation and high turbulent-heat exchange turned out to be true cold spots. In September 1998, an energy-balance station was installed at the 4300 m high firn saddle of the Seserjoch in the Monte Rosa massif. Temperature, humidity and wind speed are measured at four different levels. Additionally, shortwave radiation, longwave radiation, surface temperature and snow height are being registered. Two thermistor chains were lowered into the glacier to measure firn temperatures at the site. A 4 m chain is measuring the near-surface short-time temperature fluctuations, whereas a 30 m chain is recording the deep long-term temperature evolution. The temperature measured at 16 m depth is –9.5 °C. The observed firn temperature profile at Seserjoch could be reproduced with a heat-conduction model using measured surface temperatures as the upper boundary condition.

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Flow dynamics of Unteraargletscher

(G.H. Gudmundsson, T. Schuler, U.H. Fischer, VAW)

Work continues on investigating the morphology of the subglacial drainage system and examining how the seasonal evolution of the hydrological system influences patterns of subglacial water pressures, surface velocity and basal drag. High spatial and temporal resolution measurements of surface motion with an automated theodolite and differential GPS receivers are used to monitor surface uplift and glacier speed-up events. Hydromechanical basal processes, believed to control these events, are investigated by dye-tracing experiments and borehole observations of subglacial-water pressure and basal-sediment strength.

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Subglacial sediment texture, Haut Glacier d'Arolla

(U.H. Fischer, VAW; B. Hubbard, CG/UWalesA)

Subglacial sediment sampling has been undertaken to identify and isolate competing processes of textural alteration. All the samples recovered, from the margin of, and beneath, Haut Glacier d'Arolla, are generally composed of a broad range of clast sizes and approach self-similarity over the four orders of magnitude of grain-sizes analyzed. However, sample intercomparison reveals marked differences between sample textures that may be ascribed to the action of specific subglacial geomorphic processes: the production of fines by in-situ weathering, interpreted in terms of abrasion associated with subglacial-sediment deformation; and the loss of fines, interpreted in terms of eluviation by percolating subglacial meltwaters.

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Ice-bed coupling during a speed-up event, Haut Glacier d'Arolla

(U.H. Fischer, VAW; D. Mair, I. Willis, Geog/UCam; B. Hubbard, CG/UWalesA; P. Nienow, GTS/UGlas)

Detailed ice-motion studies of Haut Glacier d'Arolla have revealed that velocities are not consistent throughout the melt season. Instead, short-term speed-up events were observed to occur over large parts of the glacier in June of 1994, 1995, 1998 and 1999. Water-pressure, subglacial-sediment-deformation and basal-sediment-strength data are being collected within boreholes at several sites across the glacier to gain a better understanding of the coupling processes at the ice–bed interface during a speed-up event. Preliminary results suggest a sudden influx of surface water to an inefficient drainage system at the bed results in a build-up of high subglacial water pressures. As excess pressures propagate into the bed, basal sediments weaken, leading to increased rates of deformation of the basal-sediment layer. However, the data also reveal that subglacial-bed deformation accounts for less than 10% of the glacier surface motion during a speed-up event, implying significant decoupling and sliding at the ice–bed interface must occur.

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Hydraulic properties of subglacial sediments, Unteraargletscher

(U.H. Fischer, T. Schuler, G.H. Gudmundsson, VAW; P.R. Porter, Geog/ULeeds)

During summer 1999, arrays of ploughmeters and pressure transducers were deployed beneath Unteraargletscher to measure the strength of, and pore-water pressures within, basal sediments as well as water levels in boreholes. Variations in borehole-water levels are inferred to result in hydraulic gradients that drive

pressure waves vertically and horizontally through the sediment layer, thereby directly affecting its strength. From propagation velocities and amplitude attenuation of these pressure waves, hydraulic properties of the subglacial sediment can be estimated. Analysis of pressure waves that propagate from the bottom of boreholes into underlying sediments yields hydraulic conductivity values that are characteristic of a Darcian water flow through glacial materials. In contrast, a similar analysis for pressure waves propagating between different boreholes results in 5-order-of-magnitude larger conductivities which are interpreted as being indicative of a non-Darcian flow horizontally along the ice-sediment interface.

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Tidewater calving: ice-mechanical approach to derive a parameterization of calving rates

(A.Vieli, H. Blatter, M. Funk, VAW)

Field observations and numerical computations are used to identify and quantify the controlling processes for the calving rate and the flow dynamic of tidewater glaciers. The field observations are focussed on Hansbreen, a tidewater glacier in Spitsbergen. Measurements of surface-flow velocities showed strong temporal and spatial variations. They indicate that basal sliding is a crucial process governing the dynamics of Hansbreen.

In a numerical flow model which solves the full stress and velocity equations, we have introduced a basal water-pressure dependent sliding law. This model is used to calculate the time evolution of a tidewater glacier on the basis of a mass-balance scenario. Initial model results show the bed topography strongly affects the calving rate and the length change of the glacier. The developed model allows a physical analysis of the calving rate using different parameters.

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Remote sensing and GIS for early glacier- and permafrost-hazard recognition

(Ch. Huggel, A. Kääb, F. Paul, W. Haeberli, Geog/UZI)

Periglacial lakes can be detected, their changes monitored and related outburst risks assessed using aerial and satellite imagery. In a similar way, it is possible to observe glacier fluctuations endangering infrastructure and potentially causing ice avalanches. High-precision photogrammetry allows for measuring slow creep and sliding processes on frozen and nonfrozen slopes. Corresponding slope instabilities in the periglacial environment and potential starting zones of debris flows can be monitored. Computer-aided and digital aerial photogrammetry, especially a newly developed technique for determining surface-velocity fields in three dimensions, offers a wide range of possibilities to map disasters and hazard potentials, to monitor medium- and long-term development of dangerous situations and to provide area-wide boundary conditions for 2D- and 3D-modelling of kinetic and dynamic processes. Multispectral analysis techniques based on satellite imagery are used to detect glacier area changes, and glacial and periglacial lakes. The goal is to develop a long-term hazard-related monitoring system.

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Historical data for analyses of glacier floods and ice avalanches in the Swiss Alps

(Ch. Huggel, W. Haeberli, A. Kääb, Geog/UZI)

Hazards from ice avalanches and outbursts of ice- or moraine-dammed lakes in mountain areas have to be assessed on the basis of historical information. All available data of historical glacier catastrophes in Switzerland have been compiled for many years. Information collected from chronicles, the annals of the Swiss Alpine Club, historical experts and other sources from the 16th to 20th century have been entered into a single document and data bank. The historical sources are far from being homogeneous, thus hindering the extraction of complete information on every event. Analyses are nevertheless carried out in terms of maximum outburst or break-off volumes, maximum flood discharges, run-out distances and areas affected, damage and protective measures. All parameters are examined with a view to refining or adapting existing empirical models. In addition, the database is linked to a Geographical Information System (GIS) to document the spatial variability of, and the areas affected by, the events. The data represent a basis for remote sensing and GIS-based modelling of glacier hazards in the Swiss Alps.

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SNOW AND AVALANCHES

Development and operational implementation of a SNOWPACK model

(M. Lehning, P. Bartelt, C. Fierz, SFISAR; R. Brown, MSUB; P. Satyawali, SASE)

The Swiss national avalanche service aims to provide a high-quality forecast of avalanche danger with an increasing spatial and temporal resolution. This is only possible if objective methods to judge local and regional avalanche danger can support the forecaster. One important prerequisite for such an objective method is a comprehensive characterization of the snowpack status. For this purpose, a one-dimensional model based on finite-element numerics has been developed at SFISAR and is coupled to measurements of more than 50 automatic weather and snow stations (IMIS). For these locations at the altitudes of typical avalanche starting zones, the model predicts snowpack characteristics. The model has been operating since fall 1998 and delivers useful information on new-snow amount, wind transport of snow, surface-hoar formation, snow-cover metamorphic state (depth hoar etc.) and the complete energy and mass balance of the snow cover. While already in full operation, we are working to improve and complete the model, in particular with respect to snow metamorphism, snow-cover stability and interaction with the atmosphere (snow drift, energy exchange).

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Simulation of surface-hoar layers for snow-cover models

(P. Föhn, SFISAR)

The presence of surface-hoar layers in the snowpack is of prime importance for operational avalanche warning. In order to gain detailed insight into surface-hoar formation and ablation processes, a project combining field observations and simulation procedures has been set up. For two winters, meteorological conditions during surface-hoar formation and ablation have been studied, and the net deposition/sublimation rates of surface hoar measured and simulated with the aerodynamic profile method on two level snow fields in the Swiss Alps (1500 m and 2500 m a.s.l.). Although the evaluation is not complete, it is already obvious that the successful simulation of hoar layers of a given height at the snow-cover surface is only the important first step. The subsequent step, equally important, is to simulate all possible ablation processes (sublimation, melting, wind erosion of surface hoar) which definitively determine whether the surface-hoar layer survives and will be embedded as a dangerous weak layer by the next snowfalls.

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Investigation and simulation of textural and mechanical variability of mountain snowpacks

(C. Pielmeier, M. Schneebeli, SFISAR)

Spatial variability of mountain snowpacks will be investigated with a high-resolution snow penetrometer. Gridded measurements will be made in open and forested sites near the timberline. Snow samples will be investigated in detail in the cold-room laboratory. Random spatial variability within the snowpack will be analyzed using geostatistics. Layers will be defined based on objective criteria gained from high-resolution penetration measurements. Discriminating the systematic trends from random spatial variability is an important task and will be analyzed using statistical models and autocorrelation. Spatial variability will be visualized and simulated, and scaling laws gained from the analysis of the measurements will be defined.

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Two-dimensional snowpack modelling

(P. Bartelt , M. Christen, SFISAR)

A 2-D finite-element program to model the creeping deformation, temperature distribution and water transport in a phase-changing snowpack has been developed. Snow is treated as a three-component porous medium. This program is used to simulate field and laboratory experiments in order to develop numerical models for heat conductivity, snow settlement and snow metamorphism. A result has been a simplified 1-D model that is used operationally to predict the state of the snowpack at over 50 different locations in the Swiss Alps.

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Triaxial tests and snow

(P. Bartelt, SFISAR; M. von Moos, IGT)

Using a special-purpose triaxial apparatus, micro-structure-based snow-viscosity laws are formulated. The triaxial apparatus is deformation controlled and can apply strain rates between 10^{-3} s^{-1} and 10^{-8} s^{-1}. During the past two winters (1998, 1999) over 100 experiments have been carried out. Strain-rate-dependent laws have been formulated as a function of snow density, coordination number and grain and bond size. These laws are used to simulate the settlement and stability of the snowpack. Next, a load-controlled triaxial apparatus will be constructed and the temperature dependence of snow viscosity will be investigated. Snow-failure criteria will be formulated.

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Gliding on snow

(H.U. Rhyner, D. Buhl, C. Bruderer, M. Fauve, SFISAR)

The heart of this project is the description of the entire ski/snow-board/binding/ski-base/wax/snow system. A partnership between winter-sport companies (Stöckli skis, IMS ski bases, Toko wax, Nidecker snowboards and Fritschi bindings) and SFISAR has been established with the support of the KTI (Commission for Technology and Innovation).

The main effort is the collection of data for all relevant parameters of the system and adaptation of the measurement methods so all parameters are within the same measurement range. Special efforts are made to investigate new methods of describing the snow. With the adjustment of all relevant parameters, a complete description of gliding and turning of skis on snow is now available. In addition, the dynamics of ski/snow interaction were modelled using the finite-element method. The combination of this with the precise measurement of the main parameters of the entire system also enabled simulation of the interaction in a non-linear manner.

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Nutrient release of melting snow

(P. Waldner, M. Schneebeli, SFISAR; M. Schwikovski, PSI; H. Flühler, M. Stähli, ITESP)

Release of chemical trace species from seasonal-snow cover during melt results in significant ionic input into soil and vegetation. Its spatial and temporal distribution influences retention in the soil and uptake by plants. We measured the spatial and temporal variation of the nutrient release of the snow cover on an open field at 1210 m a.s.l. in Switzerland last winter.

In the cold laboratory, we reconstruct natural-snow covers by sieving typical snow types into a column to investigate the influence of the pack's structure on most important transport processes. Based on the results, a new simulation code describing the nutrient release of a snow cover will be developed and added to an existing model.

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Monitoring mountain snow cover with SAR

(H. Haefner, P. Piesbergen, D. Small, St. Biegger, H. Hoffmann, D. Nüesch, Geog/UZI)

Methods were developed and successfully tested to apply SAR data for monitoring geoecological processes in high-mountain terrain, particularly the wet-snow cover. Using the "multitemporal optimal resolution

approach" (MORA) concept, and merging ERS with Landsat TM or NOAA-AVHRR data, and a DEM, the snowmelt process could be monitored in detail in various watersheds and over large areas.

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Vegetation and soil related to physical and chemical properties of artificial snowcover

(V. Stöckli, Ch. Rixen, Ch. Huovinen, K. Huovinen, W. Ammann, SFISAR)

The temperature, density, chemical composition and air quality in and under the snow are being measured in an experimental field near Davos and at ten different ski areas in Switzerland. At each site, the variants (1) artificial snow on ski slopes, (2) natural snow on ski slopes and (3) untouched snow are sampled. The data will be used to determine the physical properties (thermal conductivity, viscosity) of artificial snow and to explain changes in vegetation and soil. The field experiments will be simulated using SFISAR's snowpack model.

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Snow, climate change and tourism in the Swiss Alps

(H. Elsasser, R. Bürki, Geog/UZI)

Snow modelling, with ETHZ and UBern, shows that the lower boundary of snow reliability for Swiss ski resorts could rise from 1200 m up to 1500–1800 m during the coming decades, leading to a new combination of winners and losers. Ski resorts at lower altitudes, especially, would be severely affected by the expected higher frequency of snow-deficient winters. A skier survey in five resorts shows that climate change will lead to a new structure of demand. About 50% of the skiers would ski in a higher resort and more than 30% would ski less often. With regard to the tourism industry, focus groups with tourism managers are run to investigate aspects relating to perception of climate change and corresponding adaptation strategies. The focus groups indicate a rather ambivalent behaviour of the tourism managers. They perceive climate change as a minor problem and play down possible impacts. At the same time, however, they use climate change as an argument to install artificial snow making and to expand activities into areas at higher altitudes. Despite the threat of climate-change effects, the tourism industry is unlikely to play an active role in mitigating adverse effects from climate change.

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Avalanche Warning Service

(T. Russi, T. Stucki, SFISAR)

The SFISAR is in charge of the avalanche warning service in Switzerland. Using SFISAR's vast body of knowledge and experience in snow and avalanche research, as well as cutting-edge computer tools and information technology, forecasters at SFISAR issue regional and national avalanche forecasts on a daily basis during the winter. These forecasts are disseminated by Internet, telephone, fax, as well as radio and TV stations. This warning service is extremely useful for local safety services, off-piste skiers, snowboarders and ski mountaineers alike and helps reduce the number of avalanche accidents in the Swiss Alps.

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Avalanche Warning Switzerland 2000

(W. Ammann, T. Russi, SFISAR)

New advances in snow and avalanche research, as well as breakthroughs in computer and communication technologies, have made it possible to improve the spatial and temporal resolution of avalanche forecasts over the last few years. New services and customer-friendly products have helped improve avalanche safety in the Swiss Alps.

Within the framework of the "Avalanche Warning Switzerland 2000" programme, a number of research projects have been launched. Three of the building blocks of the programme are described below.

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Early warning system for avalanches (IMIS)

(T. Russi, M. Zimmerli, SFISAR)

In order to have up-to-date information on the current snow and avalanche situation, a network of about 70 remote snow and weather stations has been established over the last few years. The stations are located near avalanche starting zones at altitudes between 1600 m and 3200 m a.s.l. and continuously monitor parameters related to the avalanche risk, such as snow, temperature or wind. Readings are collected every hour and fed into an information system called InfoBox. This system has been implemented in close cooperation with the cantons and villages threatened by avalanches. More than 200 organizations, e.g. safety services in villages, road departments and ski areas, are currently connected to this system. In addition to the measurements, weather and avalanche forecasts are available, as well as early warnings in cases of catastrophic situations.

NXD2000: tool for local avalanche forecasting

(M. Gassner, SFISAR)

Local avalanche forecasters have to make daily decisions such as whether to open or close roads and ski runs. Such decisions are very difficult because of the human and economic impacts. Therefore, a tool that helps the responsible person make such decisions is needed. NXD2000, based on the nearest-neighbour method, provides the forecaster with days in the past similar to the present, enabling him or her to check on potential avalanche activity. To run a forecast, it is necessary to input weather and snow data, which can be obtained from SFISAR through InfoBox, into NXD2000. To get reliable neighbour days, it is essential to input all avalanche observations. With daily use of the program, a local database of weather and snow data and avalanche observations is built, allowing the forecaster to obtain statistical information.

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Computer-aided regional avalanche forecasting

(B. Brabec, R. Meister, A. Stoffel, T. Stucki, SFISAR)

Computer assistance is crucial for improving the spatial

and temporal resolution of the SFISAR avalanche forecasts for Switzerland. A computer system supporting the complete process of regional bulletin construction is therefore being developed at SFISAR. The use of GIS and visualization software has allowed us to build a program for editing daily avalanche-hazard maps of Switzerland efficiently. These maps are the basis for regional avalanche forecasts that are disseminated over several regions of about 5000 km^2. To assist the avalanche forecaster in assigning avalanche-hazard levels to each of 100 areas, a statistical model has been developed: NXD-REG can calculate the current and future avalanche hazard by comparing present, forecasted and past situations. As for NXD2000, the approach of nearest neighbours is applied for each of 60 observer stations. The 10 nearest neighbours are combined to calculate a forecast of the avalanche hazard. Weather-forecast data allow us to predict the avalanche hazard for the next day. The system has been operational at SFISAR since February 2000.

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Numerical analysis and validation of flowing avalanches with special consideration of avalanche-deflecting and -catching dams

(W.J. Ammann, P.B. Bartelt, SFISAR; L.Vulliet, Soil Mechanics Lab/EPFL)

Presently, in the frame of dense-snow avalanche-dynamics models, snow is treated as a continuum fluid and avalanches are modelled by solving the steep-slope shallow-water equations numerically. Though well-calibrated and in practical use, these avalanche models provide little insight into the complex granular nature of avalanche flows and do not take into account snow entrainment from the encumbent snow cover. Furthermore, model applications to avalanche-defence dam calculations have not been validated experimentally.

The current project is concerned with resolving these problems using in-parallel concepts of granular-mechanics, laboratory-chute experiments and continuum-dynamics avalanche models. In granular mechanics, the avalanche flow is assembled from a big number of individual particle interactions. Establishing a link between granular- and continuum-mechanics avalanche models provides deeper insight in the complex-avalanche flow structure. Continuum models for flow friction and mass entrainment can be formulated this way.

The models are verified by laboratory-chute experiments, which also provide a test configuration for physical modelling of avalanche-catching and -deflecting dams in the run-out zone.

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Analysis and prediction of large avalanche events

(M. Laternser, M. Schneebeli, SFISAR)

Based on the visualization of weather, snow cover and avalanche data of the last 50 years, a comprehensive tool for the hazard assessment of large avalanche events will be created. For different regions of the Swiss Alps, a forecast model for large avalanche events will be developed by means of multivariate-data analysis.

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Dendrochronological survey of debris flows and avalanches at the Multetta debris fan

(C. Borter, K. F. Kaiser, Geog/UZI and WSL)

Following reconstruction of historical debris-flow frequencies since the late 15th century on the debris fan of Multetta above Tschierv in Val Müstair, eastern Swiss Alps, dendrochronological methods are now also used to to determine frequencies and reaches of snow avalanches during the past three centuries. The architecture of trees and the structure of tree stands on the fan reveal repeated and severe avalanche impacts. For the analysis of such past events, entire mountain pines (*Pinus mugo Turra*) were cut into discs from top to bottom. The discs are investigated for tree-ring anomalies such as scars, abrupt growth changes and reaction wood that allow precise determination of winter-event years (avalanches and snow pressure).

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Experimental avalanche dynamics

(W. Ammann, F. Dufour, D. Issler, M. Schaer, M. Hiller, U. Gruber, P. Bartelt, SFISAR)

In summer 1997, the experimental avalanche test site in the Vallée de la Sionne was equipped with various measurement devices. A shelter was built at the foot of the opposite slope in which Doppler-radar measurement devices (X and Ka band) are located. Three pairs of FMCW radars were installed at 2300, 1900 and 1600 m a.s.l. to measure flow depths, velocity profiles and entrainment/deposition rates. At 1600 m a.s.l., a 20 m oval-shaped mast, a girder mast and a 3 x 5 m wall were built to measure pressures on and stresses in these obstacles. In January and February 1999, three large to very large avalanche events were successfully triggered. In addition to the velocity and pressure measurements, the released and deposited masses were determined by photogrammetry and the avalanches were documented with video recordings. The measurements on the three avalanche events in winter 1999 provide important information to improve the knowledge about extreme avalanche events. Evaluation of all existing and new measurements at the test site will be the ongoing work in this project.

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Dynamics of powder-snow avalanches

(D. Issler, SFISAR)

The winter 1999 showed very clearly the lack of a simple model to consider the danger of powder-snow avalanches in avalanche-hazard mapping. To fill this gap, guidelines for practitioners and a new 1-D powder-snow avalanche model were presented to more than 80 practitioners in November 1999. The model is a two-layer model that divides the powder-snow avalanche into a saltation layer (snowballs of 1.0 mm to 50 cm diameter, directly above the dense-flow avalanche) and a suspension layer (grains of 0.1 to 1 mm). The mathematical model of the suspension layer is based on the turbulence-averaged Navier–Stokes equations for the ice–air mixture. The boundary conditions at the bottom are formulated in terms of mass- and momentum-exchange rates with the saltation layer that depend on con-

centration and velocity differences between the layers. Depth-average mass and momentum balances are solved for the saltation layer. The model ties erosion and sedimentation rates to local variables of the saltation layer. A follow-up project focusing on coupled dense-flow/powder-snow avalanche model will be the main goal of the ongoing research of avalanche dynamics by P. Bartelt.

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Avalanche-hazard mapping using numerical models and GIS

(U. Gruber, S. Margreth, P. Bartelt , M. Christen, SFISAR)
In winter 1999, more than 1000 large avalanche events occurred. In most cases, the existing avalanche-hazard maps covered the run-out distance of these avalanches. Nevertheless, some avalanches passed the boundaries of the existing hazard maps for several reasons. This project will inventory the largest avalanches that occurred and identify weaknesses in the methodology of avalanche-hazard mapping. The new numerical dense-flow and powder-snow models are used with GIS-technology to back-calculate these avalanches and improve knowledge about the friction parameters and the initial release conditions. The inventory of large avalanche events and the results and parameters for the back calculations are presented to practitioners through a web-site.

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Dynamics of flowing avalanches

(P. Bartelt, M. Kern, U. Gruber, M. Christen, SFISAR)
Depth-averaged hydraulic models are used to simulate flowing avalanches. These 1- and 2-D models have been extensively validated by field events. They can be used to predict avalanche run-out distances accurately. However, at present, they do not model avalanche flow velocities and mass balance well. For this reason, new constitutive-flow models which no longer assume a constant velocity profile, hydrostatic-pressure distribution, cohesionless-flow material and no entrainment of the snow cover (constant mass), are under development. The new models are based on kinetic-particle simulations, avalanche-chute experiments and field observations.

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Avalanche flow in forests

(P. Bartelt, V. Stöckli, SFISAR)
During the extreme avalanche winter of 1999, flowing and powder-snow avalanches often destroyed large forested areas. Avalanche deposits contained large amounts of fractured-tree material. Overturned trees were clearly visible along the avalanche tracks. In this project, observations from the winter of 1999 will be used to validate a theoretical model describing the fracture, entrainment and overturning of forested stands. The model will be used to formulate friction coefficients for flowing and powder-snow avalanche models based on forest and tree parameters such as tree type, tree spacing, tree height and root strength. The work will also be used to develop forest-maintenance guidelines.

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FROZEN GROUND

Permafrost monitoring

(D. Vonder Mühll, VAW; R. Delaloye, GGUF; W. Haeberli, Geog/UZI; M. Hoelzle, Geog/UZI and VAW; B. Krummenacher, SFISAR)
A concept for the Permafrost Monitoring Network Switzerland (PERMOS) was approved by both the Swiss Coordinating Group Permafrost and the Glaciology Commission within the Swiss Academy of Sciences (GK/SANW). PERMOS will complete the traditional glacier-monitoring network of the GK/SANW with a further component of the cryosphere; corresponding to international programmes (Global Geocryological Database, Global Climate Observing System). The principal purpose consists of documenting long-term modifications of permafrost in the Swiss Alps with regard to ongoing and potential future-warming trends. In different climatic regions of the Swiss Alps, thermal state is systematically observed and aerial photos are taken allowing later photogrammetrical analyses of permafrost environments.

Three parts are observed:
1) Temperatures in permafrost boreholes and horizontal/vertical deformation depending upon situation.
2) Temperature at the base of the snow cover (BTS), soil temperature and qualitative development of the snow cover (duration, thickness).
3) Aerial photographs (black-and-white and infrared). They form the basis for photogrammetric analyses of rock glaciers and for the documentation of geomorphologic, hydrologic and biological modifications in permafrost areas.

Initially (2000–03), the monitoring will be conducted by eight institutes (Canton Valais, Geog/UBern, Geog/UFrib, Geog/UZI, IGT, Geog/ULaus, SFISAR, VAW).

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Temperature evolution in Alpine permafrost

(D. Vonder Mühll, VAW; S. Springman, IGT; W. Haeberli, Geog/UZI)
The 60 m deep borehole through the active rock glacier Murtèl-Corvatsch (Upper Engadin), drilled in 1987, enabled the start of a unique series of temperature measurements within creeping mountain permafrost. Two additional permafrost drillings at Pontresina-Schafberg (Upper Engadin, established in 1990) allow the evolution of permafrost temperatures at a regional scale to be assessed: comparison of the temperature records from the two drill sites at about 3 m depth, i.e. immediately underneath the permafrost table, show a synchronous behaviour. In 1998 and 1999, additional boreholes in the bedrock of Schilthorn and through the Muragl rock glacier augmented the available data. Thermal regimes at these new drill sites are quite different, allowing for investigations of permafrost thermal conditions in massive limestone and in frozen debris near melting temperature. Key variables governing the permafrost temperatures in the Alps are global radiation, air temperature and the snow-cover development during wintertime.

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Geophysical methods to characterize and map mountain permafrost

(D. Vonder Mühll, C. Hauck, VAW; H.R. Maurer, Geophys/ETH-Z)

Several different geophysical methods are being applied for mapping and to develop methodologies for permafrost applications. At most places, d.c. resistivity tomography (2-D), refraction seismics (1-D and 2-D tomography) and electromagnetic induction (with the EM-31) are applied. However, to distinguish between the characteristics of geological and thermal effects, a combination or complementary geophysical methods (gravimetry, PROTEM, etc) has to be applied. Additional information (e.g. from borehole data, numerical modelling or d.c. resistivity measurements) are very useful for calibration.

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Permafrost modelling in the Bernese Alps

(M. Imhof, GIUB)

Based on field data collected in the Bernese Alps, a permafrost model was developed. Besides MAAT and potential direct shortwave radiation, the model considers snowmelt evolution mapped from aerial photographs. This is closely related to permafrost distribution; its use as a modelling parameter therefore improves the spatial differentiation of the modelling results.

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Energy-balance modelling of mountain permafrost

(C. Mittaz, M. Hoelzle, W. Haeberli, Geog/UZI)

Modelling the spatial distribution of permafrost under climatically disturbed conditions requires detailed knowledge of the energy-exchange processes at the atmosphere/lithosphere boundary and a better understanding of the processes of Alpine permafrost formation or decay. As a first step, an energy-balance model is developed using suitable parameterizations for all important energy fluxes. The model is mainly applied to two areas around the Piz Corvatsch (Engadin, 16 km^2) and around Schilthorn (Bernese Oberland, 35 km^2) and uses simple meteorological data, a digital elevation model and surface information as input. To verify the model calculations independently, energy-balance measurements are carried out at two permafrost sites. As a main result, the daily surface ground temperatures can be calculated, which deliver important information on the near-surface thermal regime of the ground. In a next step, a thermal offset model will link the near-surface temperatures to thermal conditions at depth.

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Distribution and characterization of permafrost, Mont Gelé area (western Swiss Alps)

(E. Reynard, C. Lambiel, Geog/ULaus; R. Delaloye, Geog/UFrib)

The distribution and the current modifications of permafrost in the Verbier/Nendaz area, western Swiss Alps, are being modelled. Both field measurements (BTS, d.c. resistivity soundings, borehole temperatures) and computer modelling are carried out. Data are integrated in a GIS to facilitate planning tourist development in the area. First results show a substantial "warm" permafrost with temperatures very close to 0°C. A complex distribution of ground ice has also been shown in various areas deglaciated since the end of the Little Ice Age.

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Low-elevation permafrost in the Jura

(R. Delaloye, Geog/UFrib; E. Reynard, Geog/ULaus)

The long-term evolution of permafrost at very low elevations in the Jura Range is being observed and characterized. Different field measurements (BTS, d.c. resistivity, meteorological) are carried out in the Creux du Van (1200 m a.s.l.). First results show that pockets of permafrost exist at very low elevations with little solar radiation and a globally cold and wet microclimate.

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Digital photogrammetry for monitoring creeping mountain permafrost

(A. Kääb, M. Vollmer, Geog/UZI)

The rock glacier is typical in cold and relatively dry mountain areas. Its kinematics, as reflected in the viscous-type surface morphology, is among the clearest characteristic of creeping mountain permafrost. Photogrammetry is a suitable tool for measuring area-wide thickness changes and 3-D displacements. A new generation of digital methods is used to automatically derive repeated digital terrain models. Software has been developed to extract surface displacements automatically from repeated digital imagery. Thus, derived velocity fields and elevation changes represent an important basis for understanding process and modelling. The new technology greatly facilitates the acquisition of kinematic data, compared to analytical or analog photogrammetric techniques.

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Surface deformation of creeping mountain permafrost – photogrammetric investigations

(A. Kääb, M. Hölzle, Geog/UZI; H. Gudmundsson, VAW)

Computer-aided aerial photogrammetry is applied to analyze surface topography and surface kinematics, i.e. changes in elevation and horizontal surface velocities, on Murtèl rock glacier. With 3-D borehole-deformation measurements, the area-wide information about surface kinematics is used to estimate the magnitude of different components of the kinematic boundary condition at the surface. Analysis of surface kinematics along a longitudinal profile, measured with high spatial resolution, shows that transverse ridges on Murtèl rock glacier propagate downstream with a velocity approximately equalling that of the surface rocks. The first appearance of the transverse ridges coincides with a point of a marked decrease in average slope. The subsequent increase in ridge amplitude seems to be related to general longitudinal compression. The formation and growth of transverse ridges towards their maximum amplitude takes several millennia.

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Snow-supporting structures in permafrost

(M. Phillips, P. Thalparpan, W. Ammann, SFISAR)

The thermal influences of snow-supporting structures on ground temperature are being investigated at two experimental sites in Alpine permafrost at 3000 m a.s.l. in Valais and Graubünden. Snow-supporting nets and bridges, equipped with thermistors, were built on steep avalanche slopes in frozen ground in 1996. Ground temperatures are measured in boreholes, at the ground–snow interface and in the immediate vicinity of the structures. Snow-cover distribution is monitored using an automatically triggered camera and snow stakes. The structures artificially modify spatial and temporal snow-cover distribution: spring snowmelt is delayed and the long-term effect of the structures is to induce cooling of the ground. Various types of structures and foundations are being tested and grout experiments have been effected in the laboratory and in the field. Guidelines for the construction of snow-supporting structures in permafrost have been developed. Stability of the structures and of the slope are monitored regularly using inclinometer pipes and surface triangulation. Data obtained are used to calibrate and drive a 2-D finite-element program based on heat conduction.

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Unstable permafrost: a potentially important natural hazard

(S.M. Springman, L. Arenson, IGT; H. Maurer, M. Musil Geophys/ETH-Z; D. Vonder Mühll, VAW)

The aim of the project, a collaboration of three institutes (IGT, Geophys/ETH-Z, VAW), is the characterization of the thermomechanical properties of Alpine permafrost.

Geophysical-reconnaissance surveys were conducted on the Muragl rock glacier in 1999/2000. On the basis of these results, the location for an array of 4 boreholes was selected. The holes were drilled to 64–72 m depth with about 20 m of cores. In addition, several geophysical tests were performed in the holes. These results are being used as information for a laboratory triaxial-testing program, on artificial permafrost and on the cored samples. Subsequently, these data will be compared in order to describe the stress–strain/time–temperature dependence of the mechanical response in one constitutive model.

The geophysical-borehole experiments included application of borehole-to-borehole transmission tomography techniques using seismic and georadar data. To improve the reliability of the 3-D subsurface models, new approaches to inverting the data are being implemented.

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Relative-age dating of rock-glacier surfaces

(W. Haeberli, M. Maisch, M. Egli, A. Kääb, Geog/UZI)

Active rock glaciers evolve over thousands of years. Their surfaces reflect permafrost-related debris production and rockfall activity within the cliffs at their head during the upper Holocene. In order to decipher this environmental archive and document long-term variability ranges, systematic Schmit–Hammer and weathering-rind measurements are compared with photogrammetrically determined flow trajectories and corresponding age estimates. First results from rock glaciers in the Upper Engadin indicate significant trends, but with high scatter. Relict rock glaciers, probably dating from the Late-glacial time, will be investigated for comparison.

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GIS-based modelling of creeping mountain permafrost

(R. Frauenfelder, M. Hoelzle, B. Schneider, W. Haeberli, Geog/UZI)

In recent years, there has been a renewal of interest in the climatic and geomorphic significance of rock glaciers. The present study aims at applying two complementary approaches: (a) the development of a GIS-based model simulating Alpine rock-glacier distribution and (b) the evaluation of presently relict rock glaciers to reconstruct past permafrost distribution limits. The synthesis of these two approaches should allow for assessing paleoclimatic fluctuations in the time range of millennia.

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Talik formation and geothermal anomaly at Murtèl/Corvatsch

(W. Haeberli , Geog/UZI; Th. Kohl, IG; D. Vonder Mühll, VAW)

Evidence from an increasing number of borehole-temperature measurements indicates that permafrost in mountain areas is quite generally warming at a secular time-scale. Such long-term permafrost warming may trigger changes in hydraulic properties of ice-containing rock masses and contribute to the destabilization of steep, frozen rock, slopes near the lower boundary of permafrost occurrence. Understanding the processes involved is difficult because of the heterogeneity of the materials and the lack of direct observations. The permafrost borehole Murtèl/Corvatsch was drilled in 1987 and has been monitored since then. Mean annual temperature at the permafrost table is around –2.5°C with a rising tendency. Permafrost conditions at the site are assumed to have existed throughout the entire Holocene. At a depth of 55 m below the surface, temperatures are affected by seasonal water flow in a thin layer (talik) at the debris/bedrock interface. A characteristic geothermal anomaly is observed with stable negative ground temperatures above and below the seasonally unfrozen zone. The shape of the temperature profile together with a sensitivity analysis using a 1-D heat-conduction calculation, indicates that total permafrost thickness may have been around 100 m or more during the colder 19th century and that talik formation with its thermal anomaly took place several decades before the drilling, probably as a consequence of 20th-century warming. Various scenarios have been modelled by numerical simulations concerning transient states of permafrost thermal conditions in the past and for assumed future warming. The results indicate that the development of the observed talik formation strongly depends on the specific thermal and hydraulic material parameters.

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Distribution of mountain permafrost in peripheral areas

(M. Monbaron, R. Delaloye, Geog/UFrib; E. Reynard, Geog/ULaus)

Peripheral areas of permafrost distribution are sectors at the edges of normal permafrost existence: the lower limit of permafrost distribution, recently deglaciated proglacial margins, rock-face bases with little solar radiation, etc. Climate warming will lead to melting of some of this frozen ground, which could cause an increase in catastrophic events such as debris flows, rock falls and landslides. The sensitive areas are those where the permafrost is most precarious, i.e. close to the lower limit of permafrost and areas which have undergone recent modifications (proglacial margins).

The aims are to determine permafrost zones and evaluate their temporal evolution. Geophysical investigations and GIS simulations are used to determine whether permafrost exists or not. The results will provide elements allowing the prevention of natural hazards and management of water resources in the Alpine environment.

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ICE CORES

Ice-core drillings on Alpine glaciers

(Th. Stocker, B. Stauffer, H. Rufli, M. Leuenberger, KUP)

The Division for Climate and Environmental Physics is participating in the European ALPCLIM project. For this we provided a new shallow drill for core drilling in the Mont Blanc region in October 1999. The operation was directed by the Laboratoire de Glaciologie et Géophysique de l'Environnement in Grenoble (S. Preunkert). At Col du Dôme, bedrock was at about 100 m depth, and at about 40 m at Dôme du Goûter. For other Alpine ice cores, we performed various measurements on air extracted from ice samples. Comparison of the methane record with polar records allows dating of the Alpine cores for the past 250 years. $\delta^{18}O$ measurements on oxygen in samples close to the bedrock did not confirm that this ice originated from the last glaciation as isotopes measured on the ice suggested.

(http://www.climate.unibe.ch)

Reconstructing paleo-atmosphere from Alpine ice cores

(M. Schwikowski, PSI; H.W. Gäggeler, A. Eichler, U. Schotterer, PSI and UBern; M. Funk, VAW; A. Dällenbach, KUP)

To understand atmospheric cycling of species with short atmospheric life times, such as aerosol particles, paleo-atmospheric data from mid-latitude regions are highly desired. In Europe, such data can be reconstructed from Alpine ice cores. We are studying different ice cores in order to acquire (1) a record which covers the largest time period accessible in the Alps and (2) records from the northern and southern part of the Alps to identify air-pollution sources. For (1), we use a core from the Colle Gnifetti, a low-accumulation site. 95 of the 124 m core cover more than 1000 years, determined using the known methane-concentration record. For (2), ice cores are analysed from the Fiescherhorn glacier and Grenzgletscher, where regular snow deposition allows dating by layer counting (1946–88 at Fiescherhorn, 1937–94 at Grenzgletscher).

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Glaciochemical records from Andean glaciers

(M. Schwikowski, PSI; H.W. Gäggeler, P. Ginot, U. Schotterer, PSI & UBern; B. Zweifel, M. Funk, VAW; B. Pouyaud, IRD La Paz; A. Rivera, Universidad de Chile, Santiago; F. Stampfli, FS Inventor, Riggisberg, Switzerland)

The central Andes is a key area for paleoclimate and paleo-atmosphere reseach, since it lies in a transition zone between two precipitation belts; the extratropical westerlies receiving moisture from the Pacific and the tropical circulation with a continental/Atlantic moisture source. To reconstruct climate variations related to El Niño, ice-core drilling to bedrock was performed in February 1999 on top of Cerro Tapado (5550 m, 30°08' S, 69°55'W, 36 m long core) in northern Chile and in June 1999 on Illimani (6432 m, 16°39'S, 67°47'W, Bolivia, 138 m long core). These glacier sites are assumed to preserve the chemical and isotopic signature of a precipitation regime affected by the westerlies with a strong El Niño influence (Cerro Tapado) and by the tropical circulation (Illimani). First results of chemical analyses indicate that the Tapado ice core covers a period of about one century. Minimum values of ^{210}Pb initial activity and δ^2H were identified as fingerprint signatures of El Niño events.

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Miniature cold ice caps as potential Holocene climate indicators

(W. Haeberli, R. Frauenfelder, A. Kääb, Geog/UZI)

Long-term ice-core records of Alpine glaciers are characterized by their intimate connection to the continental source regions. Besides high-altitude Alpine archives from cold-firn areas, especially on Mont Blanc and Monte Rosa, perennial-ice bodies at lower altitudes also bear information about the past. Moreover, recent findings (Ötztal iceman, wooden bows at Lötschental), reveal the so far unknown fact that small, and more or less static, perennial-ice bodies, slightly cold and frozen to the underlying bedrock, may contain very old ice and, hence, important paleoclimatic information on warm stages with minimum ice extent in the Alps. Since autumn 1998, various investigations were carried out on a promising crest-type location at Piz Murtèl (Engadin). Specific characteristics of this site – are: cold ice (a few °C below zero), no basal sliding, small mass turnover, accumulation mainly by superimposed ice, striking lack of a firn zone and direct access to very old layers (centuries, millennia?) at the ice/bedrock interface.

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Cosmogenic nuclides in the GRIP ice core

(J. Beer, G. Wagner, R. Muscheler, EAWAG; AMS group of ETH-Z/PSI)

The analysis of the cosmogenic radionuclides ^{10}Be and ^{36}Cl in the glacial part of the GRIP ice core has been completed and the analysis of the Holocene part is in progress. During the glacial period, the long-term trends of ^{36}Cl and ^{10}Be fluxes mainly reflect changes in the production rate, which have been calculated from paleomagnetic data using a new production model. During the Holocene, the ^{10}Be and ^{36}Cl data are consistent with the $\Delta^{14}C$ derived from tree rings indicating that the observed short-term changes in ^{14}C (e.g. Maunder minimum 1645–1715 AD) are due to periods of low solar activity.

These results have important implications for solar models, but also for climatology, because the solar constant depends on the solar activity. A good knowledge of the cosmogenic-nuclide flux provides information on the precipitation rate which is a fundamental climate parameter and also crucial for establishing a depth–age scale. The $^{10}Be/^{36}Cl$ ratio, which changes with an apparent half-life of 375,000 years, clearly indicates that the lower part of the GRIP ice core is considerably older than estimated, based on ice-flow modeling.

Ice-core drillings in Antarctica

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

The Division is participating in EPICA together with laboratories from 10 nations. In 1997/98 and 1998/99 it participated in the deep-drilling operation at Dome Concordia, as well as the reconnaissance in Dronning Maud Land. Our main responsible is continuous analyses performed in the field.

(http://www.climate.unibe.ch)

Reconstruction of atmospheric composition

(B. Stauffer, Th. Stocker, J. Schwander, A. Indermühle, A. Dällenbach, J. Flückiger, KUP)

CO_2 analyses on ice samples from the U.S. ice core from Taylor Dome allowed reconstruction of a very detailed record of the atmospheric CO_2 concentration for the past 60,000 years. The record covering the Holocene shows a surprising minimum at about 8,000 years BP, followed by a steady increase to 280 ppmv at the beginning of industrialization. The record during the last glaciation confirms variations of the atmospheric concentration parallel to the largest Dansgaard/Oeschger events. Additional measurements of the CH_4 concentration on ice samples from Greenland (GRIP ice core) and Antarctica (Byrd Station) also allowed reconstruction of interhemispheric concentration gradients for the glacial epoch.

Measurements of the N_2O concentration on samples from Greenland provided the most precise atmospheric N_2O record for the past 1000 years and showed that the atmospheric N_2O concentration varied parallel to the last glacial–interglacial transition and to fast climatic variations during the glacial epoch.

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Continuous chemical analyses along ice cores

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

We have developed the Continuous Flow Analyses (CFA) method further and applied it successfully in Antarctica. The ice core from Dome Concordia was analyzed from top to 580 m depth, covering about the last 25,000 years. The concentrations of Ca^{++}, Na^+, NH_4^+, H_2O_2, HCHO and NO_3^-, as well as the electrical conductivity of the meltwater, have been measured with a resolution of 10 mm. The ammonium, calcium and sodium measurements along three intermediate-depth ice cores (100–150 m) from Dronning Maud Land allowed seasonal variations along cores from the Antarctic plateau to be detected for the first time. CFA has also been performed during the past two years along a intermediate-depth core from North Greenland and on selected sections of Alpine ice cores.

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Reconstruction of stable-isotope composition

(M. Leuenberger, Th. Stocker, C. Lang, P. Nyfeler, KUP)

By analyzing the isotopic composition of atmospheric nitrogen trapped in polar ice, we were able to determine temperature changes during two abrupt climate variations, 8200 and 70,000 years before present (BP). This reconstruction of temperature variations is based on the thermal-diffusion effect within the static firn column altering the air composition according to the thermal-diffusion sensitivity. The Greenland temperature for the Holocene, at 8200 BP, was more than 7°C cooler for a couple of centuries compared to adjacent time periods. During the Dansgaard/Oeschger event 19, temperature increased by as much as 16°C within about a century. Last year, we were able to purchase two new mass spectrometers equipped with peripherals, which allow precise isotope determinations on tiny amounts of trace gases, such as δ13C on CO_2 and CH_4, as well as $\delta^{15}N$ and $\delta^{18}O$ on N_2O to be performed.

(http://www.climate.unibe.ch)

Firn-air measurements

(J. Schwander, T. Stocker, M. Leuenberger, A. Dällenbach, A. Indermühle, H. Loosli, KUP)

Besides the enrichment of heavier molecules and isotopes as a consequence of the Earth's gravity field, thermal diffusion is another physical mechanism that leads to a slight separation of the air components in the firn. In the presence of a temperature gradient, heavier air components generally tend to accumulate at the colder end. The main thermal-diffusion effect comes from seasonal temperature variations and affects the topmost firn layer. Thermal diffusion has now been successfully implemented in our firn-diffusion model. Firn-air samples from Devon Island (Canada), Dronning Maud Land and Dome C were analysed for CO_2, CH_4, $\delta^{15}N$ of N_2, $\delta^{18}O$ of O_2, O_2/N_2, Ar/N_2 and ^{85}Kr. CO_2, CH_4, and ^{85}Kr are used to determine the age of the extracted air. Isotope ratios show clear signals of thermal diffusion in the upper strata, in good agreement with the results of the diffusion model. Measured elemental ratios in the

bubble close-off zone show significant deviations from the atmospheric ratios, which are thought to originate from a molecular-size dependent gas loss from freshly closed bubbles.

(http://www.climate.unibe.ch)

SNOW/ICE CLIMATOLOGY AND HYDROLOGY

Boundary-layer wind field and snow transport over high Alpine topography

(M. Lehning, J. Doorschot, N. Raderschall, SFISAR; J.-A. Hertig, EPFL)

Since blowing and drifting snow are major factors influencing avalanche danger, the local microclimate and hydrology, an objective and quantitative assessment and forecast of snow transport by wind is of great practical value. We have developed model formulations of snow drifting and distinguish the transport modes, preferential deposition, suspension and deposition. The model formulations are coupled to the SFISAR SNOWPACK model and provide local to regional indices of snow drifting. At the same time, basic research into the physics of snow transport is conducted and snow drifting as a fully 4-D phenomenon in Alpine terrain is investigated. We use a mesoscale atmospheric-prediction model (ARPS) to calculate high-resolution wind fields in Alpine terrain and use the wind field to drive transport models. We improve current drift models by investigating snow saltation and preferential deposition in particular. The theoretical concepts are based on, and evaluated against, extensive measurements at our experimental field sites, and in a cold wind tunnel which will be built in Davos in 2000. This wind tunnel will be operated with natural and artificial snow and provide a unique opportunity to study snowdrifting, behavior of artificial snow and mass, and energy exchanges between the snow cover and atmosphere.

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Snow cover and snow albedo in general circulation models

(A. Roesch, M. Wild, A. Ohmura, IKF)

Different global and regional data sources have been used to assess mean monthly albedo, snow-cover extent and snow depth simulated in the ECHAM4 GCM. A number of deficiencies have been identified in the parameterization of the snow-covered land surfaces. To investigate the influence of modifications in the parameterization of the ECHAM4 GCM, several ten-year model experiments have been performed. These modifications include a changed parameterization of the snow-cover fraction, the splitting of the surface albedo into the visible and the near-infrared band and the introduction of subgrid-scale orographic effects. Furthermore, a simple canopy model and an annual cycle of the leaf-area index have been used to improve the albedo of snow-covered forests.

Effects of snow cover on European climate: a regional modelling study

(G. Walser, C. Frei, C. Schaer, IKF)

To investigate the influence of snow-cover variations on the regional climate in Europe, two experiments with "Europa Modell", the operational weather-prediction model of the German Weather Service (DWD) and the Swiss Meteorological Institute, were conducted for January 1991. The large-scale dynamics is retained by the chosen methodology and, hence, made it possible to examine the thermodynamical and radiative effects of snow-cover changes in isolation. A control run was driven at the lateral boundaries with the observed weather evolution. In a sensitivity experiment (C4K), the same driving fields were used, but with a uniform temperature decrease of 4 K leading to a largely extended snow cover in central Europe. A validation with satellite-derived data reveals that the used model reproduces present-day snow coverage satisfactorily. The C4K scenario exhibits on the regional scale (in addition to the externally imposed one) a decrease in temperature which is less than 1 K on the monthly average. This decrease is confined to the lowest decametres of the atmosphere and, hence, leads to an enhancement of the stability of the near-surface air layer. With regard to the surface energy budget, reductions in net shortwave and longwave radiation are found to be compensated to a large extent by changed turbulent-energy fluxes. The temperature feedback is more pronounced for a cloudless period of six days over western Europe, amounting to 2 K on average. Furthermore, investigations of this cloudless period indicate that, on a smaller scale, the snow-covered surface is, unlike for more active weather periods, able to strongly affect energy budget and temperature through the snow-albedo feedback.

Remote sensing in snow hydrology: snowmelt-runoff forecasting in a changing climate

(H. Haefner, Geog/UZI; K. Seidel, IKT; C. Ehrler, J. Schaper, IKT and Geog/UZI)

Within the framework of this long-term research program, the continuous monitoring of the accumulation and melting process of the snowpack and of the water equivalent in its regional differentiation was fully operationalized for three main basins in the Swiss Alps (Rhine above Felsberg, Rhone above Sion; Ticino above Bellinzona). The results are used for daily and seasonal snow melt runoff forecasts applying the Snowmelt Runoff Model (SRM), and for simulating the alterations of the snowcover and run-off in a changing climate for various climate scenarios. To refine the model, research is under progress to separately determine the ice cover of the glaciers and to simulate the run-off from melting ice.

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Water balance of Unteraargletscher

(T. Schuler, U. H. Fischer, G. H. Gudmundsson, VAW; R. Sterr, Innsbruck University; R. Hock, CIRC)

A distributed temperature-index melt model, including potential clear-sky solar radiation, was applied to Unteraargletscher to quantify water input to the glacial

hydraulic system during the 1999 ablation season. Model parameters were determined by calibrating calculated melt with direct ablation measurements. Discharge was measured in the proglacial stream for 17 days, until the station was destroyed by an outburst flood.

Comparison of modeled melt and measured discharge reveals that the transfer of water through the glacier varies with time as the water is routed through a dynamic drainage system. Furthermore, an imbalance of water input and output suggests that water was stored in, or beneath, the glacier during this period. The culminating outburst flood presumably released this en- or subglacially stored water and may be related to a change in the configuration of the glacial drainage system, as inferred from measurements of subglacial-water pressure.

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Hydrological catchment modelling in glacierized drainage basins

(Badoux, J. Gurtz, IKF; L. Klock, UWAG; H. Lang, K. Jasper, K. Roelofsma, UWAG; J. Schulla, M. Zappa, IKF)

A glacier submodel was successfully integrated into two complex spatially distributed catchment models of GIETH in order to simulate the complex hydrological processes (including snowmelt), the runoff components and water-balance elements in glacierized and partly glacierized catchments. One of these models is the more detailed grid-based catchment model called WaSiM-ETH. The other one is the more conceptual Hydrological Response Unit related model, called PREVAH. A combined temperature and radiation approach, based on a study by R. Hock, was introduced for a spatially distributed modelling of glacier melt from the snow, firn and ice surfaces of glaciers.

The transformation of the meltwater-runoff components of these subareas to the glacier snout and to the catchment outflow stage was realized using three parallel linear reservoirs which are integrated into the complex structure of the flow paths of the models. Spatial differences in the inputs of radiation and temperature are taken into account depending on the topography and surface conditions. The new configurations of the models were successfully tested in three high Alpine catchments with different portions of glacierized areas. The different runoff components, the water-balance elements and the discharge hydrographs were simulated in the catchments of:

(a) Rhone /stage Gletsch (38.9 km^2, 52.5% glacierized) for the period 1990–96;
(b) Rosegbach /stage Pontresina (66.9 km^2, 30% glacierized) for the period 1991–98; and
(c) Dischmabach /stage Kriegsmatten (43.3 km^2, 2.1% glacierized) for the period 1981–96.

The performance of models was validated with good results by comparison of the hourly simulated and measured discharge values in the catchment outlet profiles.

Antarctic sea-ice simulation

(H. Huwald, H. Blatter, IKF, L.-B. Tremblay, LDEO)

A dynamic–thermodynamic sea-ice model with granular material rheology is used to simulate Antarctic sea ice. The stand-alone version is coupled to a simple slab ocean and a simplified atmospheric model. In a first step, validation of the model was performed by comparing results to satellite-derived sea-ice concentration data. A series of sensitivity experiments demonstrated the relative importance of various physical parameters of the atmosphere, the ocean mixed-layer and of heat fluxes within or between the different system components: ocean, ice and atmosphere. The present study upgrades the model allowing for a snow layer atop the ice with vertically resolved, transient temperature profiles for both layers and for penetrating shortwave radiation. The influence of the snow layer, as well as the impact of a resolved daily cycle of shortwave radiation, is investigated. The long-term aim is the coupling to an atmosphere–ocean global climate model.

Contribution of small glaciers and ice caps to future sea-level changes

(C. Schneeberger, H. Blatter, O. Albrecht, IKF; R. Hock, CIRC)

This study will provide a forecast of the mass balance of glaciers in an enhanced greenhouse climate, and assess the contribution of mountain glaciers and small ice caps to sea-level changes for the coming century. We use a melt/accumulation model forced with a climate scenario based on the IPCC greenhouse scenario IS92a. The melt/accumulation model is based on a distributed (dependent on location) temperature-radiation index model. The available climate scenario has been computed with the ECHAM4 global climate model of the Max-Planck-Institute for Meteorology, Hamburg, in a time-slice experiment with a T106 high resolution "control run" (present climate) and a T106 high resolution 2 x CO_2 time slice around the middle of the next century.

The method is applied to glaciers and small ice caps according to their potential contribution to sea-level changes: About 20,000 of an estimated total of 60,000 existing glaciers are registered in the World Glacier Inventory. However, a small number of larger glaciers and small ice caps contain more than 50% of the ice locked in mountain glaciers. It is therefore possible to assess a large fraction of the possible contribution of glacier ice to future sea-level changes with a relatively small number of case studies. The contribution of the remaining glaciers will be estimated with a simplified method, based on regional mass-balance sensitivities and an inventory of the regional ice coverage. A statistical downscaling methodology will be adopted to constrain climatic conditions on glacier surfaces.

Effects of polar ice sheets on global sea level

(M. Wild, A. Ohmura, IKF)

Projections of future global sea level critically depend on reliable estimates of mass-balance changes on the polar ice sheets. The most sophisticated tools to allow for such estimates are general circulation models (GCM). A major impediment, until recently, has been their coarse grid resolution (3°–6°) causing substantial uncertainties in the mass-balance calculations on the poorly resolved ice sheets. At ETH, climate-change experiments of the high-

est resolution currently feasible (1.1°) with ECHAM4 GCM have been performed, thereby increasing confidence in the projected mass-balance and sea-level changes. This new experiment with doubled carbon-dioxide concentration suggests that the mass gain in Antarctica, due to increased accumulation, exceeds the melt-induced mass loss in Greenland by a factor of three. In terms of sea-level change, this corresponds to a net sea-level decrease of 0.6 mm a^{-1} at the time of doubled carbon-dioxide. This may compensate for a significant portion of the melt-induced sea-level rise from smaller glaciers and ice caps, thus leaving thermal expansion as the dominant factor for sea-level rise over the next decades. The compensating effect, however, fades if atmospheric carbon-dioxide were to reach levels above doubled values. This would then induce sufficient warming to initiate melt also on the Antarctic ice sheet. Thus, the deceleration of sea-level rise due to the net mass gain on the polar ice sheets may only be effective as long as carbon-dioxide concentrations can be stabilized below double the present values.

GLACIAL GEOLOGY/ PALEOGLACIOLOGY

Ring-shear experiments as a tool for the classification of subglacial tills

(B.U. Müller, Geol/UBern)

Various glaciogenic sequences around the Alps have been investigated to examine the shear behaviour of subglacial tills. In addition to ring-shear experiments, clast lithology, clay mineralogy and the physical properties of all the samples were determined. At some sites, a strong relationship between local bedrock (mostly shales) and the formation of thin basal layers of strongly deformed till can be demonstrated. These locally derived basal layers show distinctly different shearing properties compared to the massive till units that are normally found in the circumAlpine region. The difference in the angle of internal friction between the two different till types can go as high as >10 ° at residual shear strength, although the clay mineralogy of both till types is similar. It can further be demonstrated that after the deposition of such a 10–15 cm thin till layer directly on bedrock, the flow dynamics of the glacier tongue may have changed due to the different glacier till lithology. The totally different shear behaviour of these two subglacial sediment types points to an important change from a "deformation till" to an overlying "non-deforming till" environment, sometimes occurring during the same glacial advance.

To compare the deformations produced in ring-shear experiments to natural glaciogenic deformations, various optical investigations such as thin sections and SEM-analyzes are made. SEM-analyses of the artificially produced deformation patterns in these sediments show very thin shear zones of 2–3 m thickness, despite the long shear distances of up to 145 mm and the presence of well-developed slickensides. Discrete shear planes in natural environments seem to be thicker, a fact that might point to very long shear distances in the subglacial environment.

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Historical glacier fluctuations and dendrochronological investigations in the Alps

(H. Holzhauser, Geog/UZI)

Paleosols and fossil woods have been dated in an attempt to reconstruct, without gaps, the amplitude of Holocene fluctuations of various Alpine glaciers situated in the Valaisian and Bernese Alps (Rhone, Grosser Aletsch, Gorner and lower Grindelwald glaciers). Special attention is paid to minimum glacial extensions during the Holocene. At present, the last 3200 years have been reconstructed. New fossil wood was found near the tongues of the Ferpècle, Ried and Gorner glaciers.
With the aid of dendrochronological investigations of larch trees from the upper timberline in the Alps, it is hoped to construct a long absolute standardized tree-ring chronology. This chronology can be used as an aid to absolute dating of fossil woods and as an indicator of past short- and long-term climatic changes. The absolute chronology is now extended from 623 to 1995 AD by this work. With the help of this chronology, the advances of Gornergletscher within the 14th and 19th centuries, and the advance of the Grosser Aletschgletscher in the 19th century, can be reconstructed very exactly. A floating tree-ring chronology from larch trees is now available from 2900–2300, 1900–1500 and 1400–1250 yr BP. The results concerning the last 700 years (Late Middle Ages and modern times) will be combined with those of C. Pfister (documentary sources) and H.J. Zumbühl (historical pictorial records) from the University of Bern. Special attention is paid to the "Medieval Climatic Optimum" and the Little Ice Age.

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Neoglacial/historical retreat, mass change and periglacial forest regrowth at Mendenhall and Herbert Glaciers (Juneau Icefield, SE Alaska, U.S.A.)

(S. Lacher, K.F. Kaiser, Geog/UZI and WSL;
W. Haeberli, Geog/UZI)

Dendrochronological investigations were carried out on living trees, as well as subfossil wood exposed in the forefields of Mendenhall and Herbert Glaciers. The ages of well-preserved recessional moraines were reconstructed. Both glaciers show similar fluctuations with an advance to a maximum extent in 1754/55. The slow retreat during the following 130 years was interrupted by short readvances. Retreat rates accelerated after 1875. Recessional moraines were deposited in 1890, 1900, 1920, 1933 and 1955. Subfossil wood samples collected in front of Herbert Glacier have been matched and two floating chronologies built. Herbert Glacier had retreated, at least as far back as today, for 95 years around 650 yr BP and for 194 years around 950 yr BP. Two more radiocarbon-dated subfossil wood samples from today's Mendenhall terminus give ages of 1200 yr BP and 1750 yr BP in a good agreement with earlier results. The recon-

structed length-change and retreat-rate information are analyzed with respect to average mass changes over decadal to secular time periods using a continuity approach. Reforestation of these forefields by Sitka spruce starts with seedling germination four to eight years after ice retreat. Sitka persists in the 300 to 400 year old Sitka-Hemlock forest of the first generation.

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Ghiacciaio del Rutor during mid-Holocene

(C.A. Burga, Geog/UZI with Università di Milano)
New material from peat-bog sediments, recently exposed by the now strongly shrinking Ghiacciaio del Rutor (2510 m a.s.l., Aosta Valley, Italy), was sampled. New radiocarbon dates and the second series of pollen analysis seem to confirm the palynostratigraphic results of the first series reported earlier. The profile gives evidence of the following sedimentary phases: glacigenic during Preboreal–Boreal (clay, silt); limnic at the transition Boreal/Older Atlantic (gyttja); telmatic-terrestric during the Older Atlantic (peat); glacigenic during the Younger Atlantic (moraine); terrestric at the transition of Younger Atlantic/Subboreal (peat); and glacigenic during the Subboreal (moraine). The organic sedimentation started about 8300 yr BP and ended about 6000 yr BP. During the Younger Atlantic (after 6050 yr BP), the peat bog was covered again by the glacier advance. Thus, the mid-Holocene temperature optimum lasted from about 8300–6000 yr BP.

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Application of exposure dating to glacial and periglacial chronology in the Grisons

(M. Maisch, D. Brandova, W. Haeberli, Geog/UZI; J. Beer, EAWAG)
The project will combine the technique of exposure dating by measuring in-situ produced cosmogenic isotopes (^{10}Be and ^{26}Al) with the conventional radiocarbon method. This will contribute to a further improvement in the chronology of late-Würmian and Holocene glacier fluctuations, as well as to a better understanding of the dynamic in landscape evolution in general. To achieve these goals, a new sample-preparation facility for exposure dating has been established at the University of Zürich (Dept. of Geography) and shall now be used for testing the method on specific samples from selected sites in Grisons (Davos, Upper Engadin and Albula). By taking samples from glacially and periglacially induced landforms, such as morainic ridges, transfluence passes, scoured bedrock and fossil rock glaciers, the project encompasses a refinement of the present knowledge, especially on events and glacier stages older than the Younger Dryas period (Gschnitz, Clavadel and Daun stadials). The results of exposure datings will be cross-checked with conventional radiocarbon samples which will be taken simultaneously at peat bogs close to the exposure-dating sites. AMS measurements of the samples will be done in close collaboration with ETH Hönggerberg (M. Suter, P. Kubik, S. Ivy-Ochs).

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Würmian Rheingletscher: digital reconstruction and ice-flow analysis

(Ch. Benz, W. Haeberli, O. Keller, R. Weibel, Geog/UZI; with University of Oslo)
A first, complete, digital registration, modelling and analysis of the Würmian Rheingletscher during its maximum extent has been done with a geographical information system (GIS). Existing data in analogue form (maps of reconstructed ice margins, ice surfaces or ground surfaces with/without Holocene sediments) are compiled from various sources. The information is then registered digitally, using ArcInfo and an intermediate-resolution digital terrain model. Existing algorithms and models for estimating surface boundary conditions are tested with the 3-D model of the Würmian Rheingletscher. First results confirm that flow, under conditions of small driving stresses in the flat piedmont lobe, was slow.

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Surface elevation and flow-line configuration of Last Glacial Maximum Alpine ice cap

(M. Kelly, Geog/UBern)
Mapping of trimlines and ice-flow indicators, such as crescentic gouges and roche moutonnées, will be conducted in the western Alps to determine the surface geometry and flow directions of Last Glacial Maximum (LGM) ice. Relatively small ice caps, such as those in the Alps during the LGM, are primarily affected by regional climate. Therefore, a reconstruction of the ice surface in the accumulation zone should reflect the areas of main precipitation and catchment, and thus yield information about paleocirculation. Previous work indicates the major LGM ice-accumulation areas in the central and eastern Alps were located south of the present weather divide. Such results suggest that circulation during the LGM was dominated by the advection of moist air masses from the Mediterranean, as opposed to the present climate in which the prevailing moisture source is (north)westerly. Mapping the western Alps will provide a more complete picture of the Alpine LGM accumulation area and thus further constrain paleoclimate interpretations.

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Submitted by Marcia Phillips, Walter Ammann and Wilfried Haeberli

Abbreviations used in the text

CG	Centre for Glaciology
CIRC	Climate Impacts Research Centre, S-981 42 Kiruna, Sweden
EAWAG	Swiss Federal Institute of Science and Technology, CH-8600 Dübendorf, Switzerland
EPFL	École Polytechnique Fédérale de Lausanne, CH-1015 Lausanne, Switzerland
ETH-Z	Eidgenössische Technische Hochschule, CH-8057 Zürich, Switzerland
GK/SANW	Glaciological Commission, Swiss Academy of Sciences
GTS	Department of Geography and Topographic Science
Geog	Geography
Geol	Geology
Geophys	Geophysics
Geotech	Geotechnical Institute
IGT	Geotechnical Institute, ETH-Hönggerberg, CH-8093 Zürich, Switzerland
IKF	Institute for Climate Research, ETH-Z
IKT	Communication Technology Laboratory, ETH-Z
ITESP	Institute of Terrestrial Ecology, Soil Physics, ETH, CH-8952 Schlieren, Switzerland
KUP	Physics Institute (Climate and Environment Project), UBern
LDEO	Lamont-Doherty Earth Observatory, Columbia University, Palisades, NY 10964, U.S.A.
MSUB	Montana State University, Bozeman, MT 59717, U.S.A.
PSI	Paul Scherrer Institute, CH-5232 Villigen, Switzerland
SASE	Snow and Avalanche Study Establishment, Ministry of Defence, P.O. Box 44, Sector 17, Chandigarh 160 017, India
SFISAR	Swiss Federal Institute for Snow and Avalanche Research, CH-7260 Davos Dorf, Switzerland
UBern	University of Bern, CH-3012 Bern, Switzerland
UCam	University of Cambridge, Cambridge CB2 3EN, England, U.K.
UFrib	University of Fribourg, Switzerland
UGlas	University of Glasgow, Glasgow G12 8QQ, Scotland, U.K.
ULaus	University of Lausanne, Lausanne, Switzerland
ULeeds	University of Leeds, Leeds, LS2 9JT, England, U.K.
UWalesA	University of Wales, Aberystwyth, Ceredigion, Dyfed SY23 3DB,Wales, U.K.
UZI	University of Zürich-Irchel, CH-8057 Zürich, Switzerland
VAW	Laboratory of Hydraulics, Hydrology and Glaciology, ETHZ, CH-8092 Zürich, Switzerland
WSL	Eidgenössische Forschungsanstalt für Wald, Schnee und Landschaft, CH-8903 Birmensdorf, Switzerland

INTERNATIONAL GLACIOLOGICAL SOCIETY

RICHARDSON MEDAL

In March of this year, the Council voted unanimously to award the Richardson Medal to John Arnfield Heap for his many years of service to the International Glaciological Society as its Treasurer. He has been a pillar of strength and a source of sage advice to both Secretaries General. He was elected to Council in 1967 and first appointed Treasurer in 1970, serving for two terms until 1976. He returned in 1980 and has served continuously as Treasurer since then.

He has played a central and stabilizing role in keeping the Society's books in order, in clarifying the manner in which those books are organized, and in ensuring that Council is informed and well-advised on how to improve the IGS's financial condition.

His contribution to the IGS epitomises the nature of service to the scientific community.

SELIGMAN GIFT

The Society is most grateful to Mrs Loris Seligman, the widow of our Founder, for the gift of his Seligman Crystal, a silver salver and his personal copy of *Snow Structure and Ski Fields.*

The Crystal was awarded to Gerald Seligman on the occasion of his retirement from the Presidency by Sir Vivian Fuchs, at the Annual General Meeting of the Society on May 2nd, 1963 (*Journal of Glaciology*, 4(37), 664-665). The salver, with a snow crystal etched in the centre, is enscribed *Gerald Seligman ● Founder and President of the British Glaciological Society ● presented by the Society 1955.*

HILDA RICHARDSON

28 May 1924 – 5 February 2000

Hilda Richardson, Secretary General of the Society from 1953 to 1993, died suddenly on 5 February 2000 after a long illness. Her funeral took place on 17 February in Selwyn College Chapel, Cambridge. There were readings by Simon Ommanney, Secretary General of the International Glaciological Society, and by Jane Zimmerman, International President of Soroptomists International. The address given by John Heap is printed below. Interment was in Cambridge City Cemetery, next to her husband, Eric. During her long tenure as Secretary General, she made an enormous impact on the Society and its members. The Richardson Medal, struck on the occasion of her retirement and now incorporated into the Society's awards system, will ensure that her memory is preserved and that future generations of glaciologists will be reminded of the incomparable role she played helping to develop the British Glaciological Society into the international society we all know today.

"There were, I suppose, two Hilda Richardsons, and I have a feeling that there is probably no one here who knew both. There was the Hilda who cast spells over a lot of glaciological chaps (for "chaps" they mostly are, although that's changing), and the Hilda who did something or other to a lot of Soroptimist ladies. But what it was she did to the ladies, and how she did it, I have absolutely no idea! I am immediately out of my depth and have to say straight away that this is, as it were, the "chaps" story of Hilda! It may be that the end point was the same .... she had us all drinking at her trough!

But the other story remains to be told, and it will be – at a memorial service which is to be arranged by Soroptimist International in the second half of August at Newnham College. I am nonetheless enormously glad, and I am sure Hilda would have been too, that Jane Zimmerman – from Tasmania – a successor of Hilda's as International President of the Soroptimists, has been able to take part in this service.

Hilda, an only child, was born in Bolton, Lancashire. She always retained a certain down-to-earth quality for which Lancastrians, dare I say it, coming from the next-door town, are well known. She went to the Bolton School and then, for a year, she did War work in the Meteorological Office before coming up to Newnham College, where she read Geography. Here it was, in the Geography Department, that she first came in touch with glaciology in the persons of Vaughan Lewis and Gordon Manley. The former famous for his studies of Austerdalsbre, a small glacier in the Jotunheim in Norway, and the latter, H.H. Lamb's predecessor, famous for his studies of climate over the centuries. She graduated in 1948 and went to work for Unilever at Port Sunlight. I must say that it stretches my capacity to suspend my disbelief to the absolute limit to conceive of Hilda testing soap powders! But there it is!

The International Glaciological Society started out in 1936 as the Association for the Study of Snow and Ice. The Association was founded by Gerald Seligman, a chemist of private means and a skier with a scientific passion for snow and ice, and James Wordie, a geologist who had been with Shackleton in the Antarctic. It went into hibernation during the War and re-emerged as the British Glaciological Society, housed in the Scott Polar Research Institute here in Cambridge.

By 1953, Seligman had retired from the day-to-day running of the Society and it was necessary to find a Secretary who would run the Society under the supervision of a Chairman. Hilda became that Secretary, and Dr Vivian Fuchs – Bunny Fuchs – was the Chairman. Around them was a constellation of powerful and opinionated characters – James Wordie, Launcelot Fleming (later Bishop of Norwich), Colin Bertram (Director of the SPRI), Brian Roberts – a driving force in many fields – Max Perutz (a Nobel Prize winner), Noel Odell of Everest fame, as well as Gerald Seligman who remained as President and Editor of the *Journal of Glaciology*. And, it has to be said, there were two women – Diana Rowley and Doris Johnson – neither of whom, to say the least, could be cast as shrinking violets. It was in this atmosphere of intellectual cut and thrust and strong argument about fine detail, that Hilda

won her spurs and, incidentally, with such as John Glen and John Nye around, the *Journal* established its high editorial standards.

Perhaps the dominant people in Hilda's life at this stage, other than her husband, Eric, were Brian Roberts and Bunny Fuchs. Brian was excellent on deciding what should be done, but less good at getting others to do it; Bunny, on the other hand, was superb at getting things done and keeping everyone's feathers in place. She learned a great deal from both of them. One taught her the value of bold ideas well thought through, and the other taught her the value of timing.

At that time, the Society consisted of a small desk on the top floor of the Scott Polar, known as the Gallery. Hilda's office space could hardly have been more than two or three square metres. Some of you here will remember it. Behind her was a radiator under a window, immediately in front of her, on the other side of her desk, was a bookcase and there was room for one chair beside her desk. On the other side was a filing cabinet and a partition wall between her and a room for research students.

Amongst the students who worked there were Bill Campbell of sea-ice fame, myself – of very much less sea-ice fame, Jack Tuck, who had commanded the first US contingent at the South Pole, and Roger Brown , the Canadian master of all things to do with permafrost. In the partition wall between us and Hilda was a small hatchway which enabled us to share a telephone and for coffee, made on one side, to be passed to the other. My recollection is that it was Hilda who kept the coffee flowing.

All of us got to know Hilda very well and value her very highly, more particularly, perhaps, because of the hospitality which she and Eric provided at Street Farm – a large and, it has to be said, initially somewhat dilapidated farm house out at Shudy Camps, some fifteen miles south of Cambridge. Any of you who remember Street Farm in its later glory should know of the blood, sweat, toil and tears of generations of SPRI staff, research students and others that lay behind the finished product! Eric, it has also to be said, ran a fine line in beer of which all of us, I seem to recall, took copious advantage! No beer, no bricks!

The trouble with glaciers is that there are none of them in this country! On the face of it, therefore, it was unlikely that the internationally accepted learned society to do with ice and snow in all its forms, should have had its beginnings in Britain. But given that it did, driven by successors to Arnold Lunn and Captain Scott, it is certainly just as remarkable that its headquarters are still here in Cambridge 64 years later. It may be that now IT (information technology) has so conclusively annihilated distance, there will be no pressure to move it. But that has not always been the case, and it is to Hilda's capacity to distinguish between the appearance and the reality that all we glaciologists owe a great deal. She recognised that it wasn't enough that the Society should have "international" in its title – it had to be international in reality and to its core.

Hilda's skill was always to have her finger on the pulse in the many centres of glaciology round the world, whether in Europe, Asia or North America. She did this through a great capacity to make friends, and by making sure that no sector of the Society, whether defined geographically or by field of study, felt itself left out. Thus members of the Council of the Society and of the Editorial Board were drawn from many countries and many fields – Japan, France, Norway, the U.S.; glaciers, sea ice, snow and glacial geology. All of them, and more, felt they had their hand somewhere within reach of the Society's tiller.

This alone, however, would not I think have been sufficient to keep the Society going, and its headquarters in Cambridge. Some positive step was needed and it turned out to be the invention of the *Annals of Glaciology* as a companion series to the *Journal*. Hilda identified a number of influences, all of which were pointing in the same direction The first was that the subject of glaciology had grown, and the number of its practitioners had also grown, to the point where there was a need for specialist gatherings. The second was that such conferences, seminars or symposia always produced proceedings. The third was that the organisers of such conferences could not, in isolation, develop a distribution system for one-off volumes which was adequate to convince contributors that their paper would be read by their colleagues and not be lost to posterity. The fourth was that it was a good thing for the members of the Society in a particular country to be able to show their scientific lords, masters and money bags that their subject was alive and kicking with clout outside their national confines.

Hilda's response to these stimuli was to offer conference organisers an editorial service, a printing service, an assured distribution into libraries as part of an accepted series, and the prestige of having the Society's name associated with the conference. It worked superbly. Hilda travelled the world assiduously urging glaciological conference organisers to buy the Society's services. Now, with slight exaggeration, Simon Ommanney sits in his office while the potential organisers bang on his door seeking audience! The manner in which she maintained cohesion within the Society has well served the subject of glaciology. It is my understanding that a web site has been set up by a member of the Society in Chicago in answer to a call from members to be able to record their feelings and stories about Hilda. She would, I think, have appreciated that.

In many ways, Hilda was a very private person, but it would be wrong of me to end without some reflection on Hilda the person, to remind many here of the warmth of welcome there always was from Eric and Hilda at Street Farm, the great fortitude with which Eric must have put up with endless "shop" from his dynamo wife – whether concerning ice or women, and to recall the immense courage with which she coped with her pain over so many years.

For many years, Hilda would invite me out to Street Farm to go over the Society's accounts and decide on the budget for the next year. Eric would get the ball rolling by offering a large G & T – not much tonic. Then supper out of the AGA, with the dogs at one's heels, and often an excellent bottle of wine from the European vineyard of a Society member. And then we would repair to the den; Eric would put on his headphones in one corner, while Hilda and I would get

down to work. I sometimes wondered how Eric put up with all this, it has to be said, slightly self-important yakking going on around him. But he was very patient and only occasionally gave us of his wisdom – it was always a pearl. Sometime after midnight, when the work had been done and I reckoned the police would probably have gone to bed, I would drive home. They were good and friendly times.

Then Eric died. He had been the solid rock on which Hilda had built all she did. It was an awful shock, but she kept going with great tenacity. The routine at Street Farm was the same except, sadly, that one did one's own G & Ts. And then came the loss of taste and smell, shingles and, finally, Wegener's granulomatosis. We all hoped that the move into Cambridge from Shudy would help. She was so much looking forward to doing things with Newnham College and in the Institute. But it was not to be.

Many here will know of her continuing desire to keep in touch with the outside world – Frans and Reit, Andrei and Melada – and others, I know, amongst her Soroptimist friends. And then her band of carers, most of all Sarah, who coped with her on the bad days, as well as on the less bad. For my part, I remember her one day in Addenbrookes, when things looked pretty awful, saying, rather wanly, that she hoped her Wegener's would proceed as slowly as the other Wegener's continental drift. When I last saw her, she was talking of financial steps she had taken so that when it came to it, she could have 24 hour care. On the inside of her telephone and address book are two slips of paper describing Wegener's and its likely course. While I am sorry for all of us here that we could not enjoy her for longer, I am glad for her that she did not have to go through with it."

John Heap

Some members have enquired about making donations in Hilda's memory. Those wishing to do so may send them to the International Glaciological Society for the Hilda Richardson Fund. Any donations will be used to support an area of the Society's activities that, in the opinion of Council, would have reflected Hilda's wishes.

JOURNAL OF GLACIOLOGY: REFEREE RECOGNITION

After two years as Chief and Assistant Chief Editor of the *Journal of Glaciology*, we have developed a deep appreciation for the essential volunteer work of two groups without which the *Journal* would not exist. They are the Scientific Editors and the Referees.

The Scientific Editors handle the papers submitted to the *Journal*, solicit reviews, remind referees to be timely and assess the reviews when they are turned in. Theirs is the scientific judgment on which the excellence of the *Journal* is based. The Referees provide comments, scientific judgment and constructive criticism that lead to higher-quality papers. From our perspective, Scientific Editors and Referees, working together, make authors look better by helping their papers reach their full potential.

We have no real mechanism to thank these two groups, other than to acknowledge them publicly. The names of the Scientific Editors appear on the inside cover of each issue of the *Journal*; the Referees are usually anonymous. We think that members of the Society should be aware of their contribution, and we want to take this opportunity to thank them for a job well done with little fanfare.

During the past several years, the following Referees provided particularly insightful or helpful reviews and deserve special thanks:

Olivier Castelnau
LPMTM-CNRS, Institut Galilée, Université Paris-Nord, F-93430 Villetaneuse, France

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Mr Nicholas Spedding
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Dale P. Winebrenner
Applied Physics Laboratory, Polar Science Centre, University of Washington, Seattle, WA 98105, U.S.A.

Will Harrison and Mathew Sturm

JOURNAL OF GLACIOLOGY

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

M Truffer, W D Harrison and K A Echelmeyer
Glacier motion dominated by processes deep in underlying till

E Wilch and T J Hughes
Calculating basal thermal zones beneath the Antarctic ice sheet

D J Wingham
Short fluctuations in the mass, density and thickness of a dry firn column

Y Yoshimura, S Kohshima, N Takeuchi, K Seko and K Fujita
Himalayan ice-core dating with snow algae

ANNALS OF GLACIOLOGY

The following papers from the International Symposium on the Verification of Cryospheric Models, held in Zürich, Switzerland, 16–20 August 1999 have been accepted for publication in *Annals of Glaciology* Vol. 31, edited by K. Steffen:

G Aðalgeirsdóttir, G H Guðmundsson and H Björnsson
The response of a glacier to a surface disturbance: a case study on Vatnajökull ice cap

W P Adams
Fritz Müller's legacy on Axel Heiberg Island, Nunavut, Canada

M R Albert, E Shultz and F Perron
Snow and firn permeability at Siple Dome, Antarctica

O Albrecht, P Jansson and H Blatter
Modelling glacier response to measured mass-balance forcing

I Baker, F Liu, K Jia, X Hu, D Cullen, D Black and M Dudley
X-ray topographic boundary dislocation/grain in ice, observations of interactions

P Bartelt and M von Moos
Triaxial tests to determine snow viscosity

M P Bishop, J S Kargel, H H Kieffer, D J MacKinnon, B H Raup and J F Shroder, Jr
Remote-sensing science and technology for studying glacier processes in high Asia

L N Braun, M Weber and M Schulz
Consequences of climate change for runoff from Alpine regions

M Braun, F Rau, H Saurer and H Gossmann
Development of radar glacier zones on the King George Island ice cap, Antarctica, during austral summer 1996/97 as observed in ERS-2 SAR data

M Braun and C Schneider
Characteristics of summer energy balance on the west coast of the Antarctic Peninsula

B W Brock, I C Willis, M J Sharp and N S Arnold
Modelling seasonal and spatial variations in the surface energy balance of Haut Glacier d'Arolla, Switzerland

V Bugnion
Reducing the uncertainty in the contribution of Greenland to sea-level rise in the 20th and 21st centuries

P Calanca, H Gilgen, S Ekholm and A Ohmura
Gridded temperature and accumulation distributions for Greenland for use in cryospheric models

T Carrieres
Operational ice model verification at the Canadian Ice Service

G Casassa and A Rivera
Topographic mass balance model for the Southern Patagonia Icefield

M C R Davies, O Hamza, B W Lumsden and C Harris
Laboratory measurement of the shear strength of ice-filled rock joints

N Deichmann, J Ansorge, F Scherbaum, A Aschwanden, F Bernardi and G H Gudmundsson
Evidence for deep icequakes in an Alpine glacier

R V Engeset, H Elvehøy, L M Andreassen, N Haakensen, B Kjøllmoen, L A Roald and E Roland
Modelling of historic variations and future scenarios for the mass balance of the Svartisen ice cap, northern Norway

G E Flowers and G K C Clarke
An integrated modelling approach to understanding subglacial hydraulic release events

R Frauenfelder and A Kääb
Towards a palaeoclimatic model of rock-glacier formation in the Swiss Alps

A D Frolov
On the physical model of frozen soil

K Fujita, Y Ageta, Pu Jianchen and Yao Tandong
Mass balance of Xiao Dongkemadi glacier on the central Tibetan Plateau from 1989 to 1995

H Fukazawa, S Mae and S Ikeda
Raman scattering and neutron-diffraction studies of fresh ice and Antarctic ice

S Gerland, G E Liston, J-G Winther, J B Ørbæk and B V Ivanov
Attenuation of solar radiation in Arctic snow: field observations and modelling

M B Giovinetto and H J Zwally
Spatial distribution of net surface accumulation on the Antarctic ice sheet

V N Golubev and A D Frolov
Model of structure and mechanical properties of dry granular snow

G H Gudmundsson, A Bassi, M Vonmoos, A Bauder, U H Fischer and M Funk
High-resolution measurements of spatial and temporal variations in surface velocities of Unteraargletscher, Bernese Alps, Switzerland

E Guseva-Lozinski
The mathematical modelling of salinity changes in ice and frozen soil as a result of thermal variations

W Haeberli, J Cihlar and R G Barry
Glacier monitoring within the Global Climate Observing System

J O Hagen, B Etzelmüller and A-M Nuttall
Runoff and drainage pattern derived from digital elevation models, Finsterwalderbreen, Svalbard

D K Hall, A B Tait, J L Foster, A T C Chang and M Allen
Intercomparison of satellite-derived snow-cover maps

C Harris, B R Rea and M C R Davies
Geotechnical centrifuge modelling of gelifluction processes: validation of a new approach to periglacial slope studies

C L Hulbe, I R Joughin, D L Morse and R A Bindschadler
Tributaries to West Antarctic ice streams: characteristics deduced from numerical modelling of ice flow

T Ikeda, A N Salamatin, V Ya Lipenkov, S Mae and T Hondoh
Spatial distribution of air molecules within individual clathrate hydrates in polar ice sheets

K Isaksen, D Vonder Mühll, H Gubler, T Kohl and J L Sollid
Ground surface-temperature reconstruction based on data from a deep borehole in permafrost at Janssonhaugen, Svalbard

I Janssens and P Huybrechts
The treatment of meltwater retardation in mass-balance parameterizations of the Greenland ice sheet

I R Joughin, M A Fahnestock and J L Bamber
Ice flow in the northeast Greenland ice stream

A Kääb
Photogrammetric reconstruction of glacier mass balance using a kinematic ice-flow model: a 20 year time-series on Grubengletscher, Swiss Alps

R Kattelmann
Snowmelt lysimeters in the evaluation of snowmelt models

H Kerschner, G Kaser and R Sailer
Alpine Younger Dryas glaciers as palaeo-precipitation gauges

C Kneisel, W Haeberli and R Baumhauer
Comparison of spatial modelling and field evidence of glacier/permafrost relations in an Alpine permafrost environment

M Kuhn
Verification of a hydrometeorological model of glacierized basins

M Lehning, J Doorschot and P Bartelt
A snowdrift index based on SNOWPACK model calculations

M Lüthi and M Funk
Dating of ice cores from a high Alpine glacier with a flow model for cold firn

D M McClung
Predictions in avalanche forecasting

C Mittaz, M Hoelzle and W Haeberli
First results and interpretation of energy-flux measurements over Alpine permafrost

R E Moritz and J Ukita
Geometry and the deformation of pack ice: I. A simple kinematic model

J Oerlemans
Holocene glacier fluctuations: is the current rate of retreat exceptional?

A Ohmura
Climate on tundra and thoughts on causes of regional differences

N I Osokin, R S Samoylov, A V Sosnovskiy, S A Sokratov and V A Zhidkov
Model of the influence of snow cover on soil freezing

F Pattyn
Ice-sheet modelling at different spatial resolutions: focus on the grounding zone

W T Pfeffer, N F Humphrey, J Harper, B Korb and B Amadei
In-situ stress measurements in temperate ice, Worthington Glacier, Alaska

M Phillips, P Bartelt and M Christen
Influences of snow supporting structures on ground temperature in permafrost terrain

Qin Dahe, P A Mayewski, C P Wake, Kang Shichang, Ren Jiawen, Hou Shugui, Yao Tandong, Yang Qinzhao, Jin Zhefan and Mi Desheng
Evidence for recent climate change from ice cores in the central Himalaya

Qin Dahe, Ren Jiawen, Kang Jiancheng, Xiao Cunde, Li Zhongqin, Li Yuansheng, Sun Bo, Sun Weizhun and Wang Xiaoxiang
Preliminary results of glaciological studies along an 1100 km transect from Zhongshan station to Dome A, East Antarctic ice sheet

W Rack, C S M Doake, H Rott, A Siegel and P Skvarca
Interferometric analysis of the deformation pattern of the northern Larsen Ice Shelf, Antarctic Peninsula, compared to field measurements and numerical modelling

S Rasmus
Snow pack structure changes in southern and northern Finland

B R Rea, D H B Irving, B Hubbard and J McKinley
Preliminary investigations of centrifuge modelling of polycrystalline-ice deformation

N Reeh, C Mayer, O B Olesen, E L Christensen and H H Thomsen
Tidal movement of Nioghalvfjerdsfjorden glacier, northeast Greenland: observations and modelling

P K Satyawali
Diffusivity and vapor flow into snow during phase change

W Schöner, I Auer and R Böhm
Climate variability and glacier reaction in the Austrian East Alps

T L Shy, J E Walsh, W L Chapman, A H Lynch and D A Bailey
Sea-ice model validation using submarine measurements of ice draft

S A Sokratov and A Sato
Wind propagation to snow observed in laboratory

O N Solomina
Retreat of mountain glaciers of northern Eurasia since the Little Ice Age maximum

O C Turpin, B Johansson, R G Caves and R I Ferguson
Verification of simulated snow cover in an Arctic basin using satellite-derived snow-cover maps

J Ukita and R E Moritz
Geometry and the deformation of pack ice: II. Simulation with a random-isotropic model and implication in sea-ice rheology

A Vieli, M Funk and H Blatter
Tidewater glaciers: frontal flow acceleration and basal sliding

D S Vonder Mühll, C Hauck and F Lehmann
Verification of geophysical models in Alpine permafrost using borehole information

R C Warner and W F Budd
Derivation of ice thickness and bedrock topography in data gap regions over Antarctica

R L S Weaver, K Steffen, J Heinrichs, J A Maslanik and G Flato
Data assimilation in sea-ice monitoring

A Wiesmann, C Fierz and C Mätzler
Simulation of microwave emission from physically modeled snowpacks

T Zhang and M O Jeffries
Modeling interdecadal variations of lake-ice thickness and sensitivity to climatic change in northernmost Alaska

H J Zwally and M B Giovinetto
Spatial distribution of surface mass balance on Greenland

BRITISH BRANCH ANNUAL MEETING 2000

Department of Geography, University of Southampton, U.K., 13–15th September 2000

First Circular

The 25th annual meeting of the British Branch of the International Glaciological Society will be held at the Department of Geography, University of Southampton on Wednesday 13th to Friday 15th September 2000. The meeting will be preceeded on Wednesday afternoon by a workshop based on the NERC ARCICE thematic programme. This will be a problem-solving session addressing issues raised in ARCICE glacier dynamics projects, but open to all.

The main meeting will be on Thursday 14th and Friday 15th. Presentations are invited on all aspects of ice and snow research, as either short talks or posters. Time for individual talks will be 15 minutes, with 5 minutes for discussion. There will also be a session for shorter talks of 8 minutes (plus 2 minutes for discussion) for less-formal presentations (e.g. by new postgraduate students or hot-off-the-press field results). The number of talks will be restricted to ensure sufficient time for informal discussion and viewing of posters. Pin-boards will be provided for posters, which will be on display throughout the meeting.

If you wish to give a talk or poster, please submit your abstract of up to 1 side of A4 by e-mail to a.j.payne@soton.ac.uk or by posting a 3.5" diskette with the Registration Form before **30th June 2000.** A booklet of abstracts will be distributed at the meeting. Registration for the meeting, including tea/coffee/ biscuits and the booklet of abstracts, is £28 for waged

and £20 for unwaged delegates.

Bed and breakfast accommodation will be available on Wednesday, Thursday and Friday nights in Glen Eyre Hall, a short walk from the Department of Geography. The price of a single room is £20.50 per night (including breakfast). A limited amount of floor space for sleeping bags can be provided for post-graduates if needed. Please indicate if this is required on the registration form.

The annual dinner will be held at the Chinese Palace at a cost of £20 plus drinks. A variety of dietary requirements can be catered for (e.g. vegetarian). Please indicate these on the registration form.

If you wish to attend the meeting, please complete a registration form and return it to the IGS British Branch Meeting, Department of Geography, Highfield, University of Southampton, Southampton SO17 4BJ by **30th June 2000**, together with a cheque for registration, accommodation and the annual dinner; made payable to the University of Southampton. Updated details will be posted on the Department of Geography website (http://www.geog.soton.ac.uk/research/IGSBB/index.htm). A second circular, including maps and programme, will be circulated to all who have registered in due course.

Limited financial assistance may be available to help postgraduate students attend the meeting when all other avenues of potential funding (e.g. department, university and grant-awarding body) have been exhausted. Please request an application form when registering. Refunds will be made at the meeting.

Tony Payne
Department of Geography, University of Southampton, Highfield, Southampton SO17 1BJ, U.K.
Tel 023-8059-3823; Fax 023-8059-3295;
A.J.Payne@soton.ac.uk

4TH INTERNATIONAL SYMPOSIUM ON REMOTE SENSING IN GLACIOLOGY

College Park, Maryland, U.S.A., 4–8 June 2001

CO-SPONSORED BY
EOS/Icesat

FIRST CIRCULAR

The International Glaciological Society will hold the Fourth International Symposium on Remote Sensing in Glaciology in 2001 at the University of Maryland Conference Center, College Park, Maryland, U.S.A. with registration on 3 June 2001 and sessions from 4–8 June 2001.

THEME
Snow and ice are interactive components of the Earth system and knowledge of these interactions with the land, oceans, atmosphere and ecosystems is vital to our understanding of global change.

TOPICS
The suggested topics include remote sensing aspects of:

1. Seasonal snow on land;
2. Sea, river and lake ice;
3. Glaciers, ice sheets and ice shelves;
4. Permafrost.

SESSIONS
Oral presentations will be held on four full days and one half-day. There will be ample opportunity for poster displays.

PUBLICATION
The Proceedings of the symposium will be published by the Society in the *Annals of Glaciology*. All papers (including poster papers) will be refereed and edited according to the Society's regular standards before being accepted for publication.

ACCOMMODATION
Accommodation will be arranged in the University of Maryland Inn and Conference Center. A full range of other hotel and hostel accommodation will be available.

EXCURSIONS
A mid-week excursion is planned to NASA's Goddard Space Flight Center.

FURTHER INFORMATION
If you wish to attend the symposium, please return the attached form as soon as possible. The Second Circular will give information about accommodation, the general programme, and preparation of abstracts and final papers. Copies of the Second Circular will be sent to those who return the attached reply form. Members of the International Glaciological Society will automatically receive one. Further information will be posted on the IGS Web site:
http://www.spri.cam.ac.uk/igs/home.htm

SYMPOSIUM ORGANIZATION
Simon Ommanney (International Glaciological Society)

CHIEF SCIENTIFIC EDITORS
Jan-Gunnar Winther and Rune Solberg

LOCAL ARRANGEMENTS COMMITTEE
Dorothy K. Hall (Chair), Robert A. Bindschadler, Donald J. Cavalieri, Alfred T.C. Chang, James L. Foster

PLEASE RETURN FORM IMMEDIATELY TO:
Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, U.K.
Tel [44](1223)355974; Fax [44](1223)336543
E-mail: Int_Glaciol_Soc@compuserve.com

INTERNATIONAL GLACIOLOGICAL SOCIETY
4th SYMPOSIUM ON REMOTE SENSING IN GLACIOLOGY

College Park, Maryland, U.S.A., 4–8 June 2001

Family Name: _____

First Name(s): _____

Office Address: _____

_____

Tel: _____ FAX: _____

E-mail: _____

I hope to participate ☐

I expect to submit an abstract ☐

My abstract will be on the following topic(s):

_____

I am interested in an accompanying person's programme ☐

INTERNATIONAL SYMPOSIUM ON ICE CORES AND CLIMATE

Kangerlussuaq, Greenland, 19–23 August 2001

CO-SPONSORED BY
Danish Natural Science Foundation
University of Copenhagen

FIRST CIRCULAR

The International Glaciological Society will hold an International Symposium on Ice Cores and Climate in 2001 in the Kangerlussuaq Hotel and Conference Center in Kangerlussuaq, Greenland. Registration will take place on 18 August and sessions will be held from 19–23 August 2001.

THEME

Ice cores provide a wealth of information on the past climate. Measurements range from detailed studies of the air–snow transfer processes in firn to those of deep ice cores that cover several hundred-thousand years of climate evolution. Comparison of ice-core records from different geographical sites, as well as with other palaeoclimatic data, can establish detailed information about past climates. Their interpretation helps in understanding climatic processes.

Recently, several deep ice cores and many shallow cores have been drilled and analysed. New and more sophisticated analytical methods have been developed.

This symposium will focus on results from ice-core measurements and what they reveal about our understanding of global, regional and historical climates.

TOPICS

The suggested topics include:

1. Interpretation of ice-core records;
2. Comparison of results from different ice cores;
3. Meteorological, modelling and air-snow transfer studies aimed at improving ice-core interpretation;
4. Comparison between ice-core records and other palaeoclimatic and palaeoenvironmental records;
5. Geophysical and borehole measurements;
6. Ice rheology in relation to the flow of ice sheets.

SESSIONS

Oral presentations will be held on four full days and one half-day. There will be ample opportunity for poster displays.

PUBLICATION

The Proceedings of the symposium will be published by the Society in the *Annals of Glaciology*. All papers (including poster papers) will be refereed and edited according to the Society's regular standards before being accepted for publication.

TRAVEL AND ACCOMMODATION

Arrangements are being made for a comprehensive package that will include the return flight to Kangerlussuaq, either from Europe (Copenhagen) or from North America (boarding point to be decided), hotel accommodation, all meals and the registration fee, for an inclusive price expected to be less than £1000.00. Details will be given in the Second Circular.

EXCURSIONS

There will be a mid-week excursion to enable participants to view the local scenery and wildlife (muskox, reindeer, etc.). Depending on demand, visits may be organized to the ice front, as well as talks and guided tours provided by other science groups working in Kangerlussuaq.

Consideration is being given to organizing a 4 day post-symposium tour to Ilulissat/Jakobshavn, a charming town with museums, shops and a wonderful view of the Icefjord. Such a tour, including travel and accommodation, but not meals, would likely cost in the region of £450. Please indicate your interest in joining such a tour on the return form.

FURTHER INFORMATION
If you wish to attend the symposium, please return the attached form as soon as possible. The Second Circular will give information about travel and accommodation arrangements, the general programme, and preparation of abstracts and final papers. Copies of the Second Circular will be sent to those who return the attached reply form. Members of the International Glaciological Society will automatically receive one. Further information will be posted on the IGS Web site:
http://www.spri.cam.ac.uk/igs/home.htm

SYMPOSIUM ORGANIZATION
Simon Ommanney (International Glaciological Society)

CHIEF SCIENTIFIC EDITOR
Eric Wolff

LOCAL ARRANGEMENTS COMMITTEE
Dorthe Dahl-Jensen (Chair), Gary Clow, Heinz Miller

PLEASE RETURN FORM IMMEDIATELY TO:
Secretary General, IGS, Lensfield Road, Cambridge CB2 1ER, U.K. (Fax [44](1223)336543

INTERNATIONAL GLACIOLOGICAL SOCIETY
SYMPOSIUM ON ICE CORES AND CLIMATE

Kangerlussuaq, Greenland, 19–23 August 2001

Family Name: _____

First Name(s): _____

Office Address: _____

_____

Tel: _____ FAX: _____

E-mail: _____

I hope to participate ☐
I expect to submit an abstract ☐

My abstract will be on the following topic(s):

_____

I would participate in a post-symposium tour ☐

I will travel from: Europe ☐ North America ☐

I am interested in an accompanying person's programme ☐

FUTURE MEETINGS (of other organizations)

NORTHWEST GLACIOLOGISTS' MEETING

Smith Center, Portland State University, Portland, Oregon, U.S.A., 20–21 October 2000

For more information contact:
Andrew G. Fountain, Departments of Geology and Geography, Portland State University, Portland, OR 97207-0751, U.S.A. (Email: andrew@pdx.edu; Tel [1](503)725-3386; Fax [1](503)725-3025
http://www.geol.pdx.edu/Glaciers/

MILLENNIAL-SCALE EVENTS IN NORTH ATLANTIC REGION DURING TERMINATION 1

University of Ulster, Northern Ireland, 13–18 June 2001

Oral and poster contributions are invited for an international conference on millennial-scale events in the North Atlantic region during Termination 1, to be held at the University of Ulster at Coleraine, Northern Ireland, U.K., 13–18 June 2001. The conference will focus on evaluating the timing, signatures and correlation of high-frequency hemispheric-scale climate and environmental changes during Termination 1 (last deglaciation) in the North Atlantic region, as can be deduced from ice core, marine core, and terrestrial (glacial, peat, lake) records. Papers presented are invited for submission to a associated volume, most likely a Geological Society Special Publication, edited by Marshall McCabe and Jasper Knight.

Paper sessions based at the University of Ulster (days 1–3) will be followed by a field meeting (days 4–6) examining onshore field evidence for Heinrich event 1 in Ireland. This is the only known dated site where ice advance associated with H1 is demonstrated in the northeast Atlantic region. A field guide will accompany this component of the meeting.

FOR MORE INFORMATION
Dr Jasper Knight, Glacial Research Group, University of Ulster, Coleraine, Co Londonderry, Northern Ireland BT52 1SA, U.K.
Tel [44](28)7032 3179; Fax [44](28)7032 4911;
Email j.knight@ulst.ac.uk
http://www.ulst.ac.uk/termination1.html

2nd INTERNATIONAL CONFERENCE ON MARS POLAR SCIENCE AND EXPLORATION

21–25 August 2000 Reykjavík, Iceland

CO-SPONSORED by the International Glaciological Society

PURPOSE AND SCOPE

Investigations by robotic spacecraft have revealed that Mars is a dynamic planet that has undergone a lengthy and complex evolution. At perhaps no other location is this history better recorded than at the Martian poles, where extensive mantles of ice and dust, 3–4 km thick, may preserve a record of climate change, volcanic eruptions, large impacts, catastrophic floods, glaciation and perhaps even indigenous life, dating back as much as a billion years.

In the last two years, our understanding of the Martian polar regions has been revolutionized by data from the Mars Global Surveyor (MGS) spacecraft. These data have yielded the first high-resolution topographic maps of the north and south polar ice caps, meter-scale images of the polar layered stratigraphy, and year-round coverage of variations in the thermophysical, radiative and compositional properties of the polar atmosphere and surface. New discoveries will be highlighted at this conference, the latest in a continuing series of meetings to promote the exchange of knowledge and ideas between planetary and terrestrial scientists interested in Mars polar research.

Some of the specific issues and questions that will be addressed at the meeting include:

How did the Martian polar ice caps and layered deposits originate? How old are they? And what is the chronology of events recorded in their strata?

How do the compositional, physical, thermal and radiative properties of the deposits vary, both geographically and with depth?

What does their stratigraphy tell us about the annual cycles of CO_2, H_2O, and dust? How have these cycles changed with time?

Is there evidence of past or present glacial flow? How did the spiral pattern of scarps and troughs develop and how do they evolve with time?

Is the base of either cap at the melting point?

Do basal lakes or other liquid-water environments exist that are suitable for the survival and growth of indigenous life?

How can the experience gained from investigations of the Earth's polar ice sheets (e.g. radio-echo sounding, core drilling, ice-margin studies, planned Lake Vostok sampling) benefit Mars polar exploration?

LOCATION

The five-day meeting will be held at the University of Iceland, with sessions running Monday, Tuesday, Thursday and Friday. Optional one-day field trips to sites of interest will be arranged Wednesday and Saturday and a three-day preconference field trip will be offered as well. (These excursions are being coordinated with the organizers of the Workshop on Volcano/Ice Interactions on Earth and Mars that will be held at the same location during the week of August 13–18.)

The decision to hold the conference in Iceland was strongly influenced by the country's large number of glacial, hydrologic and volcanic analogs to potential past or present conditions in the polar regions of Mars. These include shield volcanos, subglacial volcanism, table mountains, subglacial lakes and jökulhlaups, and landscapes carved by wind erosion. A special session at the meeting will address these phenomena.

PROGRAM

The program will consist of invited and contributed talks, panel discussions and poster presentations, and will be supplemented by several special sessions and social events that will be held throughout the meeting. Any scientist with relevant theoretical, experimental or polar field experience is strongly encouraged to participate and to submit an abstract. Contingent upon review and acceptance by the program committee, abstracts will be published as part of an LPI report that will be distributed to conference participants at the meeting. The abstracts and preliminary program will also be available in electronic format and accessible via the conference web page on or around 12 May 2000. The deadline for abstract submission was 3 April 2000.

CONVENERS

Helgi Björnsson, Stephen Clifford, David Paige, Thorsteinn Thorsteinsson

CONTACT INFORMATION

For further information regarding the format and scientific objectives of the meeting, please contact Stephen Clifford (Tel [1](281)486-2146; clifford@lpi.usra.edu) or Thorsteinn Thorsteinsson (ththor@raunvis.hi.is).

Questions concerning the meeting logistics should be addressed to Asa Hreggvidsdóttir, Mars Polar Conference, Iceland Conferences, Lagmula 4, IS-108 Reykjavík, Iceland (Tel [354]585-4400; Fax [354]585-4490; e-mail: congrex@icelandtravel.is; http:// www.icelandtravel.is).

Mars Polar Conference II
Publications and Program Services Department
Lunar and Planetary Institute
3600 Bay Area Boulevard
Houston TX 77058-1113, U.S.A.
Tel [1](281)486-2142; Fax (281)486-2125;
e-mail: tanner@lpi.usra.edu
www.lpi.usra.edu/meetings/polar2000/

NEWS

LANZHOU INSTITUTE OF GLACIOLOGY AND GEOCRYOLOGY (LIGG)

LIGG has been combined with two other institutes. The new name is the Cold and Arid Regions Environmental and Engineering Research Institute, 260 West Donggang Road, Lanzhou, Gansu 730000, China

CURRENT WEB CONTENTS

The Institute for Scientific Information, following a review using structured evaluation criteria , have selected the IGS website for inclusion in Current Web Contents (http://www.isinet.com/products/webselect/webselect.html), a new section of Current Contents Connect™. This offers web access to Current Contents, the ISI current awareness database that provides information in the fields of science, social science, technology, and the arts and humanities.

THE DEFINITION OF "GLACIOLOGY"

It has recently come to our knowledge that in some quarters the word "Glaciology" is understood to mean the study of glaciers and that alone.

This is incorrect. The word is derived from the Latin *glacies* — ice, and has always been intended to cover every form of ice. The first definition of the word that we can find appears in the *Oxford Dictionary* as "The scientific treatment of ice or glaciers". The Dictionary quotes *Nation* (New York) 29 December 1892, p. 492, col. 2, "already this suggestion finds favour among some of our leaders in glaciology". Used *in this broad sense* the word appears in Charcot's Expédition Antarctique Française (1903–05), and in Shackleton's *The heart of the Antarctic* (1909).

In Wright and Priestley's *Glaciology*, written to record the results of the British (Terra Nova) Antarctic Expedition 1910–13, but only published in 1922, every form of snow and ice is dealt with under the single heading — "Glaciology". This title included chapters dealing with "snow and its derivatives", "ice crystals formed from vapour", "crystalline structure of ice", "glacier motion", "classification of land-ice formations", "ice formations of an advanced stage of the glacial cycle", "structure of glaciers", "fast-ice", "pack-ice", "icebergs", "causes of glacierization", etc.

Sir Charles Wright, co-author of the above, has written to us in confirmation of this: "To me from the beginning glaciology was the study of ice in all its forms ... I think it will be a great pity if "Glaciology" is restricted to glaciers and I hope you can scotch this heresy."

In recent times Professor P.A. Shumskiy in his *Principles of structural glaciology* (Kraus' translation) 1955, writes to the effect that the tendency to call glaciology the study of glaciers is incorrect "since the word, derived from the Latin, means the study of ice, consequently the study of ice in general and not just glaciers".

Professor R. Finsterwalder, President of the Committee on Snow and Ice of the International Association of Scientific Hydrology, writes that he and his colleagues agree with us that "Glaciology" includes every form of ice and snow from the time of snowfall until it disappears.

Naturally some aspects of ice overlap into pure physics, into meteorology, into geology and into other sciences, but this does not alter what has been stated above.

Professor F. Debenham, one of the best known authorities on these matters, writes: "It seems curious that some people should persist in a narrow connotation . . ."

Professor P.L. Mercanton, formerly of the Swiss Glacier Commission, who also speaks with great authority and life-long experience, writes that he is horrified by this "new restricted use of the term".

It is puzzling to know how this false definition arose, particularly in view of the fact that this Society, which can claim some authority in these matters, has, from its early days, covered in its journals and at its meetings, *every* form of ice.

It is to be hoped that the evidence and opinions cited above will be accepted in the very few quarters where there has been this recent deviation.

Reprinted from the
Journal of Glaciology, 3(29), March 1961, p.802

It has been brought to my attention that some individuals and, of more concern, some translators, subscribe to the much-more limited definition of glaciology. It therefore seems appropriate to restate the broad definition of glaciology endorsed by the founders of the International Glaciological Society.

C. Simon L. Ommanney

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

20–21 October 2000
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30 October–1 November 2000
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This news bulletin is issued to members of the International Glaciological Society and is published three times a year. Contributions should be sent to your National Correspondent or 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:

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