

Ice

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Cover picture: River Skeiðará flowing along the terminus of the outlet glacier Skeiðarárjökull from southern Vatnajökull ice cap. The river changed course in July 2009. Until then the river flowed directly to the south from the outlet on the eastern side of the terminus and under the longest bridge in Iceland, the ~900 m long Skeiðará bridge. The river now flows to the west along the terminus and merges with the river Gígjukvísl near the centre of the glacier and the Skeiðará bridge is more or less on dry land. Photo: Oddur Sigurðsson.

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

EXCLUSION CLAUSE. While care is taken to provide accurate accounts and information in this Newsletter, neither the editor nor the International Glaciological Society undertakes any liability for omissions or errors.

From the Editor

Dear IGS member

We have now had the opportunity to test our two new digital systems. The online membership payment has worked very well, and you have responded very well – but there are still some stragglers out there. As I mentioned in my last editorial in *ICE* 150, it is much more economical for us to send out as many of the *Journals* as possible when we print them. We sent out the second reminder in March which brought on another flurry of renewals. We will now target those who have been members of the IGS in the past but for whatever reason have not renewed. If you know of anyone like that, please encourage them to rejoin. We are constantly trying to think of things that will make IGS membership more attractive: the latest is that we are making back issues of all IGS publications available online. That means that volume 1, issue 1 of the *Journal* is now online and so is volume 1 of the *Annals*. So please help us in getting former members back.

Quite a few of you have come back to us with suggestions as to how we can further improve the system. In particular you have mentioned that you would like to be able to purchase back issues of both the *Annals* and *Journal* at the same time as you renew. That is of course our intention but we decided to take it one step at the time. We will introduce a ‘shop’ where you will be able to put other IGS publications into a ‘shopping basket’, just like you do when you shop at any other online vendor. You have also asked us to enable you to change your type of membership, i.e. from ‘student’ to ‘ordinary’ or ‘ordinary’ to ‘contributing’. That is something we will be working on and hopefully it will be up and running later this year. You also asked whether you could print out receipts once you have paid your membership dues. That is also in the pipeline. This online presence opens up all sorts of possibilities for the future.

The online submission system was a little later getting off the ground than I had hoped, as the online membership took up much more of our time than anticipated. But that did not deter you from submitting as we had a record number of submissions in January. It is really interesting and enjoyable for us to report that 2009 was yet another record-breaking year as regards the number of submissions. And that is the fourth year in a row that we have broken the submission record. With the online submission system we anticipate that we will make that five years in a row.

As we are now publishing six issues per year we decided to go back to the tradition of having a new cover photograph on each issue. That means we are going to need a steady stream of high-quality pictures. So please look at your photo album and check to see if you have any stunning pictures in your collection. This applies especially to authors whose papers we are going to publish, as we would like the cover to illuminate an article in the issue. So if your paper is accepted for publication, please check to see if you have a potential cover photograph that is relevant to the subject of your article.

On a similar note, some of you may have noticed that the last issue of 2010 is going to be the 200th issue of the *Journal of Glaciology*. We are planning to commemorate this by republishing some classic papers that have appeared in the *Journal*. In addition we are going to invite our members to submit potential cover pictures to celebrate this milestone. So start looking at your slides and send us a sample. Remember that the picture must be of a very high quality. As a prize for the winning photograph, we will present you with a framed picture of the cover and one year’s free subscription to the *Journal*.

Magnús Már Magnússon
Secretary General



Recent work

Italy

ALPINE GLACIERS

Glacier variations, long term length and mass balance monitoring

Long term monitoring of length changes

Comitato Glaciologico Italiano (CGI), Carlo Baroni (UNIP-DST), Mirco Meneghel (UNIPD-DG), Giovanni Mortara (CNR-IRPI)

Since the beginning of the last century the CGI has been paying attention to the fluctuations of Italian glaciers. Actually a yearly monitoring of the snout position on selected glaciers is carried out by the surveyors of the CGI in close cooperation with several organizations involved in glaciology (among others SMI, SGL, CGT-SAT, SG-CAIAA). The present (last 15 years) monitoring program was also sustained by recent COFIN-PRIN Projects funded by the Italian Research Ministry.

The collected data are published annually in a report in the CGI official journal named 'Geografia Fisica e Dinamica Quaternaria'. Moreover data of many glaciers are also periodically sent to WGMS to be published in the volumes 'Fluctuations of Glaciers'. Snout position is commonly measured on the ground by topographic instruments (mainly tape, in some cases laser rangefinder, GPS). A description of the year by year glacier changes is usually given along with the measurements. For some glaciers these measurements have been collected since the end of the XIX century thus making their data-records more than 100 years old. Over the last ten years 134 glaciers (average value) have been monitored in the Italian Alps (66 glaciers in the Western Alps, 25 in the Central Alps and 43 in the Eastern Alps). About 88% (average value) of the glaciers measured are retreating (from 69% in 2001 to a maximum of 99% in 2007); some of them are now vanishing.

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A century of Italian glaciers fluctuations

Guglielmina Diolaiuti, Carlo D'Agata, Claudio Smiraglia (UNIMI-DST), Michele Citterio (GEUS), Francesco Apadula, Giuseppe Stella (CESI)

The project is based on the analysis of all the available Italian terminus fluctuation data published since 1908 by the CAI journal (named 'Bollettino del Club Alpino Italiano') and since 1914 in the yearly reports of CGI (published in the CGI official journal). The data were entered in a special data base (named GLAD) available online through the website of CESI which supported the research.

In GLAD information and data regarding 883 Ital-

ian glaciers were inserted. The glaciers entered in GLAD were surveyed with variable continuity between 1908 and 2002. Since the time series for most of the 883 glaciers are short or very discontinuous, a representative subset of 95 glaciers featuring longer and more reliable data was selected for further analysis.

This subset contains a total of 3776 field-surveyed measurements, with an average record length of 39.7 years per glacier, ten glaciers in the 60- to 70-year class of record length, four glaciers surveyed for more than 70 years and one glacier (i.e., Ventina) with records covering 85 years.

Glaciers known to surge (i.e., Belvedere) or affected by active calving at the terminus (i.e. Sab-bione Meridionale) were excluded. Because of this, it is not possible simply to average the curves of cumulated terminus fluctuations, and for inter-comparison purposes, the 95 selected glaciers were sorted according to their maximum length (<1 km, 1–2 km, 2–4 km and >4 km) and the data were averaged over time intervals of 10 years (from 1913 to 2002).

The results show that the general trend for Italian glaciers, in spite of the fact that such glaciers show strong fluctuations with large amplitudes, is one of retreat for most of the 20th century. The only significant interruptions in the retreat trend proved to have taken place in the 1913–1922 interval (though very few glaciers were monitored during those wartime years) and then in the 1970s and 1980s. The lowest fraction of retreating glaciers and the lowest rates of retreat or even significant advances were recorded in the decade from 1973 to 1982, compared to the preceding and subsequent decades, regardless of glacier size. However, a consistent pattern was recognizable with respect to glacier size, both in the percentage of retreating glaciers and in the average rate of terminus fluctuation within the 1973–1982 decade itself: while the longest glaciers (i.e. >2 km in length) were mostly advancing, only a minority of glaciers shorter than 2 km advanced. Longer glaciers, on average, had positive or slightly positive rates of terminus position change, while shorter glaciers saw only a temporary slowdown of their retreat.

The last period (1993–2002) is the only one, together with 1933–1942, without any advancing glaciers at all (on the decadal scale) in the sub-sample of 95 glaciers, and it is interesting to observe that average decadal rates of retreat in these two periods are similar for all size classes but the shortest (i.e. glaciers shorter than 1 km). It also

must be added that all the glacier classes showed a retreat acceleration from the decade 1983–1992 to 1993–2002.

The next step of the project is the GLAD data uploading and the analysis of the terminus fluctuation data over the last decade (2003–2012).

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Glacier retreat in the Maritime Alps area

Paolo Roberto Federici, Marta Pappalardo (UNIPi-DST)

In the southernmost tract of the Alps (Italian-French Maritime Alps, 44° N), extensively covered by glaciers during the Last Glacial Maximum, about 30 small glaciers were present by the end of the Little Ice Age and only six persisted in the early 1990s. The focus of this research activity is to quantify the progressive decrease towards exhaustion of these glaciers, highlight the factors affecting their retreat and state their current condition. All available data sources were investigated, including: the yearly glacier fluctuations record, comparative analyses of historical maps and multitemporal oblique photographs and direct surveys in the field. The history of the Maritime Alps glacier fluctuations was thoroughly researched since 1896. Time-distance curves were obtained for some of the glaciers. In particular during the past two decades, the Maritime Alps glacier termini experienced a global retreat of about 100 m, with a sharp acceleration after 2002. Currently ice patches along cirque walls and/or semi-buried lenses of ice are still present, as testified by geo-electrical surveys carried out in three cirque hollows; morphological evidence of permafrost creeping in the glacier forefield accounts for the incipient transition to periglacial landforms (i.e., rock glaciers). The main factors controlling glaciers retreat seem to have been their original extension at the beginning of the current regressive phase and their distance from the main chain divide. From a climatic point of view unfavourable factors for glaciers persistence have been in the last decades a remarkable and sharp temperature increase, a decrease in winter snowfall and a shift of the rainfall peak from autumn to spring.

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Glacier monitoring in Aosta Valley – North Western Italian Alps

Alex Théodule, Elena Motta, Marco Vagliasindi, Claudio Lucianaz (FMS-CRGV), Umberto Morra di Cella, Paolo Pogliotti (ARPA-VdA)

Aosta Valley is a medium size alpine region covering a surface of about 3300 km²; here glacial and periglacial environments represent important land elements (i.e. more than 50% of the region area is located above an elevation of 2000 m a.s.l.). Consequently is important to acquire and update detailed information on glaciers and glacial environments.

At the regional scale, by analysing aerial photographs, orthophotos and satellite imagery glacier changes are quantified. All this information is collected in the Regional Glacier Inventory, which was performed according to the World Glacier Inventory standard and recommendations.

At the local scale, mass-balance measurements, terminus fluctuations and snow accumulation surveys are carried out on glacier sample sites. The yearly mass balances are measured on Timorion Glacier (Gran Paradiso Massif, from 2001), Rutor Glacier (from 2004), Pré de Bard Glacier (Mont Blanc Massif, from 2007) and Indren Glacier (Mont Rose Massif, from 2007) by applying the traditional glaciological method (through ablation stakes and snow pits). Moreover, from 2005 some other representative glaciers (Chérillon, Mont Gelé, Tsanteleina and Verra Grande) are monitored by surveying their terminus with GPS and performing snow depth and density measurements.

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Integration of iconographic historical and recent data in an GIS for the Multitemporal analysis of the Miage Glacier evolution (Monte Bianco)

Marco Giardino, Luigi Perotti, Walter Alberto (UNITO-GSL), Giovanni Mortara (CNR-IRPI)

The available data on the geomorphological changes of the Miage glacial environment are huge; besides the splendid iconographical representations of the 18th and 19th centuries, it is also possible to admire the numerous photographs from the end of the 19th century, most of them preserved at the CGI in Torino.

Another important iconographical patrimony is constituted by the aerial photographs (stereo pairs), first taken in the 1930s, that document the glacial characteristics of the Miage in recent times. This great amount of data has allowed to realize a first catalogue on the aerial documentation of the Miage glacier. At last, the iconographical patrimony can be completed with the recent photograph research and catalogue of glacial and alpine interest at the FMS of Courmayeur, Valle d'Aosta.

With the available documentation it was possible to realize a Geographical Information System containing an inventory of all the cartographical, iconographical, photogrammetrical and satellite data on the Miage glacier. The structure of the database has not only been conceived as a scientific tool on the glacial area, but also as an important information resource on the high mountain environment. Therefore, it represents a valid instrument for the data integration on the territorial transformations. Besides, on the base of the aerial and satellite data, some quantitative and qualitative analyses have been developed with photogrammetric and digital classification techniques

of the images that allowed, where possible, a temporal planimetric and volumetric reconstruction of the Miage Glacier. This system, also allowed to analyze natural hazards interfering with human activities. In the next few months, it will be possible to create a monitoring system of the study area based on the available data.

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Multitemporal analysis of Gran Paradiso glaciers

Valerio Bertoglio (PNGP), Luigi Perotti, Walter Alberto, Marco Giardino (UNITO-GSL)

The last 15 years has been brought forward a project of tracking glacier termini of most of the glaciers in the Gran Paradiso Group. The work was done through the use of GPS code and phase instrumentation. The collected data were entered into a GIS in order to be analyzed.

A map of the multitemporal changes was produced in order to have an updated progress of the glacier environment.

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Mass balance of the Grand Etrêt Glacier, Gran Paradiso

Valerio Bertoglio, Stefano Cerise (PNGP), Luigi Motta, Michele Motta (UNITO-DST)

Grand Etrêt is a medium-size valley glacier located in the Gran Paradiso Massif (Western Alps). Since 1999 its yearly mass balance was studied in the framework of a cooperation between the Gran Paradiso National Park and the University of Turin. From 1999 to 2009 the glacier had lost 10.6 m of thickness (9.22 mm w.e.). The mass balance result was particularly negative in the hydrological years 2002–2003 and 2005–2006. Instead, the mass balance was found positive in the hydrological years 2000–2001 and 2008–2009, mainly due to heavy snow precipitations.

The analysis of mass balance data over the last ten years showed that generally at the beginning of the ablation season, in June, ablation increases fast, reaching generally high values (up to 7–9 cm/day in sunny days), although with wide oscillations, up to the middle of September. Moreover ablation resulted quite homogeneous at all elevations due to the compensation between air temperature (which decreases with increasing altitude) and solar radiation (which rises at higher altitude). Generally accumulation was found to increase with altitude with the exception of the glacier central sector where snow cover resulted decreasing probably due to glacier local aspect and/or to wind erosion. Moreover during some summer seasons exudation ice was found outstanding at the glacier surface thus emphasizing the role of the solar radiation in driving glacier ablation.

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History of the Rutor Glacier retreat (Valle d'Aosta, Italy) from the Little Ice Age

Fabio Villa, Mattia De Amicis, Valter Maggi, Giuseppe Orombelli (UNIMIB)

Variations in the surface area and volume of the Rutor Glacier (Val d'Aosta), from the maximum expansion in the Little Ice Age to the present retreating phase, were determined by combining ground surveys, digital techniques and pre-existing data time series. From the mid-19th century to 2004 the glacier terminus retreated by about 2 km, nevertheless there was evidence of two (cooler) periods of glacier advance. Furthermore, the most recent glacier retreating phase, which started in 1990, seems to be faster than the previous ones. The Rutor Glacier lost about $480 \times 10^6 \text{ m}^3$ of ice between the Little Ice Age and 1991. Morphologic and volumetric analysis indicate that in the last decades the Rutor Glacier had lost large quantities of ice with no significant terminus retreat (an ice loss of $-46 \times 10^6 \text{ m}^3$ and a surface decrease of -1.4 ha , this latter with respect to a total surface area of 911 ha); the glacier has gradually thinned while maintaining an almost constant surface area. The Equilibrium Line Altitude changed from 2775 m in the Little Ice Age maximum to 2850 m in 1991, with a total rise of 75 m.

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The mass balance network of Lombardy glaciers

Claudio Smiraglia, Guglielmina Diolaiuti (UNIMI-DST), Giacomo Casartelli (CGI), Riccardo Scotti (SGL)

Part of the network was developed in the framework of several COFIN-PRIN Projects funded by the Italian Research Ministry and under the umbrella of a partnership with the CAI.

On the Lombardy Alps mass balance monitoring has been performed without interruptions since the end of the 1980s on the Sforzellina Glacier, a small (less than 1 km² wide) cirque glacier in the Ortles-Cevedale group. Other benchmark glaciers are the Scalino Glacier, in the Bernina group, monitored from 1993, and the Dosdè Orientale Glacier, in the Piazzzi-Campo Group, monitored from 1995. The mass balance data are acquired according to the glaciological method (ablation stakes and snow pits). All mass balance data calculated for the last 20 hydrological years resulted negative but one (the only exception was 2001) thus witnessing a considerable glacier mass loss. The mean ice loss was 2.1 m w.e. during the heat wave of 2003.

Analysing Lombardy mass balance data and comparing them with the ones of other European glaciers shows this glaciological parameter encloses not only a temporal index of climate change but also a spatial determination of the climate variability. In this way it is possible to describe glacier regions characterized by differ-

ent mass balance patterns. The Lombardy glaciers results form part of the results of glacier regions up to 200 km wide.

Other benchmark glaciers are the ones monitored by SGL: the Suretta Meridionale in the Spluga-Lei Group (surveyed from 2002) and the Alpe Meridionale in the Ortles-Cevedale Group (from 1998). The mass balance data of the Suretta glacier are evaluated from GPS surveys coupled with glaciological investigations; The Alpe Meridionale data, instead, derived from glaciological surveys. Both the balance records show negative results over the last decade: the Alpe Meridionale Glacier had lost 16 m w.e. from 1998 to 2008. Contacts: claudio.smiraglia@unimi.it, guglielmina.diolaiuti@unimi.it, riccardo.scotti@alice.it

Recent surface variations of the Lombardy glaciers

Recent surface variations of glaciers in the Adamello group

Guglielmina Diolaiuti, Davide Maragno, Carlo D'Agata, Claudia Mihalcea, Claudio Smiraglia (UNIMI-DST), Daniele Bocchiola (POLIMI-DIIR)

In the framework of the Project CARIPANDA managed by the Adamello Regional Park and funded by Fondazione Cariplo, an investigation on the recent surface area changes of the Adamello glaciers (Lombardy Alps) has been carried out. Four surface area records (1983–1991–1999–2003) were compiled by combining aerial photo analysis, Differential Global Positioning System (DGPS) surveys of glaciers and Geographic Information System (GIS) data processing. The analysis led to a quantification of surface reduction ca. 19% from 1983 to 2003 (total surface about 17 km² in 2003) with strong glacier morphology changes, including growing rock outcrops, tongue separation, formation of ice-contact lakes, increasing supraglacial debris and collapse structures, well detected on the 2003 orthophotos.

Moreover small glaciers proved to contribute strongly to total area loss: in 2003, 31 glaciers (c. 91% of the total number) were smaller than 1 km², covering 2.28 km² (c. 10% of the total area), but accounted for 39% of the total loss in area (losing 2.05 km² from 1983 to 2003). Presently an update of the variations using the most recent orthophotos (2007) is continuing.

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Fifty years of glacier changes in Dosdè-Piazzì group

Guglielmina Diolaiuti, Davide Maragno, Claudio Smiraglia (UNIMI-DST)

In the framework of the 'Water & Glaciers' Project funded by San Pellegrino-Levissima Spa, the glacier surface area variations along half a century (1954–2003) of the Dosdè-Piazzì group in the up-

per Valtellina have been analyzed by using aerial photos (1954–1981), a former glacier inventory (1991) and orthophotos (1999, 2003). The Dosdè-Piazzì glacierized area was 8.21 km² in 1954 (19 glaciers and 3 glacierets), 6.53 km² in 1981 (22 glaciers and 3 glacierets), 5.55 km² in 1991 (24 glaciers), 4.10 km² in 1999 (14 glaciers) and 3.77 km² in 2003 (23 glaciers). The area change between 2003 and 1954 was –3.97 km² (–51% of the area coverage in 1954). Moreover, the surface reduction seems to be stronger in the last time frame. Presently an update of the variations by using the most recent orthophotos (2007) is continuing. Contact: guglielmina.diolaiuti@unimi.it

Twenty years of glacier changes in the Ortles-Cevedale group

Guglielmina Diolaiuti, Davide Maragno, Claudio Smiraglia (UNIMI-DST)

In the framework of the 'SHARE-STELVIO' Project funded by Lombardy Region and managed by FLA and EvK2CNR, the glacier surface area variations over the last 20 years (1981–2003) of the Ortles-Cevedale group in the upper Valtellina were evaluated. For this purpose aerial photos (1981), a former glacier inventory (1991) and orthophotos (1999, 2003) were analysed.

Surface data of 53 glaciers were compared thus permitting to quantify a surface area change of ca. –25.3%. Moreover, the surface reduction seems to be stronger in the last time frame.

Presently an update of the variations by using the most recent orthophotos (2007) is continuing. Contact: guglielmina.diolaiuti@unimi.it

Investigations on the cryosphere of Eastern Italian Alps

Alberto Carton, Mirco Meneghel (UNIPD-DG), Roberto Seppi (UNIPV-DST), Luca Carturan (UNIPD-TeSAF)

The objective of this project is a quantitative analysis of the climate change effects on the cryosphere of Eastern Italian Alps. The analysis is focused on glaciers and permafrost, and is intended to: (1) evaluate the historical variations of these components, (2) to understand the spatial variability of the reaction to climate change and (3) to model the distribution of glaciers and permafrost in the future. The investigations on glaciers are focused on three mountain groups: Adamello-Presanella, Ortles-Cevedale and Dolomites. Past changes of the glaciers are studied through the collection of historical documentation (photos, maps, topographic surveys, field campaigns) and detailed geomorphological investigations. The application of a mass balance modelling tool is useful to understand the dominant processes involved in the present deglaciation phase and to predict the potential future extent of glaciers.

The research on permafrost combines different investigation methods. These include the map-

ping and inventorying of rock glaciers and other permafrost-related land forms, the monitoring of ground surface and spring thermal regime and geophysical surveying. It is planned to compare the results among different geographic areas of Eastern Italian Alps, in order to put in evidence possible differences in present and past permafrost distribution and their causes (lithology, climate, etc.).

Further investigations regard the relationship among glaciers and permafrost and the progressive transition from glacial to periglacial morphogenesis in the former glaciated areas.
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Monitoring and modelling the climate change effects on the cryosphere of Ortles-Cevedale

Luca Carturan, Giancarlo Dalla Fontana (UNIPD - TeSAF), Federico Cazorzi (UNIUD-DSAA)

The Ortles-Cevedale is a 1638 km² wide mountain group located in the Eastern Italian Alps. The glaciers currently cover a surface of 80 km², and the lower limit of discontinuous permafrost averages 2700 m a.s.l.. Since 2003 an extensive effort has been undertaken, to collect detailed field data and to develop operational modelling tools for the study of the climate changes in act and their effects on cryosphere and hydrology.

The investigations are carried out in the upper part of Val de La Mare (Trentino), and in the Vedretta Alta dell'Ortles (Bolzano Province). The main research topics are: (1) meteorological investigations at high altitude, (2) process-oriented mass balance measurements on glaciers, (3) glacier mass balance modelling and (4) permafrost distribution observation and modelling.

The meteorological investigations are mostly focused on the estimation of precipitation at high altitude, on the spatial and temporal variability of glacier surface albedo and on the temporal and spatial variability of cloud cover. Experimental data are collected by means of automatic weather stations which are placed both inside and outside the glaciers, and by distributed measurements with portable instrumentation.

Detailed mass balance measurements are carried out on three glaciers (Careser, La Mare and Vedretta Alta dell'Ortles) and provide the experimental basis for the development of an operational tool for the glacier mass balance modelling. Model implementation involved the parameterization of major processes controlling accumulation and ablation, like snow redistribution, glacier cooling effect, surface albedo and cloud cover. The modeling approach only uses currently available off-site meteorological data (temperature and precipitations).

The researches on the permafrost distribution are carried out by means of observations regarding the periglacial geomorphology and the ther-

mal regime of springs and ground surface. We are currently involved in the development of a permafrost distribution map and further investigations are planned to improve the knowledge on the interactions between permafrost, lithosphere and climate.

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Long-term monitoring of length and mass balance of Trentino glaciers

Luca Carturan (UNIPD-TeSAF), Stefano Fontana (CGT-SAT), Roberto Seppi (UNIPV-DST), Alberto Trenti (PAT-M), Alberto Bellin (UNITN-DIA), Michele Lanzinger (MTSN)

A team of specifically educated volunteers and professional glaciologists monitors the annual variations of glaciers in the Trento Province. The observations regard the length changes and the annual mass balance of a subset of glaciers, that were selected as benchmarks. The investigated mountain groups are the Adamello-Presanella, Dolomiti di Brenta, Ortles-Cevedale, Pale di San Martino and Marmolada. The length changes are measured in the month of September. Additional observations are carried out on morphological changes and residual snow cover, and photographic documentation is also collected.

Mass balance investigations according to the direct glaciological method are carried out on Careser Glacier (Ortles-Cevedale) since 1967, Agola Glacier (Dolomiti di Brenta) since 2002, La Mare Glacier (Ortles-Cevedale) since 2003, Mandrone Glacier (Adamello-Presanella) since 2005, Marmolada Glacier (Marmolada) and Lobbia Glacier (Adamello-Presanella) since 2009. Additional mass balance investigations are performed since 1990 on five other glaciers by means of the geodetic method. High resolution LiDAR data and orthophotos were acquired in 2003 and were used to compile a GIS-based inventory of Trentino glaciers, which currently cover an area of 38.29 km².

The observations are collected and archived. Annual reports are compiled including a discussion of the climatic conditions during the observation period, in relation to the observed behaviour of monitored glaciers.

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Long-term mass-balance monitoring of Careser and La Mare Glacier

Luca Carturan (UNIPD-TeSAF), Stefano Fontana (CGT-SAT), Roberto Seppi (UNIPV-DST), Alberto Trenti (PAT-M), Michele Lanzinger (MTSN), Alberto Bellin (UNITN-DIA)

The Careser is a south facing mountain glacier with a total surface area of 2.4 km² and an average altitude of 3057 m a.s.l.. It is located in the central sector of the Italian Alps, in the Ortles-Cevedale Group. Mass balance investigations on Careser Glacier started in 1967 and the measurement se-

ries extends until present without interruptions. Since the beginning, the research activity has been promoted by the CGI. The mass balance is monitored according to the direct glaciological method, evaluating the seasonal components (winter and summer balances). The series is reported to WGMS. The glacier has been near to equilibrium conditions in the first 14 years of monitoring. However, since 1981 increasingly negative mass balances were measured, with almost the entire glacier in the ablation area. Since 2003 the mass-loss rate nearly doubled, and the average mass balance in the 2003 to 2009 period has been -2141 mm y^{-1} w.e., as a result of both the warmer ablation seasons and the feedbacks of the elevation and albedo. The stakes movement is near to zero and the glacier has started to disintegrate, due to the rapid surface lowering and widespread outcrop of the bedrock. A further fragmentation and a complete vanishing of the ice body are expected in the next 30 years, with the ongoing unfavorable climatic conditions. In order to provide an overlapping series and to study the spatial variability of the deglaciation process in this area, mass balance investigations have been initiated in the nearby La Mare Glacier in 2003. This east facing valley glacier has an area of 3.8 km^2 . Its average altitude is 3285 m a.s.l. and it still has an accumulation area (30% of the total surface). Therefore, the current mass-loss rate is an order of magnitude lower compared to Careser Glacier.

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Mass balance measurements on the Vedretta di Ries occidentale/westlicher Rieserferner glacier

Roberto Dinale, Michela Munari (PAB-UI), Stephan Galos, Georg Kaser (UNINN-IG)
The name Vedretta di Ries/Rieserferner refers to three glaciers in the southern Zillertaler Alps, which formed one single ice body during the Little Ice Age. In this region a gap in glaciological information was not closed until 2008 when mass balance measurements were started in collaboration with the Institute of Geography of the Innsbruck University. The aim of this was to select a glacier for mass balance investigations in the north-east of South Tyrol. The Vedretta di Ries occidentale/westlicher Rieserferner was chosen on the basis of various considerations. First off all its surface (of about 2 km^2) and altitude (range from 2620 to 3220 m a.s.l.) proved to be suitable for detecting the interannual ELA variability. Secondly, also the safe and easy accessibility both in summer and winter as well as the close neighbourhood of Kasseler mountain hut were taken into account. A network of 20 ablation stakes has been designed to cover the entire glacier elevation along its longitudinal profile and taking possible lateral mass balance variations into account. The drilling operations were performed using Heucke's steam drill. The

balance year 2008/2009 brought a mass loss of 0.61 m w.e. To evaluate the maximum mass accumulation on the glacier, a winter balance survey was performed on May 12. The winter balance of the glacier was $+1.27 \text{ m w.e.}$, the summer balance resulted as -1.90 m w.e. The analysed Equilibrium Line Altitude (ELA) was at 3100 m a.s.l. , the Accumulation Area Ratio (AAR) was 0.167 .

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Mass balance measurements on the Fontana Bianca/Weissbrunnferner glacier

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Fontana Bianca/Weissbrunnferner is a small east-exposed glacier in the southern part of the Eastern Alps (Ortler/Cevedale Group, Italy). It now covers an area of 0.37 km^2 and extends from 3340 m to 2920 m a.s.l. It has two short tongues on which blown-in winter snow tends to last far into the summer months. At the nearby Weissbrunn meteorological station (1900 m a.s.l.) mean annual air temperature is 3.2°C and precipitation amounts to 1023 mm per year on average.

On this glacier mass balance studies began in 1983/84 but were interrupted in the period from 1988/89 to 1990/91. They started again the following year and are currently still progressing. Therefore, the available data series of winter, summer and net mass balances consists of 23 years of measurements. Since summer 2004 the direct glaciological method is integrated with the hydrological data collected on two gauging stations. These are positioned immediately downstream the glacier tongues on the orographic left and right parts of the glacier. Discharge measurements allowed calculating maximum ice melt rates of 8 cm ice/day averaged over the entire glacier.

The progressive retreat of the glacier is emphasized by the enlargement of the rock outcrops in the central part both in the steep upper limit and at the borders of the ice body. The surface loss is about 46% since 1983. Ice thickness measurements were performed in 1995 using a ground penetrating radar and a volume of 0.0165 km^3 of water equivalent was estimated. The cumulative mass balance since 1983 reaches -2.0 m w.e. , that means -0.88 m w.e. in average per year. The relative volume loss is 60.1%. The mean winter balance of the Fontana Bianca glacier is $+1.05 \text{ m w.e.}$, the mean summer balance results of -1.93 m w.e. The ELA was often higher than the highest point of the glacier. Only two hydrological years (1983/84 and 2000/01) had a positive net mass balance, each one accumulating $+0.39 \text{ m w.e.}$

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Mass balance monitoring on Ghiacciaio Malavalle/Übeltalferner and Vedretta Pendente/Hangenderferner, Italian Alps

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The mass balance measurements on the Ridnaun-Ridanna Valley glaciers (Breonie Alps, Alto Adige-South Tyrol) cover the two largest ice bodies: the Vedretta Pendente-Hangenderferner (0.85 km²) observations began in the 1995–96 hydrological year, while the Malavalle Glacier-Übeltalferner (6.16 km²) ones began in the 2001–02. The Hydrographic Office of the Autonomous Province of Bolzano, which supports the field measurements, identified this glacial basin as a ‘representative basin’ for the monitoring of the Climate Change on the Alpine Glacial basin, and two years ago installed an AWS for meteorological and hydrological data acquisition. A recent high-resolution DTM and orthophoto, associated with regular GPS measurements, provide a thorough geographical environment for GIS assisted mass balance computations. Mean annual mass balance values on the whole observation time are –1043 mm w.e. for the Vedretta Pendente, and –932 mm w.e. for the Malavalle Glacier.

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Ice thickness measurements on the Malavalle/Übeltalferner glacier

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The Malavalle/Übeltalferner glacier is situated in the Stubai Alps close to the border to Austria, it has a meanly east exposed compound basin form and covers an area of about 6.4 km². In May 2009, a cooperative of the Hydrographic Office of the Autonomous Province of Bolzano and the Institute of Meteorology and Geophysics of the University of Innsbruck measured the ice thickness using a 6.5 MHz ground penetrating radar. Ideal snow cover conditions allowed us to perform 155 point measurements and to get the pre-defined longitudinal and transversal transects. The snow depth was measured and subtracted from the measurement results to get the net ice thickness.

The bedrock topography is characterized by many plateaus divided by rock ridges, which force and accelerate the ice-flow producing the depression where the highest ice thickness values were found. The lowest ice thicknesses were measured on the upper south exposed glacier part. The mean ice thickness was 68 m, the maximum value calculated was 214 m ice. The ice volume was determined to be 0.434 km³.

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Long term monitoring of length changes in the Julian and Pusteresi Alps

Rossana Serandrei-Barbero (CNR-ISMAR)

Measurements of the snout variations of the Julian Alps Glaciers are available from the beginning of the last century. They indicate a general retreat interrupted by two short advances around 1920 and around 1960. The morphological features of the rocks surrounding the glaciated surfaces make possible the evaluation of the change in their surfaces and thickness. The climatic parameters recorded starting from the ‘20s at Cave del Predil allow some evaluation on the mechanisms that control the snout and thickness variations and their response time. The short advances of the ‘20s and ‘60s seem due to the concomitance between colder temperatures in summer and a higher amount of precipitations in winter. On these very small alpine glaciers, the correlation between summer temperature and winter precipitations indicates that the response time of the position of the glacier terminus with respect to each measuring station results in a one year time lag.

On the Pusteresi Alps, frontal measurements, made since 1977, show a prevailing retreat from 1983 and a more intensified retreat since 1991. Their comparison with the trend of temperature and precipitation data recorded at Predoi since 1977 shows temperature increases in 1986–87 as the main factor controlling the snouts with a response time around 5 years; the progressive increase of the glacier retreat still ongoing is due to the scarcity of winter precipitation and their further decrease since the 1990s.

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The Italian debris covered glacier project

The expansion of insulating debris mantles across glacier ablation zones feeds back negatively on melt rates. This is important for forecasting the glacier response to climate change on a decadal scale. Debris covered glaciers, which are typical landforms of the Pamirs, Karakoram and Himalaya, on the Italian Alps are quite rare, but with the current warming climate, their number and also the magnitude of debris cover on single glaciers seem to be increasing. The study has been devoted to Italian debris-covered glaciers, to improve understanding of their special behavior, to collect more data concerning their fluctuations, their dynamics, energy exchanges and mass balance.

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Supraglacial debris cover and thickness pattern on Miage Glacier (Mont Blanc Massif)

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Miage is the largest debris-covered glacier of the Italian Alps. It was studied in the recent years in the framework of a cooperation between Italian and Scottish scientists supported by the British Council, the CRUI and the NERC organizations. Several field campaigns were performed starting from 2004 summer season up to now. Moreover the Miage Glacier was studied in the frame of the GLIMS (Global Land Ice Monitoring from Space) Project thus permitting us to take advantage of ASTER satellite imagery.

High resolution in situ surface temperature measurements of supraglacial debris cover were compared to ASTER-derived surface temperature data. The ground- and remotely-sensed temperatures were strongly correlated over continuously debris-covered areas, while on partially debris-covered ice (i.e. crevassed areas and ice cliffs) the correlation was weaker. A map representing the spatial distribution and thickness of the debris cover was derived from the ASTER surface temperature data using debris surface temperature-thickness relationships. Both ground- and remotely sensed data predicted well the thick debris cover at the terminus and its upstream decrease, broad cross-and along-glacier patterns of debris thickness were revealed in the ASTER data, e.g. moraines, crevassed areas. Finer details in the debris thickness distribution were not revealed in the ASTER data, due mainly to the coarse resolution (90×90 m pixel size) of the thermal band imagery.

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Recent changes in the Miage debris-covered glacier tongue (Mont Blanc) from analysis of aerial photos and maps

Guglielmina Diolaiuti, Carlo D'Agata, Andrea Meazza, Claudio Smiraglia (UNIMI-DST), Antonio Zanutta (UNIBO-DISTART)

In the framework of a COFIN-PRIN (2005) Project funded by the Italian Research Ministry the recent (last 30 years) evolution of the Miage Glacier was analysed. The aim of the project was to identify the changes in volume and thickness in the Miage Glacier tongue during the period 1975–2003 and to compare the results with those calculated for the same period on debris free glaciers located in the Mont Blanc area. The period examined (1975–2003) addresses climate conditions which were glacier-favourable (around the 1980s), as well as glacier-unfavourable (since the early to mid-1990s), thus contributing to an understanding of the behaviour of debris covered glaciers under a changing climate.

The analysis was based on the comparison between digital elevation models (DEMs) derived from historical records, specifically maps (1975; scale 1:10,000) and photogrammetric surveys (1991 and 2003, scale 1:15,000). The results showed a general glacier volume loss from 1975 to 2003; nevertheless if we consider the two time sub-windows (i.e.: 1975–1991 and 1991–2003) opposite trends were found: in the period 1975–2003 the volume variation of the Miage Glacier was negative, in the period 1975–1991, on the other hand, a volume increase occurred. Moreover the volume and thickness changes resulted highly related to distribution and pattern of the supraglacial debris cover (derived from ASTER) thus evidencing the key role played by surface debris layer in driving glacier changes.

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Meteorology and surface energy fluxes in the 2005–2007 ablation seasons at Miage debris covered glacier, Mont Blanc Massif

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This project was performed in the framework of a cooperation between Scottish and Italian scientists supported by the British Council, the CRUI and the NERC organizations. During the 2005–2007 ablation seasons, meteorological conditions were recorded on the lower and upper parts of the debris-covered ablation zone of Miage Glacier. In 2005, debris temperature and sub-debris ice melt were also monitored at 25 points with debris thickness 0.04–0.55 m, spread over 5 km² of the glacier. The radiative fluxes were directly measured, and near-closure of the surface energy balance was achieved, providing support for the bulk aerodynamic calculation of the turbulent fluxes.

Surface-layer meteorology and energy fluxes were dominated by the pattern of incoming solar radiation which heats the debris, driving strong convection. Mean seasonal values of the net short-wave, net longwave and debris heat fluxes showed little variation between years, despite contrasting meteorological conditions, while the turbulent latent (evaporative) heat flux was more than twice as large in the wet summer of 2007 compared with 2005. The increase in energy output from the debris surface in response to increasing surface temperature means that sub-debris ice melt rates are fairly insensitive to atmospheric temperature variations, in contrast to debris-free glaciers.

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Recent variations of the Brenva debris-covered glacier (Mont Blanc) derived by comparison of maps and digital orthophotos

Carlo D'Agata, Claudio Smiraglia (UNIMI-DST), Antonio Zanutta (UNIBO-DISTART)

In the framework of the 2003 and 2005 COFIN-PRIN Projects funded by the Italian Research Ministry the recent (last 40 years) evolution of the Brenva Glacier was analysed. The aim of the project was to identify changes in the volume and thickness of the Brenva Glacier debris covered tongue (Mont Blanc Massif) in the second half of the 20th century. The Brenva Glacier up to summer 2004 was the Italian glacier with the lowest terminus elevation (ca. 1400 m a.s.l.).

The analysis was based on the comparison of digital elevation models (DEMs) derived from historical records, specifically maps (1959, 1971, 1983, 2003) and photogrammetric surveys (1991, 1997). The DEMs were generated by means of a digital photogrammetric workstation, with semi-automatic and automatic procedures. An unconventional photogrammetric methodology, based on the identification of homologous points in zones considered outside of the glacier area, was adopted to insert the surveys into a single reference system. Furthermore, along with the photogrammetric data, DEMs derived from digitized historical maps were generated and compared to define changes in the geometry of the glacier tongue. The results indicate a positive long-term glacier tongue balance; in fact, between 1959 and 2003, there was an average thickness increase of ca. 34 m.

This positive trend was confined to the glacier tongue only, instead the glacier debris free areas witnessed strong decrease due to ongoing climate warming. During very recent years, important changes have affected this debris-covered glacier which resulted, during the summer of 2004, in the tongue of the Brenva debris-covered glacier detaching from the accumulation basins. Actually the terminus of the Brenva Glacier is found at ca. 2400 m a.s.l.

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Tongue thickness and volume variations of debris covered Belvedere Glacier, Monte Rosa, in the second half of the 20th century.

Guglielmina Diolaiuti, Carlo D'Agata, Claudio Smiraglia (UNIMI-DST)

In the framework of the 2001 and 2003 COFIN-PRIN Projects funded by the Italian Research Ministry the recent evolution of the Belvedere Glacier was analysed. Moreover the project took advantage from the 2001 CESI research program. The Belvedere Glacier is well-known for the surge-type phenomena which occurred from 2001 and for the development at its surface of the 'Effimerous' Lake. The project here presented was performed before the glacier surge and the lake occurrence,

thus permitting to describe the Belvedere Glacier before those strong and radical changes.

Volume and thickness variations of Belvedere Glacier tongue were quantified by comparison of large scale maps from 1957 and 1991. Moreover in summer 2000 field investigations were performed to measure debris thickness and to calculate a debris distribution map. The volume and thickness changes were also analysed with respect to the debris thickness map to evaluate debris influence on glacier long term changes. A volume increase of $22.7 \times 10^6 \text{ m}^3$ was calculated equal to a mean thickness increase of 15 m. Thickening resulted major above 1830 m while thinning was found characterizing the glacier front. The glacier terminus advanced only slightly. This particular evolution of Belvedere tongue was attributed to positive balances of glacier created by the favourable climatic conditions (increase in winter precipitation between the early 1970s and mid-1980s and lower summer temperatures in the 1960s and 1970s). After the mid-1980s, reduced precipitation and a simultaneous increase in temperature led to a slight retreat of the glacier front in the early 1990s. However these climatic conditions were not sufficient to determine a significant reduction of glacier thickness up to 1991, partly due to the role of debris cover, whenever thicker than the critical value (which occurred on the 75% of the debris covered area), in reducing the ablation rates. From summer 2009 new field investigations were performed by the UNIMI DST scientists devoted to study Belvedere glacier surface changes and to describe the actual debris cover distribution and pattern after the surge phenomena.

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Recent changes of Lys Glacier tongue (Monte Rosa Massif, Italy) from remote sensing data and field measurements

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In the framework of the 2005 COFIN-PRIN Project funded by the Italian Research Ministry the recent evolution of the Lys Glacier was analysed. Moreover the project took advantage from the 2005 CESI research program. Moreover this glacier is studied in the frame of the GLIMS (Global Land Ice Monitoring from Space) Project thus allowing us to take advantage of ASTER satellite imagery. The Lys Glacier (Monte Rosa Massif, Italy) evolution was evaluated by analysing and comparing field data (DGPS campaigns, ice ablation, debris thickness and debris surface temperature measurements), remote sensing information (aerial photos, satellite imagery) and maps. Lys Glacier experienced strong changes in the ablation area due to rock-fall events from the lateral rock walls nesting the glacier tongue and rock outcrops in the glacier

ablation area and actually it is a partially debris-covered glacier as evidenced by the recent evolution of the debris coverage from 1975 to 2003 derived from orthophotos and maps analysed in a GIS environment.

Moreover from the comparison of DEMs derived from maps and aerial photos it resulted that from 1975 to 2003 the Lys Glacier tongue lost c. -15.4×10^6 m³ of ice and the behaviour of the losses occurred at the glacier tongue resulted markedly different in the median sector respect to the marginal areas. In addition a distributed ablation model was applied to Lys glacier to evaluate the total ablation amount during the summer seasons 2005 and 2006 (July - September). Meteorological data (air temperature and global radiation) from closest weather stations (i.e.: Gabiet La Trinitè and Gressoney Saint Jean) represented the data input of the ablation.

For the debris-covered area, a debris thickness map was calculated from an ASTER image (03–06–2006 10:27 GMT), TIR band, and used for the model distribution coupled with a high resolution DEM. From summer 2009 new field investigations were performed by the UNIMI DST scientists devoted to describe the actual debris cover distribution and pattern at a finer spatial scale. Moreover field campaigns were performed on the Lys accumulation basin to evaluate snow accumulation pattern.

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Calculating seasonal ablation on debris-covered Venerocolo glacier, Adamello Group, Italy

Claudia Mihalcea, Boris Mosconi, Guglielmina Diolaiuti, Carlo D'Agata, Claudio Smiraglia (UNIMI-DST), Daniele Bocchiola (POLIMI-DIAR) In the framework of the Project CARIPANDA managed by the Adamello Regional Park and funded by Fondazione Cariplo, an investigation on the seasonal ablation of the debris-covered Venerocolo Glacier (north side of Adamello, Lombardy Alps) has been carried out.

Venerocolo Glacier represents a recent debris-covered glacier and it is the first actual one in the Central Italian Alps. During 2007 an Automatic Weather Station (AWS) was positioned at the debris-covered surface to measure the energy fluxes at the ice-debris-air interface. The 2007 meteorological data (air temperature and energy fluxes) recorded by the AWS at the glacier surface and the 2008 meteorological data from Pantano weather station (2325 m a.s.l.) represent the main data input for distributed ablation models to calculate the glacier ablation. Moreover a map describing debris covered distribution and pattern with a spatial resolution of 10×10 m was obtained from field measurements and used as data input for calculating ablation with different debris thicknesses. In addition a network of abla-

tion stakes on the debris free and debris covered area were used to measure ablation rates and to validate the results from the ablation models. The correlation among calculated and measured ablation data was meaningful with some exceptions in areas with crevasses and high variability of debris thickness.

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Supraglacial meteorology

The Italian network of supraglacial automatic weather stations

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The network was developed in the framework of the SHARE (Station at High Altitude for Research on the Environment) Project managed by EvK2CNR, sub-program SHARE – ITALY. The research was also a part in the national program COFIN-PRIN 2005 funded by the Italian Research Ministry. Moreover important contributions came from San Pellegrino-Levissima and Osrarn and fundamental suggestions were given by the scientists of the IMAU of Utrecht (NL).

On Italian Alpine glaciers, in spite of the long tradition in field surveying, meteorological data and solar fluxes permanently measured on glacier melting surface were not available until 26 September 2005 when the AWS1 Forni was installed.

In fact, all other past Italian AWSs running over long time period in glacial environments were located on glacier accumulation area or on rock exposures and nunatak or buildings (such as mountain huts), thus making their data representative of high mountain atmospheric conditions but not very useful for knowing and understanding micrometeorology at the glacier melting surface.

Up to now a four year record (from 1 October 2005 to 30 September 2009) of meteorological data acquired by the WS1 Forni was analyzed. They permitted to describe glacier surface conditions, to calculate the energy balance and to evaluate the ablation amount; moreover snow accumulation was measured thus permitting to estimate the glacier mass balance over the last 4 years. In addition to summer 2009 the AWS1 Forni has been inserted in the CEOP (Coordinated Energy and Water Cycle Observations Project) network in the frame of the GEWEX (Global Energy and Water Cycle Experiment) program.

Other installations of supraglacial AWSs followed the one of AWS1 Forni, thus reinforcing the SHARE ITALY glacier network. In summer 2007 the AWS Dosdè-Levissima, which was located at the surface of Dosdè Est Glacier (Upper Valtellina, Lombardy) at ca. 2850 m a.s.l., and in winter 2007 the AWS Gigante-OSRAM, which was

located at the surface of Gigante Glacier (Mont Blanc Massif, Aosta Valley) at ca. 3430 m a.s.l. The collected data will allow to analyse the supraglacial meteorological conditions both in the western and in the eastern alpine sectors and will be useful to improve and validate energy balance models. The supraglacial AWSs do not represent a final goal, but are the first fundamental steps of scientific projects devoted to study alpine glacier changes and dynamics.

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Glacier hazard

Debris flows from glacier forefields

Marta Chiarle, Giovanni Mortara (CNR-IRPI)

Debris flows from glacier forefields, triggered by heavy rain or glacial outbursts, or damming of streams by ice avalanches, pose hazards in Alpine valleys. Glacier-related debris flows are, in part, a consequence of general glacier retreat and the corresponding exposure of large quantities of unconsolidated, without vegetation, and sometimes ice-cored glacial sediments. A research project of CNR-IRPI focuses on this type of debris flow in the Italian Alps (and specifically in the northwest sector). Past and recent occurrences are documented and investigated, in order to identify causes, triggers and dynamics, with the aim to point out the specificities of these debris flows. The outcomes of this research can help in assessing debris flow hazard in glacial and periglacial environments, where experience gained in ice-free contexts can only be partially applied.

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Glacial hazard in the Italian Alps

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Glacial hazard in the Italian Alps has been investigated in the framework of the EU Project 'Glaciork' (2001–2003), involving 11 different institutes from 6 European countries (France, Norway, Switzerland, Italy, Iceland and Austria). The project aimed at identifying, surveying and preventing catastrophic events that may occur as the result of glacial hazards. For this purpose, a specific database system (Gridabase, <http://www.nimbus.it/glaciork/gridabasemainmenu.asp>) was developed and implemented by SMI computer scientists, with the suggestions of the other partners. Gridabase stores all the data about glaciers, glacial hazard, instability events and damages. In the Italian Alps, glacial lake outburst floods (GLOF) and ice avalanches proved to be the most reported and hazardous instability processes related to glaciers. In addition, some sites have been object of detailed investigations, because of risks related to the dynamics of the glacial environment (Gla-

ciers of Croce Rossa, Belvedere and Rochemelon). These site-specific studies gave the opportunity to test innovative investigations techniques and strategies, and to outline guidelines for glacial risk assessment and mitigation.

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Experimental investigations of the Grandes Jorasses avalanching glacier

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The Grandes Jorasses avalanching glacier is a well known ice mass hanging on Ferret Valley (Mont Blanc Massif, Italian Alps). Periodically the avalanching glacier shows cycles of growth which are followed by collapses. The fall down is announced by a progressive acceleration of the glacier flow which permitted to forecast these events. The Ferret Valley, located under the avalanching glacier and then potentially interested by the fall down events, is a well known tourist location thus requiring an accurate monitoring program of the unstable and hazardous ice mass. For this purpose the local Civil Protection settled up a monitoring system based on topographic surveys performed automatically by an instruments which measures the positions of several control points located at the avalanching glacier surface. Moreover, with the same aim, the FMS developed and installed on the avalanching glacier surface a low cost GPS receiver which acquires and transmits continuously its position. The collected data permit to increase the knowledge of the glacier flow and dynamics and improve the development of new survey techniques. In addition, with the aim of monitoring the micro-seismic activity preceding ice failures and collapses, on the upper part of the glacier the FMS is now installing a seismograph.

Another on going activity on Grandes Jorasses avalanching glacier is the calculation of Digital Surface Models (DSMs) from close range photogrammetry data; the surveys are performed using an helicopter equipped with a high resolution digital camera. The registration of the acquired photos, needed to evaluate volume and morphological changes, takes advantage from permanent marks on rock exposures located in the area close to the glacier. The future planned activities embrace both the temperature measurement of glacier ice and of the rocks nearby and the evaluation of ice thickness by GPR techniques.

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The Belvedere Glacier and the 'Lago Effimero' emergency (NW Italy)

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The uppermost Anzasca Valley is dominated by the huge northeast face of Monte Rosa, which in the recent years has displayed extraordinary instability, without comparison in the Alps. A variety of natural processes, driven by a warming climate, are dramatically modifying the northeast face of the mountain and Belvedere Glacier at its base. Occasionally, the risk level has been so high that the Civil Defence Department must had to intervene to prevent people from hiking and climbing in the area. Because of this extraordinary activity, a multidisciplinary working group of Italian and Swiss researchers and technicians is supporting the administration technicians in gathering data that will assist in decision making. Logistical support and funding from this body has led to the development of a plan of field investigations and instrumental monitoring that has greatly improved knowledge about processes operating at Monte Rosa. Experience gained from this study is more broadly applicable to other glacierized areas in the Alps where similar instability is arising due to climate change.

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Glacial Hazard on the Italian side of the Mont Blanc Massif

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In the framework of a PhD fellow (1998-2001) of the Polytechnic of Turin, a study of the glacial hazard in the Mont Blanc area (Italian side) has been carried out. About 20 glaciers, set on massif granitic walls, bring great charm to landscape but, in the meantime, are a relevant source of hazards for the area. An historical analysis was carried out on the entire Courmayeur municipality and identified more than 220 instability events. One third of these events involved glaciers and all the numerous typologies described in literature are represented: emptying of ice-dammed or marginal lakes, emptying of internal water-pockets, proglacial stream debris flows, rock-ice avalanches, ice-falls, supraglacial debris fall outside the lateral moraine, rapid advance of snout of glaciers. Even if phenomena tend to occur always in the same places and with similar characteristics, the strong dynamism of the glacial environment and climatic trend towards global warming which could lead to exceed historical boundaries of variability, made it necessary to integrate historical data with the analysis of present landscape characteristics and of possible future scenery. In this contest and

taking into account outcomes from the present research, a particular attention has to be devoted in the future to ice falls, rock-ice avalanches and emptying of internal water-pockets. These phenomena are particularly dangerous because of velocity (up to 100 km/h), runout distances (up to 13 km) and involved volumes (sometimes millions of cubic meters) and for lacking, in some cases, any easily identified forerunning phase.

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The recent evolution of an avalanching glacier on Monte San Matteo (Ortles-Cevedale Group, Italian Alps)

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The project was performed in the framework of a partnership between the University of Milan and the University of Brescia.

Avalanching glaciers may be affected by periodic or occasional breaking off of ice (due to dry calving), which often leads to tragic events. These events have aroused a growing interest in the instability of avalanching glaciers. This project focused on the surveys carried out on an avalanching glacier on Monte San Matteo (Ortles-Cevedale Group, Italy). The monitoring campaigns consisted in surveying the avalanching glacier with a Total Station (Leica T 1000) over the period from July 2005 to November 2005. In addition, in May 2005 a laser scanner survey had been performed. The role of air temperature in the evolution of the ice mass was also investigated. The total station data were processed to calculate the changes of the unstable ice mass during the study period (displacements, average value 12.4 m; velocities, average value 11.2 cm/d and flow direction, main direction was found West). The laser scanner survey permitted an analysis of the unstable ice mass geometry. In addition several photographs collected during the field campaigns made it possible to describe also from a qualitative point of view the evolution of this unstable ice mass. Lastly, it was found that during the analysed period air temperature did not play a key role in the evolution of the ice mass.

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ICE CORES

Lys Glacier ice core (Valle d'Aosta, Italy)

Valter Maggi, Barbara Delmonte, Claudia Mazzola, Samuel Albani, Chiara Uglietti, Federica Marino (UNIMIB), Barbara Stenni, Onelio Flora (UNITS), Roberto Udisti (UNIFI)

High altitude glaciers in European Alps represent an important archive for atmospheric and environmental information, and for the quantitative assessment of the human impact.

Glaciers from the Monte Bianco and Monte Rosa group, located at the border between Italy, France and Switzerland, reach more than 4000 m a.s.l. and are located close to the most industrialized areas of the world. Air masses reaching these glaciers and travelling over these lands collect fine particles from both natural and human origin. Therefore, ice cores drilled on these high accumulation areas provide records both of natural and anthropogenic climate and environmental change with seasonal resolution. Moreover, transport from North Africa, mainly Sahara Desert, provide high concentration dust events that seasonally reach the Alpine area.

Colle del Lys is a saddle located on the accumulation area of Lys Glacier (Monte Rosa, Valle d'Aosta, Italy), on the Italian-Swiss border. This site is optimal for ice core activities, with annual accumulation rate of 1.3 m water equivalent. Thanks to the ENEA and Italian Antarctic Program, in a summer 2003, a 10⁶ meter deep ice core was recovered. From this core, a one century long atmospheric dust concentration, size distribution, and oxygen stable isotopes records were obtained. Dating was performed through some well known Saharan dust events (1977 and 1934-35) and the well-marked 1963 tritium peak, and the depth/age scale was subsequently refined using the seasonal variations of dust and oxygen stable isotopes. These new records allow improving the knowledge of the variability of atmospheric circulation on Southern Europe and in the Mediterranean basin, and the relationship with the North Atlantic atmospheric variability on the last 100 years. Contact: valter.maggi@unimib.it

Reconstruction of climatic and environmental variations during the Holocene inferred from a firn/ice core drilled at Colle Gnifetti Monte Rosa Group (4450 m a.s.l.)

Jacopo Gabrieli, Carlo Barbante (UNIVE), Margit Schwikowski (UNIB), Claude Boutron (LGGE)
The exploration of past climate prior to instrumental records is based on the interpretation of paleo-archives, where the most important are ice cores from both polar and low-latitude regions. Ice core drilling has a long tradition in the polar regions and was later extended to mountain glaciers in the Alps. In particular, snow in the Alps documents the effects of European anthropogenic emissions with the use of mountain glaciers as natural archives for studying historical trends of pollution. Colle Gnifetti (4450 m) is a cold-based glacier saddle in the Monte Rosa Group which has been extensively studied during the past few decades. In September 2003 two parallel cores were drilled to bedrock at a location where ice flow modeling indicated the greatest thickness of ice older than 500 years. The ice core chronology was obtained by combining results from annual

layer counting, dust stratigraphy, volcanic eruptions, tritium horizons and radiocarbon measurements which together demonstrated that ice older than 10,000 years is present near the bedrock.

The core has been analyzed for major ions, stable isotopes, heavy metals and plutonium at high resolution. A continuous record of 24 trace elements was obtained by coupling a novel on-line melting system with an inorganic mass spectrometer (ICP-QMS). Aliquots of melt water were on-line extracted by solid-phase cartridges for semi-continuous Polycyclic Aromatic Hydrocarbons (PAHs) analysis. These data represent the longest glaciological paleo-archives ever obtained in an ice core from the Alps and are integral in reconstructing the climatic and environmental conditions during the Holocene. Contact: barbante@unive.it

Historical record of European emissions of Polycyclic Aromatic Hydrocarbons since 1700s from an ice-core drilled at Colle Gnifetti, Monte Rosa Group (4450 m a.s.l.)

Jacopo Gabrieli, Carlo Barbante (UNIVE), Margit Schwikowski (UNIB), Paolo Gabrielli (OSU), Claude Boutron (LGGE)

The history of trace species (ions, heavy metals) pollution over the last centuries has been reconstructed from different alpine ice cores while trends of Persistent Organic Pollutants (POPs) are lacking in literature. Polycyclic Aromatic hydrocarbons (PAHs) are POPs originate mostly from anthropogenic combustion of organic matter and fossil fuels. The occurrence of PAHs in a firn/ice core drilled near Monte Rosa, covering the last three centuries was achieved by a continuous ice core melting system. Before 1875 the level of PAHs was very low with total mean concentrations lower than 2 ng/kg. During the initial Industrial Revolution (1770–1830) the PAHs deposition showed a weak increase which became much greater during later Industrial Revolution at the end of 19th century. In the 1920s, economic recession in Europe depressed industrial production, halving PAHs emissions until the 1930s when they increased again and reached a maximum concentration of 32 ng/kg in 1950s. From 1955 to 1975 the PAH concentrations decreased significantly reflecting improvements in emission controls while from 1975 to 2003 rose again to values equivalent to those of 1910s. The use of specific ratio Fla/(Fla+Pyr) indicates an increase in the relative contribution of gasoline and diesel combustion with respect to coal and wood in 19th century. This value has been increased in the last two decades probably due in part to the growth in the relative contribution of wood combustion has become very popular for domestic heating in many large cities.

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Mt Ortles as a new indicator of climate and environmental changes in the Tyrolean Alps

Paolo Gabrielli, Lonnie Thompson (OSU), Roberto Dinale, Michela Munari, Hanspeter Staffler (PAB-UI), Jacopo Gabrieli, Carlo Barbante (UNIVE), Luca Carturan, Giancarlo Dalla Fontana (UNIPD), Karl Krainer (UNINN), Hans Hausmann (UNIVI), Roberto Seppi (UNIPV-DST), Ludwig Noessig, Volkmar Mair (PAB-UG), Mark Zebisch, Claudia Notarnicola (EURAC), Michele Lanzinger (MTSN) Mt. Ortles (3905 m a.s.l., Trentino Alto-Adige, Italy) is the highest mountain of the Tyrolean Alps and its upper glacier Vedretta Alta, probably due to its difficult access, has never been investigated. This glacier may constitute a unique opportunity to obtain the first paleoclimate record from an ice core drilled in this untapped area of the Alps. In order to study the potential of Vedretta Alta as a drilling site, we performed the first preliminary study of its glaciological characteristics at 3830 m a.s.l. We measured snow, firn and ice thickness and we analyzed the shallow snow/firn layers. Finally we started to monitor the snow accumulation rate and the thermal behavior of the firn. The information obtained is useful in perspective of a future ice drilling operation. We have also in program a monitoring study of Vedretta Alta as strategic observatory of the current climatic and environmental changes at high altitudes in the Alps by monitoring the main meteorological parameters, the mass balance, the snow line with satellite imagery and the permafrost conditions on the adjacent deglaciated areas. Contacts: gabrielli.1@osu.edu, roberto.dinale@provincia.bz.it

ALPINE INVENTORIES

The 1999 and 2005 inventories of the Aosta Valley glaciers

Marco Vagliasindi (FMD-CRGV), Guglielmina Diolaiuti, Carlo D'Agata, Claudio Smiraglia (UNIMI-DST)

The most recent glacier inventories of the Aosta Valley Region (Western Alps), were realized in the framework of a cooperation between FMS and UNIMI-DST. The inventories, compiled according to the standards of the World Glacier Inventory, were based on 1999 and 2005 aerial photographs and orthophotos. A previous regional inventory (1975) was also available, thus allowing us to evaluate the glacier changes over the last 30 years. It resulted in 175 glaciers common to the three inventories covering, in 2005, an area of 136 km² (about 5% of the whole Aosta Valley territory), most of all concentrated in the three main mount massifs of the region: Mont Blanc (25%), Monte Rosa (18%) and Gran Paradiso (18%). Seven glaciers (among others Miage and Lys) were wider than 5 km². The comparison among the three data

records permitted to quantify the surface reduction: from 1975 to 2005 the Aosta Valley glaciers had lost ca. 27% of their area.

Inventory Information will be soon available to different kind of users through the official web site of Aosta Valley Region.

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The recent inventories of Lombardy glaciers

Guglielmina Diolaiuti, Davide Maragno, Carlo D'Agata, Claudio Smiraglia (UNIMI-DST), Daniele Bocchiola (POLIMI-DIAR), Anna Rampini (CNR-IREA)

In the framework of 'Quantification, Evaluation and Description of Lombardy glacier resource' projects (2004 and 2007) managed by IREALP and funded by Lombardy Region the most recent (1999 and 2003) Lombardy glacier inventories were compiled. The structure of the Regional Glacier database was realized by the CNR-IREA. The collection and analysis of glacier data was performed by the UNIMI-DST in cooperation with colleagues POLIMI-DIAR, who particularly investigated the relations among glacier changes and regional climate dynamics.

The most recent surface area records (1999–2003) were compiled by combining aerial photo analysis, Differential Global Positioning System (DGPS) surveys of glaciers and Geographic Information System (GIS) data processing. Moreover a previous regional inventory (1991 by SGL) was available thus permitting to evaluate the glacier changes over the last decade.

The total number of glaciers in Lombardy was 334 in 1991 (SGL, 1992), 340 in 1999 and 348 in 2003. The numerical increase is due to glacier fragmentation (i.e., the formation of two or more smaller separate glaciers from a former larger glacier) and reveals an ongoing phase of marked glacier reduction. A total of 249 glaciers were recorded in all three data series (1991, 1999 and 2003) and the respective data were compared and analyzed. Considering these 249 glaciers common to the three inventories, in 1991 they were spread over an area of 117.4 km²±0.8%; in 1999, the same 249 glaciers covered an area of 104 km²±0.3%, and in 2003 an area of 92.4 km²±0.1%. The total loss in glacierized area from 1991 to 2003 amounted to 25 km²±1%, equal to a loss of about 21% of the glacier coverage in 1991.

Moreover, the comparison between the mean yearly value of glacierized area lost over the entire period (1991–2003) and the yearly average calculated for the shorter period (1999–2003) clearly indicates a pattern of acceleration: the rate of retreat rose from -1.58 km²/y (average value for the 1991–1999 period) to -3.1 km²/y (average value for the 1999–2003 period); the mean yearly loss over the whole period (1991–2003) was

-2.11 km²/y. Data and maps are already available at the official web site of Lombardy Region. Presently an update of the variations by using the most recent orthophotos (2007) is ongoing. Contact: guglielmina.diolaui@unimi.it

The 1997 inventory of the South-Tyrolean glaciers

Roberto Dinale, Christoph Oberschmied, Michela Munari (PAB-UI), Christoph Knoll, Hanns Kerschner (UNINN-IG), Konrad Eder, Hermann Rentsch (TUM)

South Tyrol's glacier inventory was performed with a partnership between PAB-UI, UNINN-IG and TUM. During September 1997 all South-Tyrolean glaciers were covered by aerial images with the aim to create a new inventory of this region. These images were matched with digital photogrammetry techniques and the surfaces of the glaciers were analysed using an analytical stereoscope at TUM. Next UNINN-IG worked on the verification of the mapped shapes with the assistance of the 20x20 Mm DTM model of the year 2000 and applying GIS methods. The WGI standard metadata were computed for each glacier and some comparisons with the precedent inventory 1983 were performed. Another important task that was carried is the glaciers toponymy check. 259 glaciers were mapped with a total surface of 109,65 km². Estimating the mean glacier depth using the Maisch-approach (1999) results an ice volume of 3326 10⁶ m³. Since 1983 (14 years) the glacier surface retreat was of about 20%. The most part of the glaciers are located between 2660 and 3310 m a.s.l. The equilibrium line altitude for a zero net balance, i.e. a hypothetical steady state, of a theoretical 'South Tyrolean glacier' comprising the whole ice surfaces, lies at 2910 m a.s.l.

Assuming an ELA rise of 200 m due to global warming the future glaciers retreat would be of about 1/5 of surface. In case of a rise of 300 or 400 m, that means a temperature increase of about 3°C with unvarying precipitation, the surface reduction would reach respectively 50 or 80%.

Further inventory update is still planned because of the availability of a new LIDAR Laserscan model with 2.50 m raster resolution and of new aerial photos of 2006 and 2008.

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APENNINE GLACIERS

The strong reduction phase of the Calderone Glacier during the last two centuries: reconstruction of the variation with GIS technologies

Massimo Pecci (EIM), Leandro D'Alessandro (UNICH-DST), Claudio Smiraglia (UNIMI-DST)

Calderone, the southernmost glacier of Europe, is located almost in the exact centre of the Italian peninsula in the Gran Sasso d'Italia Massif. Characterized by a reduction phase since the end of the Little Ice Age, the glacier has been split into two ice bodies since the end of the Summer of 2000. A set of multidisciplinary studies started to evaluate the role of the glacier as indicator of the effects of human activities and finally of regional and global climate change. Several analysis were performed to evaluate the surface area and volume variations since the end of the Little Ice Age. Moreover the glacier surface morphology, analyzed in GIS environment and coupled with the geometry data of the bed rock (derived from Ground Penetrating Radar surveys), allowed the computation of the volume variations over time and their 3D-reconstruction. From these analysis since the end of the LIA up to 1990 it resulted an area loss of about 50,000 m² and a volume decrease of about 4 × 10⁶ m³.

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Long term mass balance of the Calderone Glacier (Central Apennine)

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Globally the 1995–2008 mass balance of the Calderone Glacier was negative, with a total cumulative loss of more than 5 m w.e. Nevertheless some exceptions were found in the hydrological years 1995, 1996, 2004, 2006, 2008 and 2009; these years were found characterized by positive mass balance data in strong contrast with the general trend affecting the largest part of Alpine glaciers. This peculiar trend can be attributed to a slight drop in local summer temperatures in the Gran Sasso area which was accompanied by a small increase in total winter snowfall (from about 5900 mm w.e. in the 1985–1994 period to about 6400 mm w.e. in the 1995–2003 period). Particularly snowdrifting and avalanche effect lead to redistribution of the snow, making longer its persistence; in fact, in the upper sector of the glacier at the end of the winter season 2006 and 2009 more than 10 m of cumulate snow were found thus driving the positive mass balance of those years.

In addition supraglacial debris was found covered a large part of the glacier surface thus reducing buried ice ablation. The debris coverage, which seems increasing during the last years, probably will make more difficult and at the end

will avoid the activity of ablation measurements through ablation stakes at the glacier lower sector. Therefore, DGPS (Differential Global Positioning System) and laser surveys will be also employed, with the aim of integrating traditional measurement methods at the glacier surface, in order to reconstruct the vertical changes and the ablation amount.

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Multitemporal radar survey for monitoring the evolution of the Calderone Glacier (Central Apennine)

Massimo Pecci (EIM), Claudio Smiraglia (UNIMI-DST)

The Calderone thickness has been recently evaluated by a ground-probing radar surveying, which also permitted to determine the bedrock morphology. The equipment included a GPR SIR 2 with a 40-MHz antenna. The comparison with data from a previous survey (1992) revealed a clear reduction of the ice near the terminal moraine and in the central part of the glacier. The current maximum thickness resulted to be about 27 m in the lower sector of the glacier.

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TROPICAL GLACIERS

Huascaran glaciers (Peru): Multitemporal and Geomorphological analysis

Valerio Bertoglio (PNGP), Luigi Perotti, Walter Alberto, Marco Giardino (UNITO-GSL)

The research group is working on the multitemporal analysis of the Huascaran massif (Cordillera Blanca, Peru). For this goal natural color stereo aero-photogrammetric images and infrared ones of 1972 and two Terra ASTER Satellite images of 2006 were acquired. The team have already performed a geomorphological survey in order to detect the landforms evolution in glacial and periglacial areas. A complete GPS survey will be made as soon as possible in order to have a sufficient set of Ground Control Points to permit the orientation of digital aero and satellite images. The aim is to produce a multitemporal comparison of the volume differences of the Huascaran ice cap during the last 40 years

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HIMALAYA-KARAKORAM GLACIERS

Glacier surface-area changes in Sagarmatha national park, Nepal

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The variations in the surface area of glaciers in Sagarmatha National Park, Nepal, during the second half of the 20th century have been analyzed, within the framework of the EvK2CNR Research Project in Himalaya and Karakoram, through the

comparison of maps of the late 1950s with the official map of Nepal in the early 1990s. The results reveal a slight overall decrease in glacier area (by 4.9%, from 403.9 to 384.6 km²), which, though subject to errors arising from cartographic elaboration and interpretation, is not so different from the area reductions found by other studies of Asian high mountain glaciers. We find that the areas of some individual glaciers, the largest situated at higher altitudes, increased during the study period. This was most apparent for the glaciers oriented to the south, with the increase occurring mainly in the glacier accumulation zones while the fronts tended to recede. Meanwhile, the smaller glaciers, situated lower and on steep basins, experienced a reduction. For the smaller glaciers, the sections most affected by change were the accumulation zones, and these glaciers showed a tendency for the front to advance. In this region there is a lack of climate data for high altitudes. Nevertheless, observations from stations situated around the park suggest that, alongside temperature variations which are often considered the primary factor eliciting glacier response, changes in precipitation play a significant role.

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The recent evolution of a surge-type glacier, Liligo Glacier, Karakoram, Pakistan

Claudio Smiraglia, Guglielmina Diolaiuti (UNIMI-DST), Marco Belò (TRI), Christoph Mayer (BAS)

Liligo glacier, in the central eastern Karakoram, Pakistan, is a small, south-to-north-flowing glacier situated in a transverse valley on the left (south) side of Baltoro glacier. Terminus variations of Liligo Glacier since 1892 were reconstructed, within the framework of the EvK2CNR 'Scientific and Technological Research in Himalaya and Karakoram' project, using various methods and sources (historical documents, cartography, photographs, satellite images and field surveys). The glacier is characterized by two phases of strong advance (beginning and end of the 20th century), separated by at least half a century of retreat. The advance rates, together with some ice-surface features such as the heavily crevassed surface and terminus morphology, are considered to be indicative of a surge-type glacier. New processing of satellite imagery enables a better quantification of terminus oscillations over the past 30 years. From the beginning of the 1970s to the beginning of the 21st century, Liligo glacier advanced about 2 km (60m a⁻¹). The progress was characterized by a significant evolution of terminus morphology, similar to that observed on the same glacier during the advance event near the beginning of the 20th century, and to those of many other Karakoram glaciers. This suggests indications of a surge-type mechanism.

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Ablation conditions on Hinarche Glacier in the Bagrot Valley, Karakoram, Pakistan

Christoph Mayer (BAS), Astrid Lambrecht (UNINN-IMG), Claudia Mihalcea, Guglielmina Diolaiuti, Claudio Smiraglia (UNIMI-DST), Marco Belò (TRI), Furrukh Bashir (PMS)

Glacial melt water is an important resource in the Karakoram and even more important in a protected area like CKNP, calling for detailed and well designed management. To establish a baseline for future monitoring and as a contribution to an inventory of ice and water resources in CKNP, a study on the specific melt conditions has been carried out on a medium size, debris covered glacier. Debris covered glaciers are largely present in the Karakoram and their role as a water source has been only partially investigated so far. The area chosen for the investigations is the Bagrot Valley and field work focused on the ablation tongue of Hinarche Glacier. Hinarche Glacier and its tributaries provide an essential part of the water utilized in Bagrot Valley, especially during the dry season. During the main ablation season 2008 a comprehensive data set on the glacier morphology, energy and mass exchange and on surface velocity has been collected within the framework of the HKKH-IUNC projects sustained by EvK2CNR. These data are of fundamental importance for validating further modelling approaches which will be developed to evaluate the ongoing glacier changes on the entire glacier and to project the future evolution under different climate change scenarios. The investigations took place on the 9 km long main glacier tongue in order to obtain information representative for the ablation zone. Contact: Christoph.Mayer@lrz.badw-muenchen.de

Spatial distribution of debris thickness and melting from remote-sensing and meteorological data at debris-covered Baltoro glacier, Karakoram, Pakistan

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In the framework of a EvK2CNR project focused on Karakoram, a distributed surface energy-balance was performed to determine sub-debris ablation across a large part of Baltoro glacier, a wide debris-covered glacier in the Karakoram range, Pakistan. The spatial distribution of the physical and thermal characteristics of the debris was calculated from remote-sensing (ASTER image) and field data. Meteorological data from an automatic weather station at Urdukas (4022 m a.s.l.), located adjacent to Baltoro glacier on a lateral moraine, were used to calculate the spatial distribution of energy available for melting during the period 1–15 July 2004. The model performance was evaluated by comparisons with field measurements for the same period.

The model resulted reliable in predicting ablation over wide debris-covered areas. It underestimates melt rates over highly crevassed areas and water ponds with a high variability of the debris thickness distribution in the vicinity, and over areas with very low debris thickness. We also examined the spatial distribution of the energy-balance components (global radiation and surface temperature) over the study area.

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Glaciological investigations on the Urdok Glacier, Karakoram

Christoph Mayer (BAS), Astrid Lambrecht (UNINN-IMG), Claudia Mihalcea, Guglielmina Diolaiuti, Claudio Smiraglia (UNIMI-DST)

In 2006 glaciological investigations have been carried out on Urdok glacier in the northern part of Karakoram. The measurements aimed at comparing ice melt of debris covered glaciers on both sides of the Karakoram divide in the framework of the project Ev-K2-CNR. The glacier tongue is completely covered by a thick debris layer and thus comparable to the lower tongue of Baltoro glacier, further to the West. The results from stake readings, weather data and in situ debris temperature measurements reveal rather similar conditions for sub-debris ice melt. Based on a period of parallel weather data records at both glaciers it is now possible to estimate the mass loss on the glacier tongue using the data from the Urdukas climate station close to Baltoro glacier. In addition, accumulation studies in the higher part of the glacier revealed a detailed record of precipitation events which could be linked to general circulation patterns.

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Impact of atmospheric absorbing aerosol on high Himalayan glacier melting: the Changri Nup Glacier (Nepal, Himalaya) study

Elisa Vuillermoz, Gianpietro Verza (EVK2CNR), Angela Marinoni, Paolo Bonasoni (CNR-ISAC), Guglielmina Diolaiuti, Claudio Smiraglia (UNIMI-DST)

Within the EvK2CNR Project SHARE (Stations at High Altitude for Research on the Environment) on February 2010 an Automatic Weather Stations (AWS) has been installed on the debris-free surface of the Changri Nup Glacier (Nepal, Himalayas) at 5,700 m a.s.l.. The AWS is acquiring meteorological data and energy fluxes (incoming and outgoing) at the glacier surface. The data will permit the calculation of the glacier energy balance and the high resolution analysis of glacier albedo. During the field campaign, ablation stakes have been positioned and snow samplings have been carried out as well. The ablation stakes will allow the evaluation of glacier ablation thus permitting a useful comparison with the melting amount derived from the energy

balance measurements. The snow samples, which are planned to be acquired periodically by the EvK2CNR scientists over the next months, will be analyzed to quantify the presence of atmospheric absorbing aerosols (e.g. black carbon, soil dust). The latter was found to play a key role in varying snow and ice albedo and in driving glacier ablations on several high elevation Himalayan glaciers. In this experiment, by coupling energy data (from the AWS) with the results from snow sample chemical analysis, will be possible to investigate the relations among atmosphere and cryosphere and to quantify the impacts, if any, of atmospheric dust and/or black carbon deposition on the Changri Nup ablation rates. Furthermore, the obtained results will be correlated with the atmospheric observations carried out at the Nepal Climate Observatory-Pyramid (NCO-P) located at 5079 m a.s.l. near the Pyramid Laboratory Observatory.

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POLAR GLACIERS AND ICE SHEETS

European Project for Ice Coring in Antarctica (EPICA)

Valter Maggi (UNIMIB) (EPICA Italian Representative) and Italian EPICA Team

A European/EU collaboration for drilling ice cores in two sites in the East Antarctic plateau aims to depict the climate history of Earth. Dome C (EDC, 75°06'S, 123°21'E) in the Pacific Ocean sector, and Dronning Maud Land (EDML 75°00'S, 00°04'N) in the Atlantic Ocean sector provide respectively 800,000 years and 150,000 years of atmospheric records.

The Italian activities were was strongly involved in the EDC ice core, with logistic, technical and scientific purposes. From 1996 to 2005, during the building-up of the Italy–France overwinter Concordia Station, EPICA project used the facilities of Mario Zucchelli Station (Italian coastal station) and Dumont D'Urville (France coastal station) and the support of PNRA (Italian Antarctic Programme) and IPEV (French Antarctic Programme) for reaching Dome C and for drilling a 3.260 m deep ice core (drilling stopped several meters above the bedrock). At EDML, the German Alfred Wegener Institute (AWI) coordinated the activities, while Italy provided people for in-field activities. Atmospheric dust (fine particles and tephra), chemistry (ions and trace metals), stable isotopes (O and H), remote sensing (radar), and drilling technology represent the main activity activities where Italy is involved, through about ten research groups from six universities and three research institutions. The international collaboration inside the EPICA project received funding from the EU and from national funding systems,

and allowed us to join scientific efforts in creating a European science network for science activities and data integration, as demonstrated by more than 200 articles published in peer-review journals. In 2007 the EPICA project was awarded the Descartes Prize for Collaborative Research, the prestigious EU scientific prize.

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Surface mass balance of Dome C and Talos Dome drainage area

Massimo Frezzotti (ENEA), Silvia Becagli (UNIFI), Anselmo Cagnati (ARPAV-CVA), Barbara Stenni (UNITS), Stefano Urbini (INGV), Luca Vittuari (UNIBO-DISTART)

Snow accumulation is one of the most direct climate change indicators and has important implications for ice-sheet mass balance and palaeoclimatic reconstruction from ice cores. In the convergence slope/coastal areas of Antarctica, a large fraction of snow is continuously eroded and exported by wind to the atmosphere and into the ocean. Wind-driven processes are fundamental components of surface mass balance. The extreme environmental conditions and remote location of Antarctica have long inhibited the systematic study of its climate and snow accumulation processes. Measurement of blowing snow in Antarctica is very difficult and limited and data are only available for a few sites. Blowing snow transport and erosion data detected by instruments, snow radar profiles, firn cores, stakes and satellite images were acquired in East Antarctica. Spatial variations in accumulation are well correlated with surface slope changes along the prevalent wind direction. Extensive presence of ablation surface (blue ice and wind crust) upwind and downwind of the measurement site suggest that the combine processes of blowing snow sublimation and snow transport remove up to 50% of the precipitation in the coastal and slope convergence area. These phenomena represent a major negative effect on the snow accumulation and, till now, they are not sufficiently taken into account in studies and simulation of surface mass balance. The observed wind-driven ablation explains the inconsistency between atmospheric model precipitation and measured snow accumulation value. Temporal variability of accumulation over the last two centuries shows no significant increase in accumulation in Dome C and Talos Dome drainage area. Observations of time/source variability of precipitation and of redistribution/sublimation process are studied for improving the climate and meteorological models and for studying post-depositional losses of chemical species by re-emission and snow metamorphism.

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TALos Dome Ice CorE (TALDICE)

Massimo Frezzotti (ENEA), Carlo Barbante (UNIVE), Valter Maggi (UNIMIB), Barbara Stenni (UNITS), Roberto Udisti (UNIFI), Stefano Urbini (INGV)

The TALos Dome Ice CorE (TALDICE, www.tal-dice.org) is a European ice core research project (Italy, France, Germany, Switzerland, UK) aimed at retrieving an ice core reaching back through the previous two interglacials (about 250,000 years), from a peripheral dome of East Antarctica. The Italian Antarctic Programme provided logistical support. TALDICE ice core analysis contributes to decipher climate change mechanisms and will help to explain past, present and future climate trends. The results obtained at Talos Dome will complement, verify, and augment the palaeorecords collected at the 'near-coastal sites' EPICA-DML, Berkner Island, Taylor Dome, Siple Dome and Law Dome DSS etc., and at other Antarctic deep drilling sites (EPICA-Dome C, Vostok, Dome Fuji). As such, it would be a significant contribution to the International Partnerships in Ice Core Sciences 40,000 years network: a bipolar record of climate forcing and response. Deep drilling, using Berkner Island drill system, started during the 2004–05 austral summer season and successfully reached a depth of 1620 metres during the 2007–08 season. Talos Dome is located in the Ross Sea sector, about 250 km from ocean, 550 km north of Taylor Dome and 1100 km East from the Dome C drilling site. The TALDICE coring site (159°11'E 72°49'S; 2315 m elevation; annual mean temperature –41°C) is located near the dome summit and is characterized by an annual snow accumulation rate of 80 mm water equivalent. Given the relatively high accumulation rate at Talos Dome when compared to sites from the East Antarctic Plateau, the uppermost 900 m of the TALDICE ice core preserve a decadal resolution climate record spanning the Last Glacial Maximum to Holocene climate transition. Termination lies at 800 m depth that is only 50% of the total ice thickness.

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Paleoclimate and paleoenvironment from the study of Antarctic ice cores (EDC, EDML, TALDICE)

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In order to improve the currently available predictive climatic models, a better knowledge of the interactions between forcing factors and environmental responses occurring in the past, likely involving complex feedback processes, is mandatory. Several issues are yet poorly understood; among them, the factors affecting the glaciation–deglaciation transitions, defining the processes able

to lead and to maintain stable interglacial stages and understanding the tele-connections between climate and atmospheric and oceanic circulations.

The availability of continuous, high-resolution stratigraphies of climatic and environmental markers from Greenland and Antarctic ice cores can help to untangle this plot. So far, they have allowed the observation of the huge glacial/interglacial sequences occurring at orbital timescales as well as the climate changes at millennial scale occurred in the last glacial period. The whole chemical records from EDML (EPICA – Dronning Maud Land), EDC (EPICA – Dome C) and TALDICE ice cores (TALos Dome Ice CorE) have highlighted some relevant features. For instance, the record of non sea salt Ca, taken as marker for terrestrial material, has shown that very major changes in the climatic conditions in southern South America over glacial-interglacial transitions must have occurred. Moreover, the flatness of non sea salt sulphate flux across the entire 800 kyr, despite the huge climate changes taking place, suggests a surprising constancy in marine biogenic production. Although sea ice surface is thought to be a significant contributor to sea salt in central Antarctica, it has also been recognized that the response falls off strongly at large ice extents, therefore the proxy (which still requires a good model calibration) is most useful under moderate or interglacial conditions. In this respect, we have pointed out that an exceptionally low sea ice extent must have played an amplifying role in the unusually high temperatures of the last interglacial.

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Paleoclimate and evolution of Antarctic cryosphere from the study of pleistocene sediments in the ANDRILL AND-1B drillcore

Roberto Udisti, Silvia Becagli, Costanza Ghedini, Francesco Rugi, Mirko Severi, Rita Traversi (UNIFI-DC)

The main target of ANTArctic Geological DRILLing Program (ANDRILL) is to determine past ice shelf responses to climate forcing, including variability at a range of timescales. To achieve this goal, 1200 m of glaciomarine, terrigenous, volcanic, and biogenic sediments have been extracted on the northwest corner of the Ross Ice Shelf: the McMurdo Ice Shelf (MIS) sector, east of Hut Point Peninsula, Ross Island. This site is located at a critical juncture between components of the West Antarctic Land Basin (VLB), the Transantarctic Mountains (TAM) and the Erebus Volcanic Province. It is one of a limited number of locations that have been influenced by three significant components of the Antarctic cryospheric system: East Antarctic Ice Sheet (EAIS), Ross Ice Shelf (RIS)/WAIS, and Ross Embayment sea-ice.

The first 90 m of ANDRILL AND-1B drillcore have been analysed by an integrated ICP–SFMS/

ICP–AES system in order to quantify 39 major and trace elements (including rare earth elements – REE). Preliminary interpretation of the obtained dataset relative to geochemical composition of sediments deposited during the last Ma at the MIS site suggests different rock sources for the material deposited before and after about 0.45 Ma BP, with the oldest sediments showing a composition more similar to that typical of trans-Antarctic mountains and the youngest showing characteristics close to McMurdo volcanic rocks composition. This variation of composition could be linked to the Mid-Brunhes Event (MBE), a climatic discontinuity dated 430 kyr BP, which marks the boundary between two different global climatic conditions, with the youngest layers characterized by a larger temperature gap between short and warm interglacials and long and cold glacials, with respect to the oldest part. Statistical procedures (e.g. principal component analysis) will be tested on the whole data-set in order to support this hypothesis.

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Aerosol/snow study at Concordia Station (Dome C, central East Antarctica) – present-day aerosol transport processes and tools for interpretation of ice core data

Roberto Udisti, Silvia Becagli, Costanza Ghedini, Francesco Rugi, Mirko Severi, Rita Traversi (UNIFI-DC)

Ice core stratigraphies of chemical components of atmospheric gases and aerosols trapped in the snow layers by scavenging processes are a powerful tool in understanding past climatic and environmental changes. Though the basic features of glacial and interglacial periods are well known by high resolution isotopic, physical and chemical records from East Antarctic ice cores (especially from EPICA Dome C ice core, spanning the last nine glacial cycles), several issues are still highly debated. In particular, the role of biogenic activity in controlling the climate by feedbacks on CO₂ uptake and cloud coverage, the relevance of sea ice extent in revealing superficial sea-water temperature and albedo variations, and the effect of hydrological cycle of southern-hemisphere continental areas in controlling atmospheric load and composition of mineral dust. These interpretative difficulties are made more complex by the occurrence of post-depositional processes at the atmosphere-snow interface and in shallow snow and firn layers, which can perturb the air-snow transfer function of chemical species and complicate the interpretation of their stratigraphies in terms of past environmental and climatic conditions.

In order to better address such controversial issues, since 2005, a continuous, high temporal resolution size-segregated aerosol and surface snow sampling has been performed at Dome C, in the framework of ‘Station Concordia’ Project. The

chemical analysis of size-segregated aerosol, collected all year-round for more than 4 years, can contribute to clarify on timing and relevance of the different aerosol sources and transport processes. Moreover, the analysis of chemical markers in aerosol, superficial snow and hoar crystals, sampled contemporaneously, will allow to understand the key factors (e.g., snow acidity, solar irradiation) affecting the preservation of components reversibly fixed in the snow layers (such as methanesulphonate, nitrate and chloride).

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Inventory of local or ‘Alpine’ glaciers in Northern Victoria Land (Antarctica)

Guglielmina Diolaiuti, Claudio Smiraglia (UNIMI-DST)

The so-called ‘local’ or ‘Alpine’ glaciers are very diffuse in Antarctica along the coastal areas. They are isolated and independent of ice flowing down from the plateau and their mass balance is mainly controlled by sublimation and aeolian erosion and accumulation. The glaciers closest to the coast undergo dry calving and melting. The most known local Antarctic glaciers are found in the Dry Valleys, but they are also diffuse in the Northern Victoria Land coastal region. By collecting data from satellite images, aerial photographs and field surveys a first group of twelve local glaciers was identified from Mount Joyce to Cape Hallet. A data sheet with the main morphometric characteristic was prepared.

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Recent evolution of the local glaciers: the case of the Strandline Glacier, Northern Victoria Land, Antarctica

Guglielmina Diolaiuti, Claudio Smiraglia (UNIMI-DST), Michele Motta (UNITO-DST), Giorgio Vassena (UNIB-DICATA)

Seasonal variations on Strandline Glacier, Terra Nova Bay, northern Victoria Land, Antarctica, obtained from field measurements during two campaigns have been performed. It was possible to calculate summer changes in thickness (mean decrease over the whole glacier surface of 0.04 m w.e.) and in volume (decrease of 352 m³ at the terminus). Numerous are the processes responsible for these variations (e.g. melting, evaporation, wind erosion/deposition and dry calving). This last revealed to be the most effective one, by causing at the terminus ice cliff at the terminus a summer retreat rate of about 1 m week⁻¹ in the central part of the front.

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Newly formed glacial lakes in Aosta Valley (Italy)

Alex Théodule (FMS-CRGV), Germain Bal, Alberto Godio (POLITO)

For the last three decades, several glacial lakes have been forming due to increasing glacier reduction. Glacial lakes could give origin to sudden outburst (the well known GLOF phenomena), thus representing hazardous elements in glacierized areas in addition to other glacier hazards. Firstly, an analysis of all the available literature has been carried out in order to describe the state-of-the-art in this topic and to know methods and techniques to be applied for classifying glacial lake hazard on the basis of lake morphological and environmental elements.

Then, to list the more recently formed (after 1975) glacial lakes and to assess, if any, conditions of outburst hazard (considering also impacts and damages on the lower lands), a glacial lake inventory has been compiled in 2009. The analysis, based on orthophotos, satellite imagery (SPOT 2009) and field surveys, allowed to detect more than 120 newly formed glacial lakes. Furthermore, in order to detect englacial or subglacial water ponds which cannot be directly observed, geophysical investigations were performed on a sample glacier. In addition, a collection and analysis of historical data allowed to identify glaciers recurrently subject to GLOF events in the past.

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Hydrology of debris covered glaciers: case study Venerocolo Glacier, Adamello

Daniele Bocchiola, Maria Cristina Rulli, Renzo Rosso (POLIMI-DIIAR), Guglielmina Diolaiuti, Claudia Mihalcea, Boris Mosconi, Claudio Smiraglia (UNIMI-DST)

In the framework of the Project CARIPANDA managed by the Adamello Regional Park and funded by Fondazione Cariplo, an investigation on the hydrology of the Venerocolo Glacier (Adamello Group, Lombardy Alps) has been carried out. We coupled field surveys of glacier climatology, ablation and stream flows during thaw season with use of historical hydrologic and climatic data base to develop energy based models able to simulate complex ice melt upon debris covered glaciers, and hydrological models able to mimic hydrological cycle therein (case study Venerocolo Glacier, Adamello Group). We developed and tested a daily (semi-distributed, with altitude belts) model coupled with a simple debris cover driven degree day ablation model for long term simulation of runoff, well performing against four years of estimated in stream discharges as from pool level reservoirs' routing. Also, we developed a event based distributed hourly hydrological model, cou-

pled with a more refined finite difference energy balance ablation model upon debris cover, able to describe spatial complexity of ablation patterns on the glacier. This was validated against in stream measured (using a 3D wading flow tracker) hourly discharges, with good results. These models will be then used for projections of future hydrological cycle, based upon climatic forcing from GCMs. Contact: daniele.bocchiola@polimi.it

Monitoring of in stream discharges from mountain glaciers (Dosedè Glacier)

Daniele Bocchiola (POLIMI-CIMI), Guglielmina Diolaiuti, Claudio Smiraglia (UNIMI-DST)

In the framework of the 'Water & Glaciers' Project funded by San Pellegrino-Levissima Spa, the in-stream discharges from a mountain glacier (Dosedè Glacier) in the Dosedè-Piazzini group has been analyzed. We carried out design, setting up, and operation of a hydrometric station based upon piezometric pressure, gauging within the catchment of a mountain bare ice glacier (Dosedè, Valtellina Valley), to measure thaw discharge for the year 2009. We calibrated a stage-discharge equation using a wading 3D flow meter, so allowing discharge estimation from stream stage. The measured discharges will be coupled to AWS meteorological variables and snow and ice ablation measurements within the Dosedè glacier area to validate hydrological budget therein. The so calibrated hydrological models will then be fed projected future climate from GCMs (plus downscaling) to depict future expected hydrological cycle and mass budget of the glacier.

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Impact of climate change upon water budget in glacierized areas

Daniele Bocchiola (POLIMI-DIIAR), Guglielmina Diolaiuti (UNIMI-DST)

The recognized evidence of global warming demands assessment of water resource from the cryosphere in temperate regions, and more challenging foresight of its destiny, including potential extinction of permanently glacierized areas, and the tremendous impact on the Alpine environment. Therefore, importance of hydrological cycle in high altitude glacierized catchments in temperate regions is paramount. Within this research line we used statistical techniques to address the presence of observable effect of climate change upon atmospheric feeding to hydrological cycle within high altitude Alpine areas of Italy (i.e. Adamello Glacier). We studied rainfall, temperature and snowfall and we found significant trend in time (from 1967 onward), as well as significant dependence against indexes of general circulation, e.g. NAO.

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Calving phenomena at the Miage Glacier (Mont Blanc)

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The Miage Lake is an Italian ice-contact lake where calving phenomena have been occurring since the end of the 18th century. The Miage calving was studied in recent years in the framework of a cooperation between Italian and Scottish scientists supported by the British Council, the CRUI and the NERC organizations. Several field campaigns were carried out, starting from summer 2002 up to now. Moreover the project took advantage of the 2003 and 2005 COFIN-PRIN projects. Our research covers rates and processes of freshwater calving at Miage Glacier (Mont Blanc Massif, Italy). Field surveys identified the main processes leading to iceberg production and quantified the calving losses over a summer season. Calving losses were compared (1) with the surface ablation of the debris-covered tongue, evaluated through a simple model based on measured ablation rates at different altitudes and debris cover thicknesses, and (2) with other inputs to the lake (stream inflow discharge) and with the lake volume. Results show that thermal undercutting by warmer surface water plays an important role in driving ice-cliff evolution. Thermal notches grow at ca. $30\text{--}35\text{ m a}^{-1}$ and cause a similar amount of cliff retreat. Calving contributes ca. 2% of the estimated summer runoff from the debris-covered part of the ablation zone, but this is equivalent to ca. 38% of the lake volume, and is of the same magnitude as the mean discharge from the inflow streams. These data indicate that calving of the ice cliff is one of the main water sources for maintaining the lake at the maximum summer volume, with the surface at the level of the subaerial outlet stream. A recent survey of Italian calving glaciers shows that calving is becoming more widespread, and that debris covers are present at all calving ice margins. The lake-ice interactions described in this project can, therefore, be considered to have wider relevance.

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Hydrological characterization of the Miage Ice-Contact Lake (Monte Bianco, Italy)

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The project was developed in the framework of the 2005 COFIN-PRIN project.

The Miage ice-contact lake is characterized by rapid drawdown episodes that have occurred with varying frequency in the lake's history. The emptying episode of September 2004 gave the

possibility of performing many activities, up to the filling phases which occurred during spring and summer 2005. In situ tests and measurements and laboratory tests lead to a reliable reconstruction of the path of water recharge and draining and to the development of a numerical model of unsaturated-saturated groundwater flow to evaluate natural losses through the lake bed sediments. Results show that material at the bed of the lake has a low permeability and can be responsible for water losses of a few litres per second, very far from the discharge calculated during the rapid drawdown episodes. These results gave the experimental and numerical evidences to support the hypothesis that identifies sudden and temporary failure in the ice floor as the only possible cause of the rapid draining events historically occurred in Miage Lake. In the monitoring period the hydrological balance has also been assessed to evaluate the factors affecting the main recharge phase of the year. Calving was found to be the most important factor contributing to recharge, followed by direct melting and precipitation while water losses occurring through the lake bed sediments and evapotranspiration are much smaller even if not negligible.

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Hydrological balance of the Miage glacier basin

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The project was started within the framework of the 2005 COFIN-PRIN project, and now is performed under the umbrella of the 2008 COFIN-PRIN project.

The aim of the project was the calculation of the hydrological balance of the Miage Glacier basin (Mont Blanc, Aosta Valley, Italy), c. 24 km^2 wide. Miage debris-covered glacier, at 10.7 km^2 the third largest Italian glacier, stretches from 1780 m at its terminus to Mount Blanc Peak (4810 m a.s.l.). The debris-covered area is 2.9 km^2 , the debris-free sector covers 7.8 km^2 . The ratio glacier surface/basin surface is 0.44. In 2006 two different methods were applied: a glaciological approach (by measuring ablation rates and by applying a simple distributed ablation model) and a hydrological method founded on river discharge measurements performed during summer months. The first data available showed the largest ablation amount (61%) to occur on the bare ice sector. Moreover the hydrological approach showed that a large part of the basin runoff was due to glacier ablation (c. 52%). The glacier ablation calculated by hydrological approach and the glacier ablation evaluated through the distributed ablation model resulted in good agreement, the small discrepancies are probably due to the simplifications we applied particularly regarding snow melt amount. Moreover since winter 2007

a permanent AWS was located at 3430 m a.s.l. (in the framework of the SHARE-Italy program) to measure snow accumulation and then to evaluate its contribute to spring and summer meltwater river discharge for improving the hydrological balance computation. The next project step to be performed in summer 2010 in close cooperation with the colleagues from UNIDUN-SSES, from FMS and from POLIMI-DIAR will be the installation of a hydro-metric station based upon piezometric pressure gauging. This will permit continuous measurements of glacier melt river discharge thus further improving our computations.

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Glacial lake surface-area changes in the Sagarmatha National Park, Nepal

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In the framework of the EvK2CNR Research Project in Himalaya and Karakoram, the recent (end of the 20th century) surface area changes of lakes in the north-eastern sector of the Sagarmatha National Park (SNP, Nepal) have been analyzed by comparing maps in a GIS environment. More precisely the Mount Everest maps (based on a survey done in the early 1980s) and the official Map of Nepal (based on a survey performed at the beginning of the nineties) have been analysed and compared. The analysis of the changes occurred in lake surface area and distribution showed that lake areas in this park sector substantially increased of about 15%, in particular in the case they were located in hydrographic basins including glacier coverage. In fact, 96% of the lakes whose surface area increased were situated in glacierized basins.

Conversely, the majority of the lakes not owing to glacierized basins showed a reduction in surface area, and in many cases disappeared (83% of the lakes that disappeared were located in basins without glaciers). The project permitted also to produce a digital tool named LIS (Limnological Information System) which provides a useful platform for extending the analysis to the whole SNP, as well as for subsequent comparisons based on earlier maps or more recent satellite images.

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APPLIED GLACIOLOGY

'Glacier Trails', an experience for the knowledge and the promotion of the high mountain environment

Claudio Smiraglia, Guglielmina Diolaiuti (UNIMI-DST)

The Glacier Trails, a particular kind of naturalistic trail, are an original means of passing on knowledge about geomorphology and glaciology of the high mountain environment and especially

about the fast ongoing evolution of glacial and periglacial landscape. The trails provide for learning 'in the field' and are usually equipped with specific signs indicating the positions of the glacier termini during the various period of glacier evolution, as well as signs explaining the different morpho-glacial evidences. That is the case of the well known trail of the Morteratsch Glacier in the Bernina Massif, Switzerland Alps. On the Italian Alps the first trail was organized on Ventina Glacier (Disgrazia-Bernina Massif) in 1992 by the SGL. One of the most interesting and frequented path is surely the Forni Glacier Trail on the Lombardy Alps (Ortles-Cevedale massif), realized by the CGI in 1995. This trail was addressed to a select tourist type because it required knowledge of the basic techniques of walking on a glacier. During the last years the strong retreat of the glacier terminus and the accelerate melting of the ice core of the lateral moraines destroyed some parts of the trails and made the path more difficult and dangerous. In the last summer, also by building some new light bridges crossing the glacial streams, the Forni Trail was renewed and opened again, thus allowing all the tourists to appreciate directly the new landscapes and morphologies of the just deglaciated terrains.

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Glaciers as geomorphosites: identification and evolution. Some examples from the Lombardy Alps

Claudio Smiraglia, Guglielmina Diolaiuti (UNIMI-DST)

Alpine glaciers are important in terms of environmental and economic systems. The rapid 'disintegration' of Alpine glaciers has already been discussed in previous studies; less attention, however, has been paid to their role as changing and potentially vanishing geomorphosites.

Most Alpine glaciers, in fact, subject to rapid change driven by climate, are now responsible for unexpected environmental impacts, which in the Italian Alps have only been partially investigated. This project, performed in the framework of the 'Water and Glaciers' program funded by San Pellegrino-Levissima Spa, analysed and discussed features and evolution in two representative glacier geomorphosites included in the official 'Geosites Inventory' of the Lombardy region (Italy). The geomorphosites analyzed are the Forni Glacier, the largest valley glacier in the Italian Alps, and the Val Viola glacierized basin, where various small glaciers with well preserved moraine ridges (dating from the upper Holocene to the present) can be found.

Both the geosites are located in areas identified as 'Sites of Community Importance' (SCI) under directive 92/43/EEC; furthermore, the Forni Glacier is also located in a protected area, the Stelvio National Park. These glacier geomorphosites represent well the variations affecting all Alpine gla-

ciers; these variations are not only driving significant changes in the morphology and ecology of the present mountain landscape, but at the same time are shaping newly formed morphologies, which may develop into smaller geomorphosites with significant value from a scientific and cultural point of view. The changes include thermokarst features such as kettles and supraglacial lakes, debris-covered glacier tongues frequently without any direct connections with the actual glacier, rounded rock outcrops emerging from the glacier surface which increase ice melting and accelerate glacier shrinkage, ice contact and moraine-dammed lakes where calving phenomena occur and icebergs drift loose, moraines affected by ice core melting with subsequent collapse and generation of mud and debris flows.

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Italian glacier geomorphosites evolution

Manuela Pelfini, Irene Bollati, Valentina Garavaglia (UNIMI-DST)

Glaciers defined as glacial geomorphosites are affected by intense shrinkage and new territories are progressively suitable for studies and valorization. Landforms related to glacial erosion and deposition are visible at different scales and the consequences of climate change on vegetation are also evident. Research on glacier geomorphosites evolution is significant not only for defining their scientific attributes through its 'model of evolution' and didactic exemplarity valences but also for glacial geomorphosites additional values like cultural and aesthetic ones. A recent realization of a database allows us to quantify glacial geomorphosites attributes; detailed researches on sample glaciers allowed to underline the ecological value represented by supraglacial and proglacial trees as recorders of glaciological data (Miage and Belvedere glaciers), the role of tree vegetation living on moraine system or buried in till as an instrument for glacier fluctuation reconstruction and as an educational tool (Marlet, Forni glacier); the role of the proglacial areas as an important part of complex geomorphosites or of geomorphological landscapes (Forni and Verra glaciers).

The results highlight the importance of monitoring geomorphosites evolution and degradation for tourist promotion, for educational purposes and for risk assessment in tourist areas.

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The recent evolution of an Alpine glacier used for summer skiing (Vedretta Piana, Stelvio Pass, Italy)

Guglielmina Diolaiuti, Claudio Smiraglia, Manuela Pelfini (UNIMI-DST), Marco Belo (TRI), Mauro Pavan (UNIGE-DIPETERIS), Giorgio Vassena (UNIBS-DICATA)

In Europe, the Stelvio Pass (2757 m a.s.l.) glacier area is a popular zone for summer ski activity;

summer skiing has been practiced there since the beginning of the 20th century. The effects of human impact on this kind of glacier was poorly known up to recent years when a project was funded by the Stelvio National Park. In the Stelvio Park area, volume and thickness variations in a sample glacier (Vedretta Piana, Stelvio Pass) were quantified through a comparison of large-scale maps (1955–1981) and field surveys (by GPS in RTK techniques during summers 1999, 2000 and 2001). A thickness increase on the larger part of the glacier profile was evident from 1955 to 1981, maximum value of +10 m. In the subsequent period (1981–1999), a strong reduction was evident, maximum of about –30 m. The field surveys performed on two following summer seasons allowed also to calculate the glacier volume variations resulted equal, for summer 1999 to –442,000 m³ w.e. (mean thickness variation of about –0.8 m) and for the summer 2000, to –606,000 m³ w.e. (mean thickness variation of about –1 m). Moreover the seasonal investigations revealed pattern and distribution of snow accumulation on Vedretta Piana Glacier to be strongly influenced by ski activities. In addition on this glacier, geophysical surveys by GPR techniques have also been performed allowing the calculation of the ice thickness and of the glacier ice volume (72.5×10^6 m³). Attention was also paid to the historical evolution of the glacier human-use by analyzing the number of infrastructures located on the glacier (especially lifts and their capacity) and the number of customers (largely skiers) using the lifts with a special focus on two summer seasons (2000 and 2001 summer seasons), trying to relate these data with glacier seasonal surface evolution (crevasses presence and snow cover persistence and distribution) and with the summer climate trends. The results underline that the climate conditions of summer of 2001 was more favourable for summer ski activities. An increase in the number of skiers was in fact evident for the 2001 summer (+21%); this datum is an exception respect to the general Italian trend of the last decade which underline an uninterrupted decline of Alpine skiers (–35% in the year 2004 respect to the year 1997).

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Strategies to reduce snow and ice ablation: investigations at the Dosdè East Glacier (Lombardy Alps)

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On Dosdè Est Glacier (Upper Valtellina, Italy) investigations to reduce snow and ice ablation were performed between May and October 2008 and between June and October 2009 in the framework of the 'Water & Glaciers' Project funded by San Pellegrino-Levissima Spa. In summer 2008 on this

Alpine glacier (ca. 1 km² of area, North aspect) a cover of Ice protector® was spread on a glacier surface 150 m² wide at an elevation of about 2800 m a.s.l. The experiments were performed close to an Automatic Weather Station located at the glacier surface (AWS Dosdè Levissima). The AWS permits the collection of meteorological data and energy fluxes fundamental to calculate the glacier energy budget. At the end of the 2008 ablation season on the glacier area without artificial cover, a snow ablation of 1.29 m water equivalent (w.e.) and an ice ablation of 1.05 m w.e. resulted; the glacier surface protected with the cover instead was affected only by snow ablation and its magnitude was lower than in unprotected areas: there was a snow loss equal to 0.73 m w.e. and no ice ablation occurred. The second time (summer 2009) the glacier covering was performed between 5 June and 14 October 2009. Moreover during summer 2009 we measured also the temperature of the artificial cover and the temperature of the covered snow pack. This second test was aimed at measuring the heat flux due to incoming solar radiation and to positive air temperature able to reach snow and ice covered by the Ice protector, thus promoting their melting. Contact: guglielmina.diolaiuti@unimi.it

Methods and techniques to reduce ablation at glacier skiing resorts: the Presena Glacier (Trento)

Guglielmina Diolaiuti (UNIMI-DST), Alberto Trenti, Nicola Paoli, Elvio Panettieri (PAT-M) and with the cooperation of SAT and SIAT On Presena Glacier (Adamello Group, Trentino Region), investigations to reduce snow and ice ablation were performed between June and September 2008 and between June and September 2009 in the framework of a regional research program. Presena is a mountain glacier used for ski activities which during the last two decades experienced a strong area and thickness reduction thus suggesting to apply strategies devoted to reduce the magnitude of glacier ablation and to preserve part of the winter and spring snow cover. For this purpose detailed field investigations were performed and ca. 2 ha of artificial cover was spread at the glacier surface at the beginning of the summer season 2008 and 2009. In particular it was covered the glacier sector considered more fragile since rock exposures were found to outstand at the glacier surface. The artificial cover was maintained for the whole ablation season 2008 and 2009 up to the month of September (both 2008 and 2009). To evaluate the role played by the artificial cover in reducing snow and ice ablation and particularly in modifying glacier energy budget three AWS were located at the glacier surface (2 AWSs) and at the glacier forefield (1 AWS). More precisely at the glacier surface one AWS was located in the covered area to measure here energy

fluxes and meteorological parameters and instead a second one was located on the natural (bare ice) glacier surface with the purpose of compare the energy budgets.

In addition a network of ablation stakes was developed at the glacier surface to measure snow and ice ablation in natural vs artificial conditions. The investigations will continue in summer 2010. Contact: alberto.trenti@provincia.tn.it

Glaciers and War: climate, ice caves, huts and deglaciation in the Ortles-Cevedale Group

Claudio Smiraglia, Guglielmina Diolaiuti (UNIMI-DST), Giovanni Peretti (ARPAL-CNV), Giuseppe Magrin

During the First World War on the Italian–Austrian alpine war lines, many military operations were carried out and many battles were fought; even if all of them had a small influence on the war evolution, they were meaningful because of the morphological and climatic context where they occurred, so that they were defined ‘the highest battles of history’. That is true overall for the Ortles-Cevedale sector, where at the beginning of the 20th century the widest glaciers of the Italian Alps were concentrated and where they are still largely present. The hard morphological and climatic conditions caused many problems, either to the war actions (especially the battles of San Matteo, 3684 m a.s.l. in the August–September 1918), or even to the soldiers’ lives (it is sadly known that in December 1916 the huge snowfalls, at least 50 m of snow, caused a lot of avalanches that killed more than 10,000 soldiers on the Alpine front). In that period glaciers were not only scenes of violent battles and conflicts but they were also locations where engineers and technicians performed feats of ‘glacial engineering’. The new science of glaciology had many practical applications: long tunnels were excavated into the ice to catch the enemy (among others, Zebrù, Ortles, Trafoi, Miniera). Moreover the recent emersion from the ice of many wooden huts on numerous summit peaks, observed during these last tens of years (for example on the tops of Mount Cevedale and Mount S. Matteo), caused by the strong present glacier shrinkage, raises interesting scientific questions about the climate and glacier conditions at the beginning of the 20th century.

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Assessment of water resources within snow fed areas

Daniele Bocchiola, Bibiana Groppelli, Renzo Rosso (POLIMI-DIIAR)

Snow cover extent, duration and dynamics influence vegetal and animal biota in Alpine areas, and freshwater availability from cryosphere during spring and summer regulates hydrological cycle of Alpine basins, and influences Alpine ecosystems development. Snow cover delays ice

melting and crevassing upon glaciers and snow surviving summer thaw at high altitudes eventually feeds ice cover in glacierized areas. As a result of the several processes governing snow cover dynamics, snow cover patterns show a tremendous variability in space and time and their proper assessment at both macro and micro-scale is of utmost importance. Any modelling approach to water and ice budget within alpine areas requires accurate assessment of Snow Water Equivalent (SWE) during winter and spring. Within this research line, we developed statistical methods for optimal (with uncertainty) estimation of SWE at different dates during accumulation and thaw season, based upon use of ground snow surveys and of remotely sensed snow covered areas. Also, we studied regionally valid statistical distribution of snowfall within Northern Italy, useful to quantify regional amount of SWE during the year and for simulation of climate feeding to hydrological cycle within snow fed areas. Further on, we developed downscaling techniques for use of coarse scale GCMs projections of future climate, at a scale suitable for hydrological conjectures.

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REMOTE SENSING

Remote sensing of the Eastern Alps in the 1980s

Rossana Serandrei-Barbero (CNR-ISMAR), Elisabetta Binaghi (CNR-CNR), Anna Rampini (CNR-IREA)

In 1999, the analysis of some Landsat TM images taken at the end of the ablation season highlighted retreat modes in the 1980s on all glaciers in the Breonie, Aurine and Pusteresi Groups (Eastern Alps). In the Italian Alps, the majority of glaciers are small (less than 1 km²), but cover a significant glaciated area, despite the fact that ground survey have only dealt with the major glaciers. In the Eastern Alps, in the early 1980s, large glaciers were advancing and small ones receding. The procedure used to identify glacier surfaces integrates Landsat TM images (bands 1, 3 and 5) and topographic data combining information derived from elevation, exposure, and morphological aspects. Between 1985 and 1987, the greatest retreat involved the glaciers with surface greater than 1 km². Between 1987 and 1989 the loss of glaciated surface was mostly found for the smaller glaciers. Quantitative assessment of glacial evolution on large areas shows inside opposite trends which generally escape ground observations on selected glaciers.

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Remote sensing of the Vedrette di Ries (Pusteresi Alps) in the 1990s

Rossana Serandrei-Barbero (CNR-ISMAR), Elisabetta Binaghi, Cristina Galli (CNR-ITIM), Anna Rampini (CNR-IREA)

In 1999 the analysis of the Landsat TM image 192/27 of 24 September 1991 was performed and all the glaciers of the Vedrette di Ries were classified and described. The procedure used to identify and describe glacier surfaces is based on the integrate use of remotely sensed data and topographic information. The first phase of the procedure is the classification of the multispectral Landsat TM images using the bands 3, 4 and 5: a supervised fuzzy-statistical classifier gives, for each pixel, the degree of membership to the classes sunny snow, shaded snow, sunny ice, shaded ice, sunny other, shaded other. The second step of the classification procedure identifies the glacier body using spectral features and other ancillary information. The glaciated surfaces were classified and measured and snow line identified in spite of unfavourable exposure, advanced season and the scarcity of snow. The results indicate the morphological changes due to the occurring retreat and update glaciated surfaces quantitative data extending to the hydrological year 1990–91 the automatic monitoring made possible by remote sensed data.

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Retreat of Aurine and Pusteresi Alps glaciers in the last decades from Landsat TM image on 2003 and previous results

Anna Rampini, Pietro Alessandro Brivio, Francesco Rota Nodari (CNR-IREA) Rossana Serandrei-Barbero (CNR-ISMAR)

The objective of the work was the analysis of Italian Alpine glacier changes in the last decades using Landsat imagery, acquired from TM sensors. In particular, Aurine and Pusteresi Alps glaciers have been studied and changes over 20 years, from 1985 to 2003, have been evaluated. A fuzzy set based classification technique permitted to quantify snow and exposed ice extents in glaciated areas. Integration with topographic information allowed to derive the elevation of glacier terminus, although the result is overestimated due to some problems with digital elevation data and frontal debris coverage. A comparison of front altitude changes data derived from satellite image processing with elevation measured during field surveys supports the knowledge of the size of glacier retreat of the last decades. On Aurine and Pusteresi Alps glaciers, the changes in the last 20 years show a retreat corresponding to the 40% of the glaciated surface in the 1980s, but a lot of them are now characterized by new debris coverage in the frontal zones.

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Optical remote sensing automatic mapping of alpine glaciers: improved techniques to face up-to-date patterns

Monica Pepe, Anna Rampini (CNR-IREA), Francesco Zucca (UNIPV-DST), Alberto Carton (UNIPD-DG)

When dealing with glacier mapping from optical satellite remote sensing two major constraints affect the mapping accuracy level: scale of observations, as related to spatial resolution of remote sensors with an adequate temporal resolution; presence of supraglacial debris which, presenting the same spectral characteristics as the surrounding terrains, is difficult to detect. The two problems are addressed separately using two different approaches.

To improve spatial resolution a sub-pixel approach has been tested and evaluated as compared to traditional methods; the basis of this improvement lies in the possibility of recognizing, by supervised unmixing classification, the percentage of different land cover classes, within a single pixel. In such a way the information extracted can be considered spatially finer than at the pixel size. This theoretical benefit in spatial accuracy has been analytically demonstrated by the application of the Pareto Boundary statistical method for comparison of classification results as obtained from different spatial resolution optical imagery. The Adamello Glacier has been considered as case study for the application.

As regards the debris covered ice issue a novel approach has been designed, implemented and tested, i.e. a decision-tree able to provide a complete delineation of glacier covers also in the presence of debris-covered ice. The method takes advantage of a new feature space, as derived from apparent reflectance values of some multi-spectral bands, allowing its application on image series in time and providing a semi-operative character to the classification scheme. The Belvedere Glacier has been considered as case study for the application. Results obtained from both proposed methodologies demonstrate their feasibility to produce valuable information as related to up-to-date glacier fluctuation patterns, helping the understanding of climate forcing over the alpine areas.

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An event-based archive of soft maps for the analysis of glacier changes

Paola Carrara, Anna Rampini (CNR-IREA)

A system for creating and managing archives of thematic maps derived from remote sensing images by soft classification techniques has been designed. Unlike traditional spatial approaches, the main key feature for query formulation is time, thus improving the investigation on changes occurred in time ranges. The system, named GeoTemp, has been applied on glaciers of the Vedrette di Ries

Group in the Southern flank of the Eastern Italian Alps. The GeoTemp analysis has been applied to images resulting from a classification procedure performed by a fuzzy-statistical classifier which provide for each pixel the degrees of membership to classes. Three classes have been identified: Snow, Ice and Other, this last collecting all land covers present in the image but not meaningful for the application.

Classified maps together with topographic data (elevation, slope and aspect) have been stored in a GeoTemp archive. At a first step, simple queries have been formulated to search for variations of the single classes in the time range from 1989 and 1991. In a second step, to confirm the analysis and to detect the elevation of the snow transient area, GeoTemp has been used to formulate a composed query to search for pixels in which the percentage of Snow decreased of the 50% and contemporary the Ice increased of 50%: the result is of 332 pixels on a total of 338 pixels in which the elevation of the pixels satisfying this query, locates the transition area at about 2900 m, according to the data measured by experts during on field campaigns.

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Geomatics techniques for multitemporal estimation of volume change in Miage glacier reservoir (Mont Blanc)

Luigi Perotti, Walter Alberto, Roberto Carletti, Marco Giardino (UNITO-GSL)

The Miage glacier is the major one on the Italian side of the Mont Blanc Massif. A wide superficial debris cover confers the Miage the typical aspect of a debris-covered glacier, acquired 150 years ago towards the end of the Little Ice Age. For these reasons, the Miage glacier shows prevailing vertical movements instead of the typical debris-free glacier retreat of the front. For its conservative landforms, the Miage Glacier have a great importance for the analysis of the geomorphological response to recent climatic changes and represent a particular type of alpine water reservoir. Thanks to an organized existing archive of multitemporal aerial images, we produced a multitemporal digital photogrammetric work to estimate the volumes fluctuations of ice/water stored in glacier reservoir since 1954. High resolution satellite images are being currently considered for future investigations, considering the possibility of ordering stereo acquisitions for different satellite missions (EROS, QuickBird, OrbView3, Ikonos, Cartosat etc.).

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Energy and mass balance of the Adamello Glacier with satellite-derived information

Ranzi Roberto, Stefano Barontini, Grossi Giovanna (UNIBS-DICATA)

Evidences of the retreat of the Adamello Glacier, the largest glacier in the Southern Alps, have been reported in the scientific literature since the half of the 19th century. The evaluation of the amount of water resource lost or gained each year is actually a very important information for managing reservoirs and river quality downstream. To this aim an energy-balance hydrological model was applied, supported by point ice ablation and snowpack measurements, as well as by meteorological, runoff and satellite data over the period 1995–2009. The accuracy of the model in simulating ablation at the point scale was verified over 2 years versus measurements at a network of ablation stakes installed in early summer 2007. Average glacier melt was also verified with hourly stream flow observation downstream. The simulated retreat of the snow covered areas during the melt season at the large scale was verified using the snow cover monitored by two ASTER images in June and July 2003, used also to estimate distributed values of snow and ice albedo. This result is framed within the GLIMS project <http://www.glims.org/>.

Over the snow free areas, the melt factor at ablation stakes was estimated as $7 \text{ mm}/(^{\circ}\text{C}\cdot\text{d})$.

A net loss of about 1400 mm/a, on average over the 1995–2009 period, results from the estimated winter accumulation and the simulated summer mass balance. The result is in qualitative and quantitative agreement with runoff measurements downstream the glacierized areas and with mass balances conducted with the glaciological method in the nearby Careser glacier for which the longest mass balance time-series in Italy is available. Uncertainties in the estimation of snowfall and in modelling turbulent fluxes cannot be neglected but the trend of glacier's retreat simulated by the energy-balance model is clearly confirmed by observations and measurements.

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PERMAFROST

The Rock Glacier Inventory of Aosta Valley

Michèle Curtaz, Marco Vagliasindi (FMS-CRGV), Umberto Morra di Cella, Paolo Pogliotti (ARPA-VdA), Stephanie Letey (UNITO)

Aosta Valley is a medium size alpine region covering a surface of about 3300 km²; here glacial and periglacial environments represent important land elements (i.e. more than 50% of the region area is located above an elevation of 2000 m a.s.l.). Consequently it is important to acquire and update detailed information on permafrost and periglacial environments. An inventory of rock glaciers of the Aosta Valley territory is currently being compiled

in the framework of the project PermaNET – Long-term Permafrost Monitoring Network (Alpine Space program). The inventory is carried out through the analysis of aerial photographs (orthophotos with a resolution of 0.5 m), Digital Terrain Models (DTM, 2 m grid spaced) and InfraRed False Colour images (IRFC, with a resolution of 15 cm). Each identified rock glacier is manually delimited in a GIS environment and the main morphological parameters are derived from the DTM. Then all data are inserted in a tables forming the inventory database. This latter was shaped and organized according to previous rock glacier inventories, moreover new fields were added. Therefore, in order to assess the main features of the Aosta Valley rock glaciers and to evaluate their distribution with respect to topography a geo-statistic analysis is being performed. A field campaign to validate the inventory data is planned for summer 2010.

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The Rock Glacier Inventory of Lombardy Alps

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An inventory of rock glaciers of the Lombardy territory is currently being compiled in the framework of a cooperation among UNIMI-DST, UNINS-DBSF and UNIBU. The source of the data are both field surveys and remote sensing investigations. The latter are supported by the IIT (Infrastructure for the Territory Information) project of the Lombardy Region providing the 2003 and 2007 orthophotos which cover the whole Lombardy territory. The inventory is based on the well known criteria (to identify and describe rock glaciers) reported in the recent available literature. All the data are being inserted in a data base linked to maps and orthophotos which will be made available through the official web site of the Lombardy Region.

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Permafrost-glacier interaction in Western and Central Alps

Mauro Guglielmin (UNINS-DBSF), Adriano Ribolini (UNIP-DST), Denis Fabre (CNA), Xavier Bodin (UNI), Matteo Spagnolo (UNIAB-GED)

In Western and Central Alps (Italy-France), ground ice of permafrost origin and sedimentary ice of glacial origin can coexist where (1) rock glaciers and glaciers interacted, as well as (2) in glacial sediments abandoned by a retreating glacier and subsequently exposed again to atmospheric cooling. In the last few years, a group of Italian, French and Scottish researchers focussed on this topic, analysing the rock glaciers and the recently deglaciated slopes of Maritime (Argentera Massif), Cothian (Monviso area) and Retich Alps (Livigno area), undertaking several geophysical prospections (electrical tomography and georadar), ground surface

temperature monitoring and geodetic measurements of surface movements. The principal aim is to understand if and at which extent the internal structure of rock glaciers and recent-deglaciated slopes can be used as a potential archive storing the different climatically-driven episodes occurred in the cryosphere of a specific area, such as events linked to the shifting between glacial to cryotic condition and vice versa. A glacial overrode disrupting permafrost can be claimed to explain the scarcity of frozen debris/ice in the upper or middle part of some rock glaciers, whereas ice transfer from a glacial snout to sectors of rock glacier can cause the embedding of fragments of sedimentary ice in a syngenetically permafrost creeping, eventually transported downvalley by the flow. Geomorphological data have served the reconstruction of glacier-rock glacier interactions, and available borehole stratigraphies were used to calibrate the subsurface geophysical characteristics.
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Investigations in periglacial and cryotic environments in Lombardia

Mauro Guglielmin (UNINS-DBSF)

Since 1995 the research on periglacial and permafrost environments arisen significantly after the realization of the National Rock Glacier Inventory. Some of these rock glaciers were also dated with the C14 method in order to reconstruct their paleoclimatic significance. A great impulse to the research was given by the European Project PACE (Permafrost and Climate in Europe). During this project the different types of geophysical prospections were tested on the Foscagno rock glacier, in Upper Valtellina) where the first borehole was cored. The crystallography and the chemical and isotopic composition of the core indicated that the massive ice found in the core was a glacier relict ice body formed during the Middle Age (1020 ± 20 BP). The same rock glacier was the pilot area for a national project to analyse the relationships between the hydrology and permafrost occurrence through the realization of other three boreholes and the installation of monitoring station to record chemical and physical properties of the main spring located at the foot of the rock glacier. The identification of the coexistence of different types of ice (buried relict glacier ice and different types of ground ice) both vertically and laterally within Foscagno rock glacier confirm the complexity of the geological and cryological nature of the rock glacier.

In addition the relationships between rock glacier dynamics and vegetation colonization were analysed in different rock glaciers of the Upper Valtellina. Regarding the permafrost distribution different techniques (e.g. BTS) were used showing a patchy permafrost occurrence even within the rock glaciers. Permafrost occurrence was modelled in different sectors of the

Italian Alps through empirical models. Moreover a physical-based permafrost model called Permaclim was developed using as input data the digital elevation model, air temperature and snow cover. During the PACE project the first deep (100.1 m) borehole fully instrumented to monitor permafrost regime was realized close to Stelvio Pass at 3000 m a.s.l.. In this site permafrost was thicker than expected, in fact assuming the thermal properties constant with depth the permafrost thickness in this site should excess of 200 m and within the share Stelvio project the deepest alpine permafrost borehole in Europe will be drilled, crossing the permafrost base, next year. The permafrost profile recorded within the pace borehole allowed us to reconstruct the last 200 years of ground surface temperature. Since 2004 a 64 m deep borehole has been monitored close to Punta Helbronner (3480 m a.s.l.). Close to this borehole, a program to monitor the rock surface and subsurface temperature oscillations was started in 2008 within the framework of co-operation between UNIMI-DST, UNINS-DBSF and EVK2-CNR. A key permafrost case study was also the Val Pola landslide where for the first time in Europe the role of permafrost in the triggering of a deep landslide was demonstrated.

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Investigations on rock glaciers and permafrost in Trentino

Roberto Seppi (UNIPV-DST), Alberto Carton (UNIP-DG), Luca Carturan (UNIPD-TeSAF), Carlo Baroni (UNIPV-DST), Saverio Cocco, Mauro Degasper, Matteo Zumiani (PAT-SG)

Several research activities are in progress on permafrost environments of the Adamello Presanella and Ortles Cevedale groups. A GIS-based inventory of permafrost evidences (i.e. rock glaciers) has been carried out in the former and in selected areas of the latter mountain group (UNIPV, UNIPD, UNIPV). The inventory is based on aerial photo interpretation and field observations, and describes the activity status, geometry and geomorphological characteristics of the rock glaciers. Furthermore, the rock glaciers distribution has been compared with the current climatic conditions of the study areas and some paleoclimatic information have been inferred from the distribution of the relict landforms. Part of these rock glaciers were selected as test sites for further investigations. Annual surface velocity measurements using terrestrial topographic surveys (total station and GPS-RTK) were initiated in 2001 on two active landforms (UNIPV, PAT-SG). The results show a marked interannual variability of the surface velocity, and both the rock glaciers display a nearly homogeneous and synchronous behaviour. The potential relationships between the dynamic behaviour of the landforms and the local climatic conditions (e.g. air and ground temperature and

snow cover) are currently under investigation. In several areas of the two mountain groups, temperature measurements at the base of the winter snow cover (i.e. BTS) were annually conducted since 2003, both on rock glaciers and numerous other slopes (UNIPV, UNIPD). In particular sites, these measurements were coupled with continuous temperature measurements at the ground surface using miniature temperature dataloggers (MTD). These investigations aim at verifying the presence of permafrost and at analysing its thermal condition in relation with the air temperature and the snow cover evolution. Finally, the springs located on numerous slopes and emerging from rock glaciers are also under investigation (UNIPV). The research focuses on using the water temperature as a useful indicator of the presence of permafrost and on the physical and chemical characteristics of the water.

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The PermaNET project in Trentino: advance of the research and monitoring activities

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Research and monitoring activities on permafrost in Trentino have received a significant increase by the approval of the Alpine Space PermaNET project. As local partner of the project, the PAT-GS co-ordinates the activities, with the collaboration of several universities (UNIPV, UNITN, UNIPD). In the framework of the project, an inventory of permafrost evidences (i.e. rock glaciers) is currently in progress in the whole province of Trento. The inventory is built in a GIS environment and is based on orthophotos and DEM analyses and on field controls. So far, the inventory includes the active landforms, and will be completed within the end of the project including also the relict ones. The measurement activities focus on three areas, located respectively in the Adamello Presanella Group (Presena ski area), in the Ortles Cevedale Group (Cavaion basin) and in the Dolomites (Cima Uomo area). In these areas, BTS and ground surface thermal regime measurements are in progress. Deep thermal measurements are conducted in two already existing boreholes located near the alpine hut 'Ai Caduti dell'Adamello' at 3030 m a.s.l.. The aim of these surveys is to investigate the existence of permafrost in the slope on which the hut is located and try to relate the observed slope movement with the permafrost degradation. Preliminary results confirmed the existence of stable below-zero temperatures in one of the boreholes, under a depth of about 5.5 m. Furthermore, a 50 m deep borehole has been drilled at the Cavaion basin (2900 m a.s.l.). This site is going to be fully instrumented with a thermistor

chain and a meteorological station. Modelling activities are also performed in the framework of PermaNET, aiming at modelling the distribution of permafrost in the province of Trento. A freezing-soil module has been developed inside the open source hydrological model GEOTop. The model allows to perform long term simulations to investigate the temperature in depth accounting for heat conduction and phase change.

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Investigations on permafrost in Antarctica

Mauro Guglielmin (UNINS-DBSF)

More than 10 years ago (1994) the Italian Program for Antarctic Research sponsored the first research campaign to begin the research on periglacial features and permafrost in Northern Victoria Land. From that first campaign, original data on the occurrence of different types of ice within permafrost were achieved. The first permanent permafrost monitoring station in all Antarctica was settled on 1998 and the following year also the first CALM grid (100 × 100m) to monitor the active layer variability was established close to the Italian Antarctic station. Through also the cooperation with the University of Ottawa several aspects of the periglacial and cryotic processes and landforms were analysed in Victoria Land. Among them icing blisters, frost blisters, patterned ground, ice wedges and other frozen ground phenomena were studied and in some cases monitored. Weathering processes in cryotic environment with particular attention to tafoni development and grooves and weathering pits formation and development were analysed. The study of weathering processes revealed a strong influence of the biotic action. Since 2000 the Italian project was more focussed on the analyses of the impacts of the climate change on permafrost and on the vegetation associated working also in Maritime Antarctica. The influence of the different vegetation types on the ground surface temperature and the underlying active layer in Maritime Antarctica and more recently in Continental Antarctica was demonstrated. Permafrost monitoring network started with the 3.6 m deep borehole at Boulder Clay in 1996 has been strongly developed with the cooperation of Waikato University with the realization of two new 30 m deep boreholes fully instrumented located at Marble Point and at Wright Valley in the McMurdo Dry valleys. Also a new 30 m deep borehole has been fully instrumented close to the Italian Antarctic station while another 30 m deep borehole has been instrumented last year at Rothera in Maritime Antarctica with the cooperation of British Antarctic Survey. Moreover another Calm grid and a 2.5 m deep borehole was set in 2005 at the northern border of Maritime Antarctica (Signy island).

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ICE CAVES

Glaciological and climatic studies of ice deposits in caves

Valter Maggi (UNIMIB), Alfredo Bini (UNIMI-SDT), Stefano Turri (PRGS), Barbara Stenni (UNITS), Roberto Udisti (UNIFI)

Ice deposits in caves, as glaciers of mid latitudes, represent a promising archive for environmental and climate information. Ice cave deposits can be found at low altitude, below the snow line, because of the very conservative hypogean environment. These deposits are usually located in deep of karstic areas, widespread throughout the world, and under optimal conditions they allow collection of natural and anthropogenic information on stratified ice deposits. Many Italian caves, mainly in the Alps, preserve ice deposits at great depth. In these environments, some glaciological, stratigraphical, climatic and environmental studies were recently performed. These allowed a preliminary modelling of the ice cave system, and some ice core drilling provided environmental and climatic information. In the Moncodeno area (Grigna Settentrionale, Lecco, Italy) ice caves were found about 1800 m a.s.l., close to one of the most industrialized area of the world (Lombardy). More than 20 m of stratified ice deposits originated from water dripping were found at 80 m depth in a vertical shaft without direct contact with surface (2330 m a.s.l.). In the framework of this study, a complete weather station was installed in the cave. Microclimatic studies of air circulation, temperature variability and humidity were done with a preliminary assessment of the relationship between epigean and hypogean environments. Other caves were found in Veneto and Trentino Alto Adige regions (Eastern Alps), inside the Dolomite area, between 2000 and 3000 m a.s.l.. In Italy, ice deposits are widespread; also in Sicily some ice deposit exist inside old volcanic pipes in Mt Etna. International collaborations are in course with Romania and Slovak Republics for studying the large ice deposits located in Apuseni Mountains (Transylvania) and in Tatras Mountains. Contact: stefano.turri@unimi.it

ECOLOGICAL STUDIES

Culturable yeasts in melt waters draining from two glaciers in the Italian Alps

Pietro Buzzini, Benedetta Turchetti, Alessandro Martini (UNIPG-DBA), Guglielmina Diolaiuti, Carlo D'Agata, Claudio Smiraglia (UNIMI-DSTI) This project was developed in the framework of a partnership between UNIPG and UNIMI.

The melt waters draining from two glaciers (Forni and Sforzellina glaciers, Ortles-Cevedale Group, Lombardy) in the Italian Alps resulted containing metabolically active yeasts isolable

by culture-based laboratory procedures. The average number of culturable yeast cells in the melt waters was 10–20 colony-forming units (CFU) L⁻¹, whereas supra-glacial stream waters originating from overlying glacier ice contained <1 CFU L⁻¹. Yeast cell number increased as the suspended-sediment content of the water samples increased. Basidiomycetous yeasts represent > 80% of isolated strains (*Cryptococcus* spp. and *Rhodotorula* spp. were 33.3% and 17.8% of total strains, respectively). Culturable yeasts were psychro-tolerant, predominantly obligate aerobes and able to degrade organic macromolecules (e.g. starch, esters, lipids, proteins). To the authors' knowledge, this is the first study to report the presence of culturable yeasts in melt waters originating from glaciers. On the basis of these results, it is reasonable to suppose that the viable yeasts observed in melt waters derived predominantly from the sub-glacial zone and that they originated from the sub-glacial microbial community. Their metabolic abilities could contribute to the microbial activity occurring in sub-glacial environments. Contact: pbuzzini@unipg.it

Psychrophilic yeasts in glacial environments of Alpine glaciers

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This project was developed in the framework of a partnership between the UNIPG and UNIMI.

The presence of psychrophilic yeasts in supra- and subglacial sediments, ice and meltwater collected from two glaciers of the Italian Alps (Forni and Sforzellina – Ortles-Cevedale group) was investigated. After incubation at 4 °C, subglacial sediments contained from 1.3×10^3 to 9.6×10^3 CFU of yeasts g⁻¹. The number of yeast cells in supraglacial sediments was c. 10–100-fold lower. A significant proportion of isolated yeasts exhibited one or more extracellular enzymatic activities (starch-degrading, lipolytic, esterolytic, proteolytic and pectinolytic activity) at 4°C. Selected isolates were able to grow at 2°C under laboratory-simulated in situ conditions. In all, 10⁶ isolated yeasts were identified by MSP-PCR fingerprinting and 26S rRNA gene sequencing of the D1/D2 region as belonging to 10 species: *Aureobasidium pullulans*, *Cryptococcus gilvescens* (over 50% of the total), *Cryptococcus terricolus*, *Mrakia gelida*, *Naganishia globosa*, *Rhodotorula glacialis*, *Rhodotorula psychrophilica*, *Rhodotorula bacarum*, *Rhodotorula creatinivora* and *Rhodotorula laryngis*. Four strains, all belonging to a new yeast species, yet to be described, were also isolated.

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Yeast and yeast-like diversity in the southernmost glacier of Europe (Calderone Glacier, Apennines, Italy)

Eva Branda, Benedetta Turchetti, Pietro Buzzini (UNIPG-DBA), Guglielmina Diolaiuti, Claudio Smiraglia (UNIMI-DST), Massimo Pecci (EIM)

This project was developed in the framework of a partnership between UNIPG and UNIMI.

Through this project the characterization of psychrophilic yeast and yeast like diversity in cold habitats (superficial and deep sediments, ice cores and melt waters) of the Calderone Glacier (Italy), which is the southernmost one of Europe, was performed. After incubation at 4 and 20°C, sediments contained about from 10² to 10³ CFU of yeasts g⁻¹. The number of viable yeast cells in ice and melt waters was several order of magnitude lower. The concomitant presence of viable bacteria and filamentous fungi has also been observed. Two-hundred and fifty-eight yeast strains were isolated and identified by 26S rRNA gene D1/D2 and ITS sequencing as belonging to 28 basidiomycetous and ascomycetous species of 11 genera (*Candida*, *Cystofilobasidium*, *Cryptococcus*, *Dioszegia*, *Erythrobasidium*, *Guehomyces*, *Mastigobasidium*, *Mrakia*, *Mrakiella*, *Rhodotorula* and *Sporobolomyces*). Among them, the species *Cryptococcus gastricus* accounted for most of 40% of the total isolates. In addition, 12 yeast-like strains were identified as belonging to the species *Aureobasidium pullulans* and *Exophiala dermatitidis*, whereas 14 strains, presumably belonging to new species, yet to be described, were also isolated. These results indicate that the Calderone Glacier, although is considered a vanishing ice body due to ongoing global warming phenomenon, still harbours viable psychrophilic yeast populations. Contact: pbuzzini@unipg.it

Cold-adapted yeasts from Antarctica and the Italian Alps. Description of three novel species: *Mrakia robertii* sp. nov., *Mrakia blollopis* sp. nov. and *Mrakiella niccombsii* sp. nov.

Skye Robin Thomas-Hall, Kenneth Watson, Benedetta Turchetti, Pietro Buzzini, Eva Branda (UNIPG-DBA), Teun Boekhout, Bart Theelen (CBS), Kenneth Watson (UNE-SBS).

Worldwide glaciers are annually retreating due to global warming and this phenomenon determines the potential lost of microbial diversity represented by psychrophilic microbial population sharing these peculiar habitats. In this context, yeast strains, all unable to grow above 20 °C, consisting of 42 strains from Antarctic soil and 14 strains isolated from Alpine Glacier, were isolated and grouped together based on similar morphological and physiological characteristics. Sequences of the D1/D2 and ITS regions of the ribosomal DNA confirmed the previous analyses and demonstrated that the strains belong to unknown species.

Three new species are proposed: *Mrakia robertii* sp. nov. (type strain CBS 8912), *Mrakia blollopis* sp. nov. (type strain CBS 8921) and a related anamorphic species *Mrakiella niccombsii* sp. nov. (type strain CBS 8917). Phylogenetic analysis of the ITS region revealed that the new proposed species were closely related to each other within the *Mrakia* clade in the order Cystofilobasidiales, class Tremellomycetes. The *Mrakia* clade now contains 8 sub-clades. Teliospores were observed in all strains except CBS 8918 and for the *Mrakiella niccombsii* strains.

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Biodiversity of cold-adapted yeasts from glacial meltwater rivers in Patagonia, Argentina

Virginia de Garcia, Silvia Brizzio, Diego Libkind, Maria van Broock (CRUB), Pietro Buzzini (UNIPG-DBA)

This project permitted to detect the occurrence of culturable yeasts in glacial meltwater from the Frias, Castano, Overo and Rio Manso glaciers, located on Mount Tronador in the Nahuel Huapi National Park (Northwestern Patagonia, Argentina). Subsurface water samples were filtered for colony counting and yeast isolation. The total yeast count ranged between 6 and 360 CFU L⁻¹. Physiologic and molecular methods were employed to identify 86 yeast isolates. In agreement with yeast diversity data from studies for Antarctic and Alpine glaciers, the genera *Cryptococcus*, *Leucosporidiella*, *Dioszegia*, *Rhodotorula*, *Rhodospiridium*, *Mrakia*, *Sporobolomyces*, *Udeniomyces* and *Candida* were found. *Cryptococcus* and *Leucosporidiella* accounted for 50% and 20% of the total number of strains, respectively. Among 21 identified yeast species, *Cryptococcus* sp. 1 and *Leucosporidiella fragaria* were the most frequent. The typically psychrophilic *Mrakia* yeast strain and three new yeast species, yet to be described, were also isolated. All yeast strains were able to grow at 5, 10, and 15 °C. Among yeast strains expressing extracellular enzymatic activity, higher proteolytic and lipolytic activities were obtained at 4 °C than at 20 °C.

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Extracellular enzymatic activities of basidiomycetous yeasts isolated from glacial and sub-glacial waters of Northwest Patagonia (Argentina)

Sinia Brizzio, Virginia de Garcia, Diego Libkind, Maria van Broock (CRUB), Pietro Buzzini, Benedetta Turchetti (UNIPG-UNIPG)

As a part of a project aimed at the selection of cold-adapted yeasts expressing biotechnologically interesting features, the extracellular enzymatic activity (EEA) of basidiomycetous yeasts isolated from glacial and sub-glacial waters of northwest Patagonia (Argentina) was investigated. Ninety-one basidio-mycetous yeasts (belonging to the genera

Cryptococcus, *Leucosporidiella*, *Dioszegia*, *Mrakia*, *Rhodotorula*, *Rhodospiridium*, *Sporobolomyces*, *Sporidiobolus*, *Cystofilobasidium*, and *Udeniomyces*) were screened for extracellular amylolytic, proteolytic, lipolytic, esterase, pectinolytic, chitinolytic and cellulolytic activities. Over 15% of the strains exhibited three or more different EEAs at 4°C and more than 63% had at least two EEAs at the same temperature. No chitinolytic and cellulolytic activities were detected at 4 and 20°C. Cell-free supernatants exhibited significantly higher ($P < 0.01$) protease and lipase activities at $\leq 10^\circ\text{C}$, or even at 4°C. In light of these findings, cold environments of Patagonia (Argentina) may be considered a potential source of cold-adapted yeasts producing industrially relevant cold-active enzymes.

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Vegetation patterns relating to rock glaciers, surface instability, snow and climate change impacts

Nicoletta Cannone (UNIFE)

The patterns of vegetation colonization were investigated on several active and inactive rock glaciers of the Italian Central Alps, focussing on the impact of surface disturbance (due to permafrost creep within active rock glaciers) on single plant species. The investigations on the relations between vegetation and surface disturbance are under investigation at Foscagno active and inactive rock glacier, where the monitoring of vegetation and surface movement is going on since 4 years. At the same site (Foscagno Valley) since three years seventy plots were installed and monitored for the analysis and monitoring of snow cover distribution and permanence and for the assessment and monitoring of the phenology of 20 target high alpine plant species in response to snow and climate

The impacts of climate change on vegetation in the last 50 years were analyzed at Stelvio Pass. At this site vegetation changes were quantified comparing through GIS a phytosociological map drawn in 2003 and a phytosociological map drawn in 1955. Above 2500 m, vegetation coverage exhibited unexpected patterns of regression associated with increased precipitation and permafrost degradation. As these changes follow a sharp increase in both summer and annual temperatures after 1980, we suggest that vegetation of the alpine (2400–2800 m) and nival (above 2800 m) belts respond in a fast and flexible way, contradicting previous hypotheses that alpine and nival species appear to have a natural inertia and are able to tolerate an increase of 1–2°C in mean air temperature. Actually measurements of the CO₂ fluxes were carried out during the growing season, showing that vegetation changes induces a decrease of CO₂ sequestration from the atmosphere to the ecosystems (plants and soils) of 22ton CO₂. Contact: cnnnlt@unife.it

Accelerating climate change impacts on Italian alpine glacier forefield ecosystems: the case of the Sforzellina Glacier (Ortles-Cevedale Group)

Nicoletta Cannone (UNIFE), Guglielmina Diolaiuti, Claudio Smiraglia (UNIMI-DST), Mauro Guglielmin (UNINS)

Recently climate change was demonstrated to affect higher levels of ecological systems, with vegetation exhibiting surface area changes, indicating that alpine and nival vegetation may be able to respond in a fast and flexible way in response to 1–2°C warming. The analysis of the vegetation succession on the forefield of the Sforzellina Glacier (Ortles-Cevedale Group) over the past three decades permit to quantify the impacts of climate change on biotic components of high alpine ecosystems, to verify that an acceleration was occurring on them during the last. Vegetation started to colonize surfaces deglaciated for only one year, with a rate at least four times greater than that reported in the literature for the establishment of scattered individuals and about two times greater for the well-established discontinuous early-successional community. The colonization strategy changed: the first colonizers are early-successional, scree slopes, and perennial clonal species with high phenotypic plasticity rather than pioneer and snowbed species.

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Alpine debris-covered glaciers as a habitat for plant life

Marco Caccianiga (UNIMI-DB), Guglielmina Diolaiuti, Claudia Mihalcea, Carlo D'Agata, Claudio Smiraglia (UNIMI-DST)

The project was developed in the frame of the 2005 COFIN-PRIN Project

Debris-covered glaciers represent a significant, increasing fraction of the worldwide glaciers which could support the development of plant life at their debris-covered surface. The research was carried out on the Miage Debris Covered Glacier (Mont Blanc massif, Western Alps, Italy). The goal of this project was to evaluate the role of supraglacial debris as a habitat for plant life in the Alps and to discuss the ecological and biogeographical implications. Physical factors mostly influencing the vascular plant distribution were evaluated and comparison of different plant cover occurring on debris-covered glaciers with that observed on other alpine environments were performed. It resulted that the glacier surface hosted a remarkable biodiversity, with 40 vascular plant species, including trees and shrubs. The main physical factor affecting plant life was expressed by an altitude-glacier surface velocity gradient, while debris thickness of 10 cm could sustain plant growth. On the most stable areas, plant communities could be compared with those of glacier forelands of the subalpine belt, but with the significant addition of

high altitude species. From our investigations it results that debris-covered glaciers represent a relatively favourable habitat for plant life if a sufficient degree of stability of the debris layer is given. In this case, they host specific plant species assemblages and can act as a refuge of high altitude taxa below their altitudinal limits. More in general debris covered ice areas, as medial moraines, could act as vehicle of dispersal of alpine plant species, and this could have been particularly important during past glacial periods.

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Dendroglaciological analysis on debris-covered glaciers in the Western Italian Alps

Manuela Pelfini (UNIMI-DST)

Dendroglaciological analysis of supraglacial trees represents an example of applied dendrogeomorphological methods for reconstructing glacier variations. Supraglacial trees react to ice and debris movement, assuming typical shapes with modified radial growth. Tree ring analysis on *Larix decidua* Mill., located on the Miage glacier tongue (M. Blanc massif, Aosta valley) allowed to reconstruct the recent glacier surface movements and to detect the passage of the last kinematic wave. Different growth anomalies (e.g. pointer years, compression wood, abrupt growth changes) were identified and dated. Reference chronologies based on undisturbed larches growing outside the glacier were constructed for comparison with tree-ring data from supraglacial trees. The simultaneous presence of different disturbance indicators occurred mainly between 1984 and 1990 on the southern lobe and during the period 1989–93 on the northern glacier lobe. These results resulted to fit with glaciological data documenting volume and surface-level variations in the same period. Surface glacier velocity controls the time life span of supraglacial trees interrupting their function of proxy glaciological data recorder. New researches are in progress on Belvedere Glacier (M. Rosa massif), where a small tree layer composed by very young specimens is present.

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Glacial stream activity in debris covered glaciers proglacial areas in the Western Italian Alps and in Extra-European chains

Manuela Pelfini, Valentina Garavaglia (UNIMI-DST)

Tree vegetation growing in the proglacial areas is suitable for hydrological information and for the correlation with surface glacier movements. Research carried out on the Miage Glacier (Mount Blanc Massif) indicated the continuous remobilization of the debris by the glacial stream flow and the consequent influence on tree growth rate. Dating scars, compression wood and sudden growth releases or reductions it has been possible to identify the areas directly affected by glacial

discharge and others characterized by boulders falling from the glacier front. The concentration of growth anomalies starting from 1984 probably indicates a more intense glacial activity influencing the forest vegetation. The tree age spatial distribution allows the reconstruction of periods of major flood events and periods of relative stability. Moreover, growth anomalies well fit with data from supraglacial trees, attesting the possibility to extract information about the debris covered glacier behaviour also from tree vegetation colonizing the proglacial environment. Following these encouraging results, dendroglaciological analysis of tree rings sampled in the Karakorum region are now in progress.

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Tree vegetation responses to glacier retreat in the alpine environment

Manuela Pelfini, Giovanni Leonelli, Valentina Garavaglia (UNIMI-DST)

In the Alps the glacial retreat is accompanied by a fragmentation of ice masses into glaciers of reduced extension, by an increase in supraglacial debris coverage and by enlargements and recolonization of proglacial areas by vegetation. Researches on recently deglaciated areas in Central and Western Italian Alps allow to investigate the ecesis time (estimation of the elapsed time between deglaciation and the germination of the first tree). On the Forni Glacier (Ortles-Cevedale Group) the tree vegetation colonizing the glacier forefield has been studied in order to evaluate the colonization rate in relation to global warming. Norway spruces present an average ecesis value between 52 years and 30 years if related to the glacier front position in 1998. Also the sampled larches present an average and minimum ecesis with trends similar to the Norway spruces. The first one varies between 58 and 25 years, the latter between 48 and 20. Even if the ecesis rate can be affected by some errors in estimation, a reduction in ecesis time from the Little Ice Age maximum and the present time seems evident. Analogous researches are in progress on the Verra Glacier (Aosta Valley) where the minimum ecesis presents values higher than the Forni Glacier. Also in this study area an acceleration in the glacier forefield has been identified.

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Tree rings and glacier mass balance

Giovanni Leonelli, Manuela Pelfini (UNIMI), Paolo Cherubini (WSL)

Tree rings and glacier mass balance are two highly sensitive climatic proxies which are often used as indicators of changes involving the biological and physical components of high-altitude ecosystems. Global warming and the stronger regional temperature trends recently recorded over the European Alps have triggered several biological

and physical dynamics in high-altitude environments. Tree-ring data have been widely used for temperature reconstructions and sporadically for reconstructing past glacier mass balance. However, these reconstructions are based on the uniformitarian principle, which assumes that the relationships found for the recent past remain stable over time. We found that tree rings and glaciers from the same alpine region recently changed their sensitivity to air temperature over time (the climatic factor to which they are mostly linked), and also responded non-proportionally to temperature extremes. Both ring-width chronologies and the mass-balance series of some glaciers from the same region have shown an increasing sensitivity to summer (JJA) temperatures. Our results demonstrate that the sensitivity to climate of both of tree-ring chronologies and glacier mass balance is not stable over time, posing some limitations to tree-ring based glacier mass balance reconstruction in the European Alps. Moreover, we found these reconstructions are more reliable for large than for small glaciers (which are increasingly showing signs of downwasting and collapse due to rapid warming rather than 'retreat') and may not be able to reveal years of extreme ablation that could have occurred in the past.
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SNOW AND AVALANCHES

Setup of regional methods for avalanche hazard assessment in Northern Italy

Daniele Bocchiola, Renzo Rosso, Michele Medagliani (POLIMI-DIAR).

Regional statistical methods have considerable bearing on the prediction of natural events with low frequency of occurrence, including snow avalanches in mountain ranges. These methods trade the time variability of the involved variables for their spatial distribution and increase sample dimensionality for model estimation, so coping with shortness of usually available data base as compared to the high return periods of the design events. In turn, regional methods require accurate assessment of homogeneous regions, where data pooling can be carried out confidently. In the Italian alpine range, the guidelines set out by AINEVA, and inspired to Swiss Procedure, prescribe hazard mapping based on design avalanches with release depth predicted using the 3 day snow depth H72, with return period up to 100 years. Considerable uncertainty is entailed in such prediction, mainly due to the average length of the observed H72 series, of 20 years or so. Within this research line, methods were introduced for regional approach based on index value to predict H72 for the case study area of Northern Italy, and then carry out hazard mapping based on the guidelines for some case study sites. Also, regional methods were used to setup methods for performing continuous

avalanche simulation in time. The regional approach allow improved prediction of avalanche hazard via the presently adopted methods, and as well increase our knowledge of avalanche phenomena, e.g. for study of their ecological and morphological effects.
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Improved methods for avalanche hazard assessment in Switzerland

Daniele Bocchiola, Emanuela Bianchi Janetti, Elisa Gorni (POLIMI-DIAR), Betty Sovilla, Christoph Marty (SLF)

The currently adopted approach for avalanche hazard mapping in Switzerland includes avalanche dynamics modelling coupled with statistical analysis of the greatest annual three-day snow fall depth, H72, used as a proxy data for the release depth. New advances in avalanche dynamics show that this approach can be improved using models with mass entrainment, requiring in turn a statistical definition of the erodible snow cover. Also, definition of conditions of snowfall depth based upon regional methods provides more accurate estimates as compared, on the one hand against single site estimation, and on the other hand against country-wide valid maps as used hitherto. Within this research line we developed a regional approach valid for the whole of Switzerland based on index value to evaluate release depth and erodible snow cover for large return periods. The territory of Switzerland is divided into 7 climatologically homogenous regions. General extreme value distributions for the growth factors were developed valid within these seven regions, together with index value estimation based upon altitude. We then used the snowfall so obtained as input for avalanche hazard mapping using RAMMS, a 2D avalanche dynamics model including snow entrainment. We studied a number of reference study sites of the Swiss procedure. The evaluation of the statistical uncertainties in the release and erosion depth results in mapping procedure with well defined accuracy, greater than that obtained using single site estimation.

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Quick chemical–environmental snowpack profile in Italian mountains

Massimo Pecci, Pinuccio D'Aquila (EIM), Mauro Valt, Valter Cagnati, Tiziana Corso (ARPAV-CVA), Alfredo Praolini, Eraldo Meraldi, Flavio Berbenni (ARPAL-CNB), Giovanni Kappenberger (METEOSWISS), Michele Freppaz, Paola Dellavedova, Gianluca Filippa (UNITO-DIVAPRA-LNSAUT)

After 3 years of observations, experimental measurements, tests and technical–scientific debates, started in winter 2005–06, over 700 measurements of pH and electrical conductivity were elaborated in 2009 in order to provide a 'photography' of the state of the environmental quality of the Alps and Apennines, though being extremely

simplified and localized. All that has led to considering snow 'in trench' an environmental framework that needs to be analyzed in depth and kept under control, also in the perspective of an 'environmental early warning' and in a more effective evaluation of the water resources quality.
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ABBREVIATIONS

AINEVA	Associazione Italiana Neve e Valanghe
ARPAV-CVA	Agenzia Regionale per la Protezione dell'Ambiente del Veneto – Centro Valanghe, Arabba
ARPA-VdA	Agenzia Regionale per la Protezione dell'Ambiente della Valle d'Aosta
ARPAL-CNB	Agenzia Regionale per la Protezione dell'Ambiente della Lombardia – Centro Nivometeorologico, Bormio
BAS	Bavarian Academy of Sciences and Humanities, Munich, Germany
CAI	Club Alpino Italiano
CBS	Centraal Bureau voor Schimmelcultures, The Netherlands
CESI	Centro Elettrotecnico Sperimentale Italiano, Milano
CGI	Comitato Glaciologico Italiano, Torino
CGT-SAT	Comitato Glaciologico Trentino – Società Alpinisti Tridentini, Trento
CKNP	Central Karakoram National Park
CNR-IREA	Consiglio Nazionale delle Ricerche – Istituto per il Rilevamento Elettromagnetico dell'Ambiente, Milano
CNR-IRPI	Consiglio Nazionale delle Ricerche – Istituto per la Protezione Idrogeologica del Bacino Padano, Torino
CNR-IRSA	Consiglio Nazionale delle Ricerche – Istituto per la Ricerca sulle Acque, Milano
CNR-ISAC	Consiglio Nazionale delle Ricerche – Istituto di Scienze dell'Atmosfera e del Clima, Bologna
CNR-ISMAR	Consiglio Nazionale delle Ricerche – Istituto di Scienze Marine, Venezia
CNR-ITIM	Consiglio Nazionale delle Ricerche – Istituto per le Tecnologie Informatiche Multimediali, Milano
CRUB	Centro Regional Universitario, Bariloche, Argentina
CRUI	Conferenza dei Rettori delle Università Italiane
EIM	Ente Italiano per la Montagna, Roma
ENEA	Agenzia Nazionale Nuove Tecnologie, Energia e Sviluppo Economico Sostenibile, Roma
EvK2CNR	EvK2CNR -URT del Consiglio Nazionale delle Ricerche (CNR) e Associazione 'Comitato EvK2CNR', Bergamo

EURAC	Accademia Europea Bozen/Bolzano
FLA	Fondazione Lombardia per L'Ambiente, Milano
FMS-CRGV	Fondazione Montagna Sicura-Cabina di Regia dei Ghiacciai Valdostani, Courmayeur
GEUS	Nationale Geologiske Undersøgelser for Danmark og Grønland
IMAGEO	IMAGEO s.r.l., Torino
IMAU	Institute for Marine and Atmospheric Research University of Utrecht.
INGV	Istituto Nazionale Geofisica e Vulcanologia, Roma
INN.TEC.	Innovation Technology Consortium, Brescia
IREALP	Istituto per L'Economia e L'Ecologia Applicate alle Aree Alpine (Regione Lombardia, Milano)
LGGE	Laboratoire de Glaciologie et Géophysique de l'Environnement, Grenoble, France
METEO	Meteo Swiss, Switzerland
SWISS	
MTSN	Museo Tridentino di Scienze Naturali, Trento
NERC	Natural Environment Research Council, UK
OSU	Ohio State University, USA
PAB-UG	Provincia Autonoma di Bolzano–Sudtyrol–Ufficio Geologico
PAB-UI	Provincia Autonoma di Bolzano–Sudtyrol–Ufficio Idrografico
PAT-M	Provincia Autonoma di Trento–Meteotrentino
PAT-SG	Provincia Autonoma di Trento – Servizio Geologico
PMS	Pakistan Meteorological Service
PNGP	Parco Nazionale Gran Paradiso
PRGS	Parco Regionale Grigna Settentrionale
POLIMI-DIIAR	Politecnico di Milano – Dipartimento di Ingegneria Idraulica, Ambientale, Infrastrutture viarie, e Rilevamento
POLITO	Politecnico di Torino
POLITO-DITAG	Politecnico di Torino, Dipartimento di Ingegneria del Territorio, dell'Ambiente e delle Geotecnologie
RL-IIT	Regione Lombardia – Infrastruttura per l'Informazione Territoriale
SAT	Società Alpinisti Tridentini, Trento
SG-CAIAA	Servizio Glaciologico Club Alpino Italiano Alto Adige, Bolzano
SGL	Servizio Glaciologico Lombardo, Milano
SLF	Institut für Schnee und Lawinenforschung, Davos, Switzerland
SIAT	Società Impianti Adamello Tonale
SMI	Società Meteorologica Italiana, Torino
TRI	Trimble Italia
TUM	Technical University of Munich, Germany.

UIO-DG	University of Oslo, Norway, Department of Geosciences	UNIPD-TeSAF	Università di Padova – Dipartimento Territorio e Sistemi Agro-Forestali
UNE-SBS	University of New England, Australia – School of Biological Sciences	UNIPG-DBA	Università di Perugia – Dipartimento di Biologia Applicata
UNIB	University of Bern, Switzerland	UNIP-DST	Università di Pisa – Dipartimento di Scienze della Terra
UNIBO-DISTART	Università di Bologna – Dipartimento di Strutture, Trasporti, Acque, Rilevamento, Territorio	UNIPV-DST	Università degli Studi di Pavia – Dipartimento di Scienze della Terra
UNIBO-DPS	Università di Bologna – Dipartimento di Scienze Farmacologiche	UNITO	Università di Torino
UNIBS-DICATA	Università di Brescia – Dipartimento di Ingegneria Civile, Architettura, Territorio, Ambiente	UNITO-DIVAPRA-LNSAUT	Università di Torino – Dipartimento di Valorizzazione e Protezione delle Risorse Agroforestali, Laboratorio Neve e Suoli Alpini
UNIBU	University of Bucarest, Romania	UNITO-DST	Università di Torino – Dipartimento di Scienze della Terra
UNICH-DST	Università di Chieti-Dipartimento di Scienze della Terra	UNITO-GSL	Università di Torino – Geositlab Gis and Geomatics Laboratory
UNIDUN-SSES	University of Dundee, School of Social and Environmental Sciences, UK	UNITN-DIA	Università di Trento – Dipartimento di Ingegneria Ambientale
UNIFE	Università di Ferrara	UNITS	Università di Trieste
UNIFI-DC	Università di Firenze – Dipartimento di Chimica	UNIUD-DSAA	Università di Udine - Dipartimento di Scienze Agricole e Ambientali
UNIGE-DIPTERIS	Università di Genova – Dipartimento per lo Studio del Territorio e sue Risorse	UNIVE	Università di Venezia
UNIMIB	Università di Milano Bicocca	UNIVI	University of Vienna, Austria
UNIMI-DST	Università di Milano – Dipartimento di Scienze della Terra	USN	The University in Svalbard, Norway
UNIMI-DB	Università di Milano – Dipartimento di Biologia	UZH-DG	University of Zurich, Department of Geography, Switzerland
UNIMORE-DC	Università di Modena e Reggio Emilia – Dipartimento di Chimica	WSL	Swiss Federal Institute for Forest, Snow and Landscape, Birmensdorf, Switzerland
UNINN-IG	University of Innsbruck – Institute of Geography, Austria		
UNINN-IMG	University of Innsbruck – Institute of Meteorology and Geophysics, Austria		
UNINS	Università dell'Insubria, Varese		
UNIPD-	Università di Padova – Dipartimento di Geografia		

Claudio Smiraglia and Guglielmina Diolaiuti



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JOURNAL OF GLACIOLOGY

Papers accepted for publication between 3 December 2009 and 31 March 2010. The papers are listed in alphabetical order by first author. Some of these papers have already been published.

Kelly M. Brunt, Matt A. King, Helen Amanda Fricker, Douglas R. MacAyeal
Flow of the Ross Ice Shelf, Antarctica, is modulated by the ocean tide

Caidong Caidong, Asgeir Sorteberg
Modelled mass balance of Xibu Glacier, Tibetan Plateau: sensitivity to climatic change

Helen Amanda Fricker, Ted Scambos, Sasha Carter, Curt Davis, Terry Haran, Ian Joughin
Synthesizing multiple remote-sensing techniques for subglacial hydrologic mapping: application to a lake system beneath MacAyeal Ice Stream, West Antarctica

K. Grunewald, J. Scheithauer
Europe's southernmost glaciers: response and adaptation to climate change

Alessio Gusmeroli, Roger A. Clark, Tavi Murray, Adam D. Booth, Bernd Kulessa, Brian E. Barrett
Seismic wave attenuation in the uppermost glacier-ice of Storglaciären, Sweden

Han Haidong, Wang Jian, Wei Junfeng, Liu Shiyin
Backwasting rate on debris-covered Koxkar Glacier, Tuomuer mountain, China

Andy Hodson, Karen Cameron, Carl Bøggild, Tristram Irvine-Fynn, Harry Langford, Dave Pearce, Steven Banwart
The structure, biological activity and biogeochemistry of cryoconite aggregates upon an Arctic valley glacier: Longyearbreen, Svalbard

Tristram D.L. Irvine-Fynn, Jonathan W. Bridge, Andrew J. Hodson
Rapid quantification of cryoconite: granule geometry and *in situ* supraglacial extents, using examples from Svalbard and Greenland

Anne-Marie Kietzig, Savvas G Hatzikiriakos, Peter Englezos
Ice friction: the effect of thermal conductivity

Matt A. King, Tavi Murray, Andy M. Smith
Non-linear responses of Rutford Ice Stream, Antarctica, to semi-diurnal and diurnal tidal forcing

Liu Qiao, Liu Shiyin, Zhang Yong, Wang Xin, Zhang Yingsong, Guo Wanqin, Xu Junli
Recent shrinkage and hydrological response of Hailuoguo glacier, a monsoon temperate glacier on the east slope of Mount Gongga, China

Sebastian H. Mernild Glen E. Liston
Konrad Steffen Petr Chylek
Meltwater flux and runoff modeling in the ablation area of Jakobshavn Isbræ, West Greenland

M. Montagnat, J. Weiss, B. Cinquin-Lapierre, P.A. Labory, L. Moreau, F. Damilano, D. Lavigne
Waterfall ice: formation, structure and evolution

Tsutomu Nakamura, Osamu Abe, Ryuhei Hashimoto, Takeshi Ohta
Dynamic method to measure the shear strength of snow

Daiki Nomura, Hisayuki Yoshikawa-Inoue, Takenobu Toyota, Kunio Shirasawa
Effects of snow, snowmelting and refreezing processes on air-sea-ice CO₂ flux

Jaime Otero, Francisco J. Navarro, Carlos Martin, Maria L. Cuadrado, Maria I. Corcuera
A three-dimensional calving model: numerical experiments on Johnsons Glacier, Livingston Island, Antarctica

Patrick Riesen, Shin Sugiyama, Martin Funk
The influence of the presence and drainage of an ice-marginal lake on the ice flow of Gornergletscher, Switzerland

Sam Roberson, Bryn Hubbard
Application of borehole optical televueing to investigating the 3-D structure of glaciers: implications for the formation of longitudinal debris ridges, midre Lovénbreen, Svalbard

David E. Shean, David R. Marchant
Seismic and GPR surveys of Mullins Glacier, McMurdo Dry Valleys, Antarctica: ice thickness, internal structure, and implications for surface-ridge formation

Bert de Smedt, Frank Pattyn, Pieter de Groen
Using the unstable manifold correction in a Picard iteration to solve the velocity field in higher-order ice-flow models

Hans Christian Steen-Larsen,
Edwin D. Waddington, Michelle R. Koutnik
Formulating an inverse problem to infer the accumulation-rate pattern from deep internal layering in an ice sheet using a Monte Carlo approach

Ken D. Tape, Nick Rutter, Hans-Peter Marshall,
Richard Essery, Matthew Sturm
Recording microscale variations in snowpack layering using near-infrared photography

Kai Ueltzhöffer, Verena Bendel, Johannes Freitag,
Sepp Kipfstuhl, Dietmar Wagenbach, Sérgio H. Faria, Christoph S. Garbe
Distribution of air bubbles in the EDML and EDC ice cores from a new method of automatic image analysis

Ioanna Vlahou, M. Grae Worster
Ice growth in a spherical cavity of a porous medium

Jiahong Wen, Yafeng Wang, Weili Wang,
K.C. Jezek, Hongxing Liu, I. Allison
Basal melting and freezing under the Amery Ice Shelf, East Antarctica

ANNALS OF GLACIOLOGY 51(54)

The following papers have been selected for publication in Annals of Glaciology 51(54) (thematic issue on Snow and Avalanches), edited by Perry Bartelt and Jürg Schweizer

Agraj Upadhyay, Amod Kumar, Arun Chaudhary
Velocity measurements of wet snow avalanche on the Dhundi snow chute

Marc Christen, Perry Bartelt, Julia Kowalski
Back calculation of the *In den Arelen* avalanche with RAMMS: interpretation of model results

J.C. Kapil, Anupam Kumar, P S Negi
Measurements of mid-winter spatial distribution of meltwater saturation

P. Mahajan, R. Kalakuntla, C. Chandel
Numerical simulation of failure in a layered thin snowpack under skier load

Prem Datt, P.K. Srivastava, G.K. Sood,
P.K. Satyawali
Estimation of equivalent permeability of snowpack using a snowmelt lysimeter at Patsio, northwest Himalaya

Ashok K. Keshari, Deba P. Satapathy,
Amod Kumar
The influence of vertical density and velocity distributions on snow avalanche runoff

Annals 51(54) is now complete and has been published

ANNALS OF GLACIOLOGY 51(55)

The following paper has been selected for publication in Annals of Glaciology 51(55) (thematic issue on Glaciology in the International Polar Year), edited by G. Hilmar Gudmundsson

Kelly M. Brunt, Helen A. Fricker, Laurie Padman,
Ted A. Scambos, Shad O'Neel
Mapping the grounding zone of the Ross Ice Shelf, Antarctica, using ICESat laser altimetry

Annals 51(55) is now complete and has been published

REPORT FROM THE NORDIC BRANCH MEETING

Höfn í Hornafjörður, east Iceland

The Nordic branch IGS meeting was held for the first time in Iceland on 29–30 October, followed by an excursion to the outlet glaciers of Vatnajökull on the way back to Reykjavík. The meeting was held on the east coast of Iceland, where the view to Vatnajökull and its outlet glaciers is fantastic and the closeness to the glacier is amazing – if only the fog would lift and reveal it. The first two days we had to do with the pictures the local people projected onto the walls to compensate for the bad visibility and believe their account of how great the views are. The weather improved, however, and during the excursion we were given the chance to confirm the stories and see the views with our own eyes.

On Thursday morning everybody was flown from Reykjavík to Höfn in a small aircraft and, had the conditions been good, we would have got a fantastic view over the glaciers in southern Iceland, but it was not granted this time. The meeting started in the afternoon, after registration, with the report from the IGS Secretary General who convinced us that the production time of the *Journal* and *Annals* has reduced so much that there is no excuse any longer not to submit papers to them. This was followed by a comprehensive talk by Finnur Pálsson about the evolution of the Vatnajökull ice cap from the settlement of the island. Two full sessions on various interesting topics followed before the meeting was treated to an excellent photo exhibition by Oddur Sigurðsson, who vividly told us interesting things about the glaciers in Iceland. The day ended with an icebreaker at the Glacier Museum in Höfn, where a very interesting exhibition was presented.

The meeting continued during Friday and we learned about the various projects in Norway, Svalbard, Iceland and other places where there is still ice, and mass balance records were presented that gave a rather bad outlook for the future of the glaciers. The lunch was given by the local hosts and we were treated to a wonderful meat soup served the Icelandic way, with a cultural event organized by the local organizer. A short but most interesting programme of the male choir Jökull culminated when Glacier sang the song Glacier, for the glaciologists. The day ended with a poster session with a number of interesting posters presented in the library of Nýheimar, the new building in Höfn where the meeting was held.

Singing continued to be a theme of the meeting. During the dinner all the countries represented provided an insight in the singing culture of each country. The Finns sang a drinking song, the French invited us to Paris and a stroll along the Champs Elysées, the Dutch ...sang *ein, zwei, drei* (can you remember?) and the sole Brit stood up and toasted everybody, the Norwegians gave an indoor ski performance, and the solitary Chileño sang a song about a broken Latin heart, and we even got a special vallon song from the Belgian participants, who managed also to team up with the Dutch and French (but skipped the Swedes although he was sponsored by them....). No wonder the EU selected a Belgian as president a few weeks later! The food was wonderful, left-over fish with bread made from left-over Danish pastries in the form of rye bread and then the main dish was the ugly fish lobster, which has not been considered human food until very recently (to quote Magnús



Fig. 1 En-route to the new lake in front of Hoffellsjökull, an outlet glacier from Vatnajökull ice cap near Höfn.



Fig. 2 Meeting participants at the margin of Hoffellsjökull. The glacier has retreated in recent years forming a new lake at the terminus.



Fig. 3 National Park Superintendent Regína Hreinsdóttir lectures about Skaftafell National Park to meeting participants. Model of the vicinity in the foreground and Öræfajökull central volcano and glacier in the background.

Már, in the old days people on farms around the village even had in their contract that they did not have to eat lobster more than six days a week!).

Saturday was spent half in the lecture hall, where we got the final dose of information, about tefra from subglacial volcanoes, deglaciation history and numerical simulations of both retreating glaciers and collapsing ice bricks. Some of the participants had caught a cold, perhaps from the rather wet party the day before (the rain poured down all that day), and coughs and sneezes were sometimes loud in the hall. The final presentation was given by our host, Þorvarður Árnason, who

had beautiful pictures of the glacier environment around Höfn and discussed the Glacier blues. Generous and loud applause thanked Þorvarður for his exposé – only drowned out by a cough attack from our beloved Secretary General, who had apparently joined the party the day before. The day was then completed by a half-day excursion to two glaciers, Hoffellsjökull and SV, and an ice cream producer. We were also warmly welcomed by the local farmer, who produced coffee and cake on the rock as well as mysterious meat pieces that the farmer had made himself from a secret recipe. The taste was interesting, a cross between beef jerky and bacon – which turned out to be boiled and dried horsemeat, a very tasty local delicacy. Jumping onto ice floes, or more correctly single pieces of dead ice on the fore field of Fláajökull, was one of the attractions of the excursion – who was to be the first in the proglacial lake? Tomas and Jon Ove led the way (you remember who fell in??).

The meeting was a great success and we are very grateful for the local organizers for giving us such a great time on the east coast of Iceland, the food was good and the entertaining excellent. We thank Tómas Jóhannesson, Sverrir Guðmundsson, Hrafnhildur Hannesdóttir, Eyjólfur Magnússon, Finnur Pálsson and the local host Þorvarður Árnason for a very generous and successful IGS Nordic branch meeting 2009.

Guðfinna Aðalgeirsdóttir
Veijo Pohjola

❄ Notes from the Production Team

Submissions

We're delighted that the average time between original submission and publication is at an all time low in the *Journal* and that, at this point in the year (March 2010), we've received more submissions than we did at the equivalent point in 2009 (itself a record-breaking year).

It would be a great help, and speed up our time from submission to acceptance further, if we could reduce the number of papers we receive written in unintelligible English! So if you are worried that your command of written English is not very good, please ask a friend or colleague with excellent English skills to check your paper before submission. Alternatively, we can give you details of professional copy editors who will be able to help.

Facebook and Twitter

If you are on Facebook, please join our group Friends of the International Glaciological Society (<http://www.facebook.com/group.php?gid=161647451062>). We are trying to instigate some lively forums and discussions on glaciological matters, but so far, although to date we have 87 friends, only Craig, Magnus, Sukie and myself have posted any comments. Please give us your thoughts! For those of you on Twitter, Craig has also begun tweeting at www.twitter.com/igsoc.

Christine Butler

Meetings of other societies

Northwest Glaciologists Meeting 2009

On Friday 23 October many of the glaciologists of the Pacific Northwest were meeting at Vancouver's University of British Columbia for the annual meeting of the Northwest Glaciologists. During two wonderful days we had the opportunity to hear about research progress in a great variety of topics and once more I was reminded why this remains my favorite scientific meeting. In traditional fashion the meeting participants showed up without abstract submission, so the program had to be assembled on the fly. Despite the fact that this is explicitly not a branch meeting of the IGS, we were very happy to welcome the esteemed Secretary General of the IGS, Magnús Magnússon. He opened the meeting by showing various graphs of journal publications and membership numbers. The *Journal of Glaciology* appears very healthy and in a remarkable turnaround has become one of the fastest publications in the field. Magnús presented a very thorough analysis and even pointed out the effects of the Chief Editor's summer vacation! Membership numbers are remaining lower than desired, however, and everybody was encouraged to join the society. These opening remarks were followed by an introduction to a new *Glossary of Mass Balance Terms* by one of its authors, Regine Hock. She reminded us that mass balance terms were often used in confusing and different ways. This immediately sent the IGS Secretary General off to a peaceful sleep. The glossary is still at the revision stage, so the precise use of mass balance, specific balance, etc, had not caught on yet, and in what followed, not



Fig. 2 Those University of Washington students are all the same – they can never be serious whether in or out of class.

even her own student would adhere to the new recommendations.

MacDougall then continued by explaining some methods to extrapolate local mass balance measurements to the regional level. This was followed with talks by Borstad and MacClung on fracture mechanisms in avalanches. After coffee break the attention shifted back to glaciers. Pfeffer gave a nice overview of all recent assessments of the cryosphere's contribution to sea level rise and projections for the next decade. Current change and projections for the next few decades are still dominated by mountain glaciers and ice caps, but Greenland is contributing at the same order of magnitude and Antarctica is no longer a

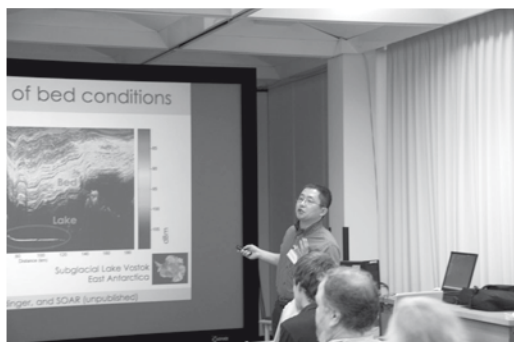


Fig. 1 The standard of the presentations was, as always, very high.



Fig. 3 Charlie Raymond came out of retirement to attend the NWG meeting and to see some of his old students, such as Neil Humphrey.



Fig. 4a The NWG meeting attracts a lot of interesting people....

negligible component of eustatic sea level rise. Obviously, all components have to be monitored and studied closely. As an example, Menounos presented work from co-author Berthier showing large changes in Alaska and neighboring Canada by analyzing digital elevation models produced from satellite imagery. Garry Clarke spoiled our picture of white landscapes and reminded us that glaciers are often quite dirty, which has a profound effect on their mass balance. He showed some ideas on how to incorporate this into glacier models. The topic then shifted rather abruptly to microbiology and Lanoil showed some evidence for life in subglacial environments. The morning was rounded out by a presentation from Miles. He does environmental consulting and showed many examples of changes in stream flow and sediment discharge caused by glacier change. It was a nice reminder that the most immediate effect of glacier change is usually not sea level rise, but the geomorphological and hydrological changes in glaciated basins.

After lunch, Piementel showed how to include hydrology into a higher order ice flow model. This was followed by Tsai's presentation of a fracture model for the rapid drainage of a supraglacial lake. McNabb presented a simple model for volume changes on Columbia Glacier,



Fig. 5 When Gwenn talks, the world listens.



Fig. 4b ... Some come from far away, like Tad Pfeffer from Boulder.

with the hope of expanding this to other calving glaciers. Bartholomaeus introduced a new project of motion, seismicity and calving at the Alaskan Yaktse Glacier. Picking up on the theme of modeling again, Andy Aschwanden presented his work on an enthalpy formulation for polythermal glaciers that avoids having to track a free boundary between cold and temperate ice. After a coffee break, Matsuoka presented some insights into radar wave attenuation in ice and some of the caveats in trying to distinguish wet from frozen beds using radar returns. Dan Shugar picked up on the subject of dirty glaciers by looking at the evolution of Black Rapids Glacier, which was covered in landslides during the 2002 Denali Fault earthquake. Florentine talked about rock glaciers and the potential to extract paleoclimate information from them. The day closed with Campbell's presentation of the changes at Crane Glacier and other glaciers on the Antarctic Peninsula.



Fig. 6 The meeting is an excellent opportunity to sit down to some face to face (computer) discussions.



Fig. 7 The bar staff at the dinner held at Garry and Julia's house.

Everybody's favorite part of Northwest Glaciologists is the Friday party, which was again graciously hosted by Julie Cruikshank and Garry Clarke. Good food and wine and plenty of opportunity for catching up with old friends rounded out a fine day.

Despite the previous night's party, people were off to a feisty start on Saturday morning. Jarosch had us all convinced that glacier dynamics really do matter, but he had most of us confused as to how he actually showed this. Things were clarified after heated discussion. Burke then followed by talking about climate glacier interactions and claiming that glacier reaction to random fluctuations in climate can be very large. The attention subsequently shifted back to Antarctica where



Fig. 8 Clarke cuts the meat with the same dedication he gives to all his projects.

Fudge was analyzing radar layers to infer past ice flow at Thwaites Glacier and Winberry presented a model for tidally induced seismicity that implies that the stagnant Kamb Ice Stream is still subject to very high basal water pressure.

After coffee break Truffer talked about seasonality in ocean temperatures and its effect on ice calving and proposed the term 'calving season' for the Mass Balance Glossary. Pettit talked about screaming infant bubbles breaking away from their icy confinements as she took on the novel subject of underwater acoustics near tidewater glaciers. The next two talks by Kennedy and Cairns were about the development of ice fabric in the snow and firn pack and in the interior of the ice sheets. Finally, Poinar presented a combined thermal and flow model to deduce both thickness of temperate layers and the magnitude of basal motion.

The afternoon was opened by Humphrey who presented fascinating year-round measurements of temperature in the upper 10 m of firn in Greenland with evidence for water motion and refreezing at all times of the year and at depths of more than 10 m. Jiskoot and her graduate student Juhlin presented an inventory of glaciers in Central East Greenland, which represents a large volume of ice that is not connected to the ice sheet proper. Dadic pointed out that there is a lack of good distributed accumulation models and proceeded to present one that was field tested on Haut Glacier d'Arolla. Anslow presented a model of regional glacier change in Western Canada on the centennial time scale. Koutnik gave a nice overview of the use of inverse methods in glaciology, together with the many opportunities and pitfalls of such methods. The meeting was closed by Lundstrom who ventured into glacial geology and talked about tunnel valleys under the Laurentide Icesheet.

Approximately 50 people attended the meeting, of which 34 elected to give talks. This left plenty of time for questions and discussion. A majority of the talks was given by graduate students or very recent post-graduates, while many of the 'old-timers', such as Charlie Raymond, Ed Waddington, and Bernhard Hallet, chose to listen and offer good advice. This has been a typical and welcome feature of many NWG meetings. The organizing committee under the able leadership of Gwenn Flowers deserves many thanks and so do Julie Cruikshank and Garry Clarke for hosting the wonderful party.

The tradition of the Northwest Glaciologists Meeting will continue in Fairbanks, Alaska, next year and we hope to welcome many of you up here.

Martin Truffer

INTERNATIONAL GLACIOLOGICAL SOCIETY

INTERNATIONAL SYMPOSIUM ON SNOW, ICE AND HUMANITY IN A CHANGING CLIMATE

*Sapporo, Japan
21–25 June 2010*



CO-SPONSORED BY:

Japanese Society of Snow and Ice



SECOND CIRCULAR

December 2009

<http://www.lowtem.hokudai.ac.jp/IGS-Sapporo/>

Registered Charity

INTERNATIONAL SYMPOSIUM ON SNOW, ICE AND HUMANITY IN A CHANGING CLIMATE

The International Glaciological Society will hold an International Symposium on Snow, Ice and Humanity in a Changing Climate in 2010. The symposium will be held from 21–25 June in Sapporo, Japan.

Theme

Snow and ice in the natural environment are facing drastic changes under the influence of rapidly changing global and regional climates. Since snow and ice play crucial roles in cold regions, such changes have substantial impacts on human societies and activities. For example, the amount of snow-fall and the duration of seasonal snow cover have been affected in many places, with consequences for the water resources and avalanche risks. Thawing permafrost causes destruction of infrastructure, and formation of glacier-dammed lakes poses potential hazards in mountainous regions. On the other hand, reduction of the summer sea ice extent in the Arctic creates new possibilities to use open water as a sea route for commercial vessels.

This symposium focuses on recent changes in the cryospheric components (snow, glaciers, ice sheets, permafrost, sea ice, lake ice, river ice) with respect to their influences on humanity. We invite contributions related to this subject in a broad sense, including ground-based observations, remote sensing, laboratory experiments, numerical modelling, data compilations and analyses, risk management and social impact assessment. Topics are not restricted to present-day issues, but also open for paleo-environmental records as they are important for understanding the present and predicting the future. The conference will bring together researchers engaged in different fields of cryospheric science in order to discuss interactions of snow and ice with humanity in the past, present and future.

Topics

The suggested topics include:

1. **Land ice and snow**, including: Snow cover, Glaciers, Ice sheets, Permafrost, Snow and glacier melt
2. **Ice and snow in the hydrosphere**, including: Sea ice, Ice shelves, Icebergs, River and lake ice
3. **Hazards and social problems related to snow and ice**, including: Snow avalanches, Glacier-dammed lake outbursts, Permafrost thawing, Snow and ice accretion, Blowing snow, Snow removal
4. **Use of snow and ice**, including: Snow air conditioning, Tourism, Teaching materials, Recreation

5. **Paleoclimate and paleoenvironment**, including: Ice core records, Past glaciation, Glaci-lacustrine and glaci-marine deposits, Subglacial and proglacial sediment-landform record
6. **Prediction of changes in the cryosphere**, including: Arctic sea ice, Area and property of snow cover, Glacier advance and retreat, Sea-level change

Sessions

Oral sessions are scheduled on four days from Monday to Friday (except for Wednesday, which is allocated for an excursion). Each oral presentation should last 20 minutes, including 5 minutes for questions and discussion. Poster sessions are planned on Tuesday and Thursday afternoons. The room for the poster sessions will be open from Monday to Thursday and posters may be displayed for approximately two days. Rooms are available during the symposium period for participants who wish to arrange small meetings. Please contact the local organizers (igs@lowtem.hokudai.ac.jp) in advance to book a room for your meeting.

Thematic publication

The Council of the IGS has decided to dedicate an issue of the *Annals of Glaciology* to the theme 'Snow, Ice and Humanity in a Changing Climate'. A first call for papers will be made in January 2010. Paper submission is open to anyone provided the topic of the paper is consistent with the theme of the *Annals* issue. Deadline for manuscript submission is 10 May 2010. Papers should be submitted through the IGS system and will be refereed according to the Society's normal standards before a publication decision is made. Every effort will be made to complete the reviews before the symposium so the associate editor and authors can discuss revisions during the symposium week. When submitting abstracts to the symposium, you will be asked to indicate whether you intend to submit a paper for the *Annals* issue, so that reviewers may be sought in advance. Papers submitted for consideration in the *Annals* issue must comply with the normal submission criteria of IGS publications.

Abstracts

Participants who would like to contribute to the Symposium should submit an abstract of their proposed presentation. This abstract must contain sufficient details, scientific merit and relevance to the symposium theme to be evaluated by the Scientific Steering Committee. The abstract should be less than 400 words with no references or illustrations. Please submit your abstract and relevant information online from the IGS or conference website. Authors may indicate a preference for an oral or poster presentation, although the number of oral presentations is limited by time. Those unable to submit their abstract online can send electronic files to

the IGS office where a member of staff will upload them onto the website.

DEADLINE FOR SUBMISSION OF ABSTRACTS IS 5 MARCH 2010

Each abstract will be assessed on its scientific quality and relevance to the symposium theme. Corresponding authors will be notified by 26 March 2010 regarding abstract acceptance. Please contact the IGS office if you do not receive the notification by this date. The accepted abstracts will be compiled into a booklet which will be provided to participants upon registration on 20 June 2010.

Participation

Online registration through the IGS system is encouraged. A link to the site will be available on the IGS and conference websites once the registration is open. For those who wish to register by post or FAX, a registration form is attached to this circular. Registration and the accompanying payment are due on 23 April 2010. There is a surcharge of £50 for later registration. The participant's registration fee includes organization costs, a set of abstracts, the ice breaker, coffee breaks, mid-week excursion, the symposium dinner and an issue of the *Annals of Glaciology*.

Registration fees

All fees are in Pounds Sterling, GBP

Participant (IGS member)	£400
Participant (non-member)	£479
Student or retired IGS member	£200
Accompanying person (18+)	£200
Accompanying person (12–17)	£160
Late registration surcharge (after 23 April 2010)	£50

Registration by mail

Though we strongly prefer registration through the website, it can also be done by filling in and returning the back page of this circular. If payment by credit card is not possible, contact the IGS office to arrange for a bank transfer. Payments made after 23 April 2010 must include the additional £50 late-registration fee. When completed, please send the form to Magnús Már Magnússon at the IGS address.

Accompanying persons

The accompanying person's registration fee (£200 for 18 and over; £160 for ages 12 to 17; under 12 free) includes the icebreaker, the mid-week excursion, and the symposium dinner. Short excursions in and around Sapporo will be offered on request at additional cost. These include short trips to sight-seeing spots in the city, day trip to the surrounding regions and experience of Japanese traditional culture (e.g. tea ceremony, dressing Kimono).

Social programme

The icebreaker reception will be on the evening of 20 June (Sun) after registration at Faculty House 'Enreiso' in the university campus. The excursion will be organized on 23 June (Wed). There will be a one day excursion to the natural and cultural sights of Sapporo and its vicinity. Details will be updated on the conference website. The symposium dinner will be held on 24 June (Thu) evening at 'The Sapporo Beer Garden' located in a former factory of Sapporo Brewery. More information will be listed on the conference website.

Venue

The symposium will be held at Hokkaido University in Sapporo. Sapporo is the capital city of Hokkaido, the northernmost main island of Japan, and is well known for its snowy winter, with a cumulative snowfall of more than 5 metres. There is no other city in the world with a population of nearly 2 million that accumulates this amount of snow. The university campus is located close to the heart of the city. The venue of the symposium is the University Conference Hall, 10 minutes walk from Sapporo's main railway station and within easy reach of the city centre. June is a wonderful season to visit the region. The city is filled with fresh green along with a feast of flowers and the climate is ideal for enjoying outdoor activities. Daily minimum and maximum temperatures in June are 12 and 21°C, respectively. Hokkaido escapes the rainy season, which lasts from June to July in the other regions of Japan. Further information on Sapporo is available at <http://www.welcome.city.sapporo.jp/english/>.

Travel to Sapporo

Sapporo's main airport is New Chitose Airport, which is connected to the city centre by JR (Japan Railways Company) airport express train. The train runs about every 15 minutes, takes about 40 minutes and costs 1,040 yen (one way). JAL (Japan Air Lines), ANA (All Nippon Airways) and some other carriers operate 40–50 flights per day between Tokyo Haneda Airport and New Chitose Airport (the world's busiest air route!). Several flights from Japan's main international airports, Tokyo Narita, Kansai Osaka and Nagoya Central Japan, as well as other regional airports are available per day. International flights are also operated from Korea (Incheon Seoul and Pusan) and China (Shanghai, Beijing, Hong Kong and Dalian).

Accommodation

A number of hotels ranging in price from budget to higher-end are available within a walking distance of the symposium venue. A limited number of rooms are reserved at these hotels for the symposium period. Available accommodation as well as booking instructions

will be provided on the conference website. To take advantage of the block bookings, please reserve your rooms online by 31 May. Please contact the travel agency of the conference (JTB: Japan Travel Bureau) at IGS-Sapporo@jtb.jp for inquiries on the accommodation booking and any other domestic travel information.

Symposium organization

Magnús Már Magnússon (International Glaciological Society)

Scientific steering and editorial committee

Perry Bartelt (Co-Chief Scientific Editor),
Douglas R. MacAyeal (Co-Chief Scientific Editor),
Luca Egli, Ed Adams, Kalle Kronholm,
Florence Naaim, Jo Jacka, Ralf Greve,
Shuhei Takahashi

Local organizing committee

Atsushi Sato (Chairman), Osamu Abe,
Kumiko Goto-Azuma, Yoshiyuki Ishii,
Yuji Kodama, Sumito Matoba, Hiroki Matsushita,
Kazuki Nakamura, Koichi Nishimura,
Toshihiro Ozeki, Shin Sugiyama, Nozomu Takeuchi

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Email: igs@lowtem.hokudai.ac.jp
Web: <http://www.lowtem.hokudai.ac.jp/IGS-Sapporo/index.html>

Dates and deadlines

Abstract submission deadline	5 March 2010
Notification of acceptance	26 March 2010
Preregistration deadline	23 April 2010
Paper submission deadline	10 May 2010
Deadline for refund	14 May 2010
Registration and Icebreaker	20 June 2010
Conference begins	21 June 2010
Final revised papers deadline	9 August 2010

INTERNATIONAL SYMPOSIUM ON SNOW, ICE AND HUMANITY IN A CHANGING CLIMATE

Sapporo, Japan, 21–25 June 2010

REGISTRATION FORM

Register online at www.igsoc.org/symposia/2010/sapporo/registration

Family Name: _____

Given Name(s): _____

Address: _____

Tel: _____ Fax: _____

E-mail: _____

Accompanied by:

Name: _____ Age (if under 18) _____

Name: _____ Age (if under 18) _____

Dietary requirements (vegetarian, pescetarian, gluten, lactose, etc.)

Registration fees (British pounds)

Participant (IGS member) £400

Participant (not IGS member) £479

Student or retired IGS member £200

Accompanying person (18+/12–17) £200/£160

Late registration surcharge (after 23 April 2010) £50

TOTAL REGISTRATION FEES £_____

Payment of registration fee by Access/Eurocard/MasterCard or VISA/Delta

Card number

Expiration (yy/mm) / CVV (last 3 numbers on signature strip)

Name of card holder as shown on card: _____

Signature: _____

INTERNATIONAL GLACIOLOGICAL SOCIETY

INTERNATIONAL SYMPOSIUM ON EARTH'S DISAPPEARING ICE: DRIVERS, RESPONSES AND IMPACTS

*A celebration of the 50th anniversary of the Byrd Polar Research Center
(formerly the Institute of Polar Studies)
Columbus, Ohio 43210, USA
15–20 August 2010*



CO-SPONSORED BY:
Byrd Polar Research Center
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The Ohio State University

SECOND CIRCULAR

January 2010

<http://www.igsoc.org/symposia/>
http://bprc.osu.edu/workshops/igs_2010/

Registered Charity

The International Glaciological Society will hold an International Symposium on 'Earth's Disappearing Ice' in 2010. The symposium will be held in Columbus, Ohio, USA, from 15–20 August 2010.

THEME

One of the most visible indicators of climate change is the response of Earth's ice cover. Over the second half of the 20th century alpine glaciers worldwide retreated. Satellite observations over the last two decades reveal rapid changes in many outlet glaciers that drain large sections of the Greenland and Antarctic ice sheets. Ice-shelf disintegration is becoming more frequent with consequences for the discharge of land-based ice to the oceans. The extent of summer sea ice on the Arctic Ocean is declining and the possibility of ice-free summer conditions well before the end of the century is not outside the realm of possibility. This symposium will focus on the drivers for such changes, the potential feedback and responses of the climate system to these changes and the likely impact that might be expected in response to the ongoing large-scale deglaciation of the planet. An additional goal of the conference is to identify major gaps in our scientific understanding, observational databases, modeling approaches and the need for enhanced human capital and fiscal resources to advance our predictive capability.

TOPICS

The suggested topics include:

1. Sea ice extent and thickness changes in the Arctic and Antarctic, focusing on the different driving mechanisms, responses in the Arctic versus the Antarctic, potential impact on the ocean–atmosphere system, regional climate variability, polar ecosystems, human systems and infrastructure.
2. Tidewater glacier dynamics, iceberg calving and sedimentation dynamics, including observations and parameterizations of calving from floating and grounded termini, the role of sedimentation in grounding line stability, and interactions between ice-marginal processes and glacier speed.
3. Ice shelf dynamics, including the preconditioning and eventual mechanisms by which breakup occurs, impacts of breakup on the ocean–atmosphere system and adjacent land-based ice, limitations to ice-shelf break-up suggested by past ice-sheet and ice-shelf configurations, and break-up scenarios under other climate regimes suggested by paleo-oceanographic and glacial geologic inference.
4. Ice streams and outlet glacier dynamics, including observations and modeling to elucidate the key mechanisms controlling flow and discharge with particular emphasis on subglacial processes.
5. Glacier and ice-sheet mass balance, including a global inventory and assessments, atmospheric and oceanic forcing, response to large-scale

modes of climate variability, observational methods, modeling approaches and predictions, up-scaling, partitioning into climatic and dynamic mass balance components, key unknowns, critical observations and limitations to progress.

6. Alpine glaciers (at all latitudes), including observations, driving mechanisms, modeling, impact on associated watersheds and associated societal impact. Special emphasis on alpine glacier changes in regions where traditional forms of glaciological survey are limited and that may be especially vulnerable to climate change (such as the Himalayas and South American Andes).
7. Records of past glacier changes, including proxy histories that elucidate key drivers, responses and response rates.

SESSIONS

Oral sessions are scheduled on four days from Monday to Friday (except for Wednesday, which is allocated for an excursion). Each oral presentation should last 20 minutes, including 5 minutes for questions and discussion. Poster sessions are planned on Tuesday and Thursday afternoons. The room for the poster sessions will be open from Monday to Thursday and posters may be displayed for approximately two days. Rooms are available during the symposium period for participants who wish to arrange small meetings. Please contact the local organizers (igs@bprc.mps.ohio-state.edu) in advance to book a room for your meeting.

THEMATIC PUBLICATION

The Council of the IGS has decided to dedicate an issue of the *Annals of Glaciology* to the theme 'Earth's Disappearing Ice'. A first call for papers will be made in March 2010. Paper submission is open to anyone provided the topic of the paper is consistent with the theme of the *Annals* issue. Deadline for manuscript submission is 5 July 2010. Papers should be submitted through the IGS system and will be refereed according to the Society's normal standards before a publication decision is made. Every effort will be made to complete the reviews before the symposium so the associate editor and authors can discuss revisions during the symposium week. When submitting abstracts to the symposium, you will be asked to indicate whether you intend to submit a paper for the *Annals* issue, so that reviewers may be sought in advance. Papers submitted for consideration in the *Annals* issue must comply with the normal submission criteria of IGS publications.

ABSTRACTS

Participants who would like to contribute to the Symposium should submit an abstract of their proposed presentation. This abstract must contain sufficient details, scientific merit and relevance to the symposium theme to be evaluated by the Scientific Steering Committee. The abstract should be less than 400 words with no references or illus-

trations. Please submit your abstract and relevant information online from the IGS or conference website. Authors may indicate a preference for an oral or poster presentation, although the number of oral presentations is limited by time. Those unable to submit their abstract online can send electronic files to the IGS office where a staff member will upload them onto the website.

DEADLINE FOR SUBMISSION OF ABSTRACTS IS 23 APRIL 2010

Each abstract will be assessed on its scientific quality and relevance to the symposium theme. Corresponding authors will be notified by 21 May 2010 regarding abstract acceptance. Please contact the IGS office if you do not receive the notification by this date. The accepted abstracts will be compiled into a booklet that will be provided to participants upon registration on 15 August 2010.

PARTICIPATION

Online registration through the IGS system is encouraged. A link to the site will be available on the IGS and conference websites once the registration is open. For those who wish to register by post or fax, a registration form is attached to this circular. Registration and the accompanying payment are due on 18 June 2010. There is a surcharge of £50 for later registration. The participant's registration fee includes organization costs, a set of abstracts, the ice breaker, coffee breaks, mid-week excursion, the symposium dinner and an issue of the *Annals of Glaciology*.

REGISTRATION FEES	\$	£	€
Participant (IGS member)	510	310	350
Participant (non-member)	650	400	440
Student/Retired	255	155	175
Accompanying person (adult)	325	198	223
Accompanying person (no field trip)	75	46	52
Accompanying person (<18)	260	158	179
Accompanying person (<12)		Free	
Late registration fee	85	50	58

Note that all online credit card payments will be in £ sterling (GBP)

REGISTRATION BY MAIL

Though we strongly prefer registration through the website, it can also be done by filling in and returning the back page of this circular. If payment by credit card is not possible, contact the IGS office to arrange for a bank transfer. Payments made after 18 June 2010 must include the additional £50 late-registration fee. When completed, please send the form to Magnús Már Magnússon at the IGS address.

ACCOMPANYING PERSONS

The accompanying person's registration fee (\$325 for 18 and over; \$260 for ages 12–17; under 12 free) includes the icebreaker, the mid-week field trip, and the symposium dinner. Those adult (18

and older) accompanying persons who do not wish to participate in the field trip can attend the ice-breaker and banquet for a fee of \$75.

SOCIAL PROGRAMME

An icebreaker reception will be on Sunday evening at the newly renovated William Oxley Thompson Library Campus Reading Room located on the 11th floor at the west end of the OSU Oval. The window-filled room provides a spectacular birds-eye view of the OSU campus, including the often photographed Oval Mall and Orton Hall.

Tuesday evening conference attendees will have the opportunity to visit the Byrd Polar Research Center. Guided tours and video presentations will give conference participants a first hand look at the extensive research that has been conducted by faculty, research scientists, post-docs and students at the Center since 1960.

The symposium banquet will be held on Thursday evening at the Ohio State University Faculty Club. The Faculty Club is located on the historic Oval between Mirror Lake and Orton Hall, home to the Geology Library and the Orton Geological Museum. The Faculty Club has been serving the OSU Community since the late 1930s and its quiet ambience makes it an excellent venue for dining and conversation.

VENUE

The symposium will be held at the Ohio State University (OSU), Columbus, Ohio in the New Ohio Union on High Street. OSU is a public research university founded in 1870 as a land-grant university and is currently the second largest university campus in the USA. Columbus is the state capital, located in the heart of Ohio, and the city has numerous historic areas including German Village, the Short North, and Victorian Village. Other attractions include the Arena District, Franklin Park Conservatory, Ohio Historical Society, Columbus Art Museum and the Center of Science and Industry. The city features restaurants of every cuisine including American, Italian, German, Japanese, Korean and Indian, with prices for all budgets. Weather in August can be very hot and humid, reaching 31°C / 88°F, and on occasion even higher. Short sleeves and light-weight clothing are recommended. Be prepared for rain or a cool spell, as in Columbus we say, 'wait five minutes and the weather will change!' More information on OSU is available at <http://www.osu.edu/> and details on Columbus can be found at <http://www.experiencecolumbus.com/>.

FIELD EXCURSION

Wednesday field trip: Visualizing Changing Landscapes: Disappearance of the Scioto Lobe of the Laurentide Ice Sheet, Ohio (the trip includes several other points of geologic and cultural interest). Landforms associated with the Scioto Lobe in east-central Ohio during the Last Glacial Maximum (LGM) reveal the processes, materials and envi-

ronments of the glacier system. We reconstruct the paleogeography and glacial history to provide a model of changes at and near the ice margin on this glaciated section of the Appalachian Plateaus Province at 40°N. In eastern Licking County, kames, terraces, moraines, ice-marginal lake deposits and reversed drainage systems record the impact of the glacier at and beyond the terminus. Field stops will highlight glacial, glacialfluvial, and glaciallacustrine landforms and related materials (e.g. till, outwash gravel, lake sediments and peat deposits) as we seek to improve our understanding and visualization of the glacier system.

As the ice disappeared, landforms continued to evolve and lake basins and kettles accumulated the record of a changing biosphere, one in which northern species of trees gave way to hardwoods and some Ice Age animals disappeared. Research on materials from the Burning Tree mastodon site (1989) in Licking County has provided new insight to the paleoenvironment, the mastodon diet, viability of bacteria, and our understanding of human occupation of Ohio 13,000 years ago. After viewing a time-line of ancient cultures at the Great Circle Earthworks Museum in Heath, participants can explore the adjacent Newark Earthworks, 'the largest set of geometric earthen enclosures in the world'. Built by the prehistoric Hopewell about 2000 years ago, the earthworks had ceremonial, social and astronomical functions. The evening meal will be in the Newark area, possibly overlooking ancient Earthworks, while we reflect on natural and human-induced landscape changes since the Scioto Lobe disappeared and we attempt to visualize future landscapes in response to continuing loss of ice far from here. The trip will conclude in Columbus by 10:00 pm.

TRAVEL TO COLUMBUS

Port Columbus International Airport is located approximately 20 minutes from the OSU campus. The airport is 7 miles (11 km) NE of the city center. Taxis, hotel shuttles and rental cars are available from the airport into the city. Columbus has connections throughout the USA with Washington DC, Chicago, Atlanta, Minneapolis and New York non-stops connecting with many international flights. Delta, United, Northwest and US Airways have daily flights in and out of Columbus with over a dozen airlines serving the area. For more information on Port Columbus please visit their website: <http://www.port-columbus.com/home.asp>.

ACCOMMODATION

Block bookings have been arranged at hotels in Columbus on or near the OSU campus. A large block of individual dorm rooms (single & double accommodation) have been reserved in the OSU North Campus area. Prices range from budget dorms to high-end hotels. For those interested, bed and breakfast offerings near the campus are also listed on the BPRC IGS web page (<http://bprc.osu.edu/workshops/>

[igs_2010/](http://bprc.osu.edu/workshops/igs_2010/)). To ensure a room please reserve it by 30 June and mention the OSU-IGS Symposium to get the conference rate. A conference bus will pick up participants at designated locations for transportation to and from the conference site. A list of available accommodation is on the conference website (http://bprc.osu.edu/workshops/igs_2010/) with individual hotel information and booking instructions included.

SYMPOSIUM ORGANIZATION

Magnús Már Magnússon (International Glaciological Society)

SCIENCE STEERING AND EDITORIAL COMMITTEE

Kees van der Veen, Chief Editor (U. Kansas), Gudfinna Adalgeirsdottir (Danish Meteorological Institute), Jason Box (Ohio State U.), Adrian Jenkins (British Antarctic Survey), Ian Joughin (U. Washington), Nina Kirchner (Stockholm U.), Doug MacAyeal (U. Chicago), Ellen Mosley-Thompson (Ohio State U.), Tad Pfeffer (U. Colorado), Stephen Price (Los Alamos National Lab.), Leigh Stearns (U. Kansas), Lonnie Thompson (Ohio State U.), Slawek Tulaczyk (U. California Santa Cruz), Dirk van As (Geological Survey of Denmark and Greenland)

LOCAL ORGANIZING COMMITTEE

Ellen Mosley-Thompson (Chair), Michele Cook, Lynn Everett, David Elliot, Paolo Gabrielli, Ian Howat, Lynn Lay, Garry McKenzie and Lonnie Thompson

CONTACTS FOR FURTHER INFORMATION

Magnús Már Magnússon

International Glaciological Society
Scott Polar Research Institute
Lensfield Road, Cambridge. CB2 1ER, UK
Tel: +44 (0)1223 355 974; Fax: (0)1223 354 931
Email: igsoc@igsoc.org
Web: <http://www.igsoc.org/symposia/2010/ohio/>

Local Organizing Committee

Byrd Polar Research Center
The Ohio State University, 108 Scott Hall
1090 Carmack Road, Columbus, OH 43210
USA
Tel: +1 614-292-6531 or 614-292-9909
Fax: +1 614-292-4697
Email: igs@bprc.mps.ohio-state.edu

IMPORTANT DATES

Abstract submission deadline	23 April 2010
Notification of acceptance	21 May 2010
Preregistration deadline	18 June 2010
Paper submission deadline	5 July 2010
Deadline for refund	9 July 2010
Registration and Icebreaker	15 August 2010
Conference begins	16 August 2010
Final revised papers deadline	4 October 2010

INTERNATIONAL SYMPOSIUM ON EARTH'S DISAPPEARING ICE COVER

Columbus, Ohio, USA, 15–20 August 2010

REGISTRATION FORM

Register online at www.igsoc.org/symposia/2010/ohio/registration

Family Name: _____

Given Name(s): _____

Address: _____

Tel: _____ Fax: _____

E-mail: _____

Accompanied by:

Name: _____ Age (if under 18) _____

Name: _____ Age (if under 18) _____

Dietary and other requirements

Registration fee	\$	£	€
Participant (IGS member)	510	310	350
Participant (non-member)	650	400	440
Student/Retired	255	155	175
Accompanying person (adult)	325	198	223
Accompanying person (no field trip)	75	46	52
Accompanying person (<18)	260	158	179
Accompanying person (<12)		Free	
Late registration fee (after 18 June)	85	50	58

TOTAL REGISTRATION FEES £_____

Payment of registration fee by Access/Eurocard/MasterCard or VISA/Delta

Card number

Expiration (yy/mm) / CVV (last 3 numbers on signature strip)

Name of card holder as shown on card: _____

Signature: _____



Future meetings of other societies

11th International Circumpolar Remote Sensing Symposium

Scott Polar Research Institute, Cambridge, UK

20–24 September 2010

The 11th International Circumpolar Remote Sensing Symposium (<http://alaska.usgs.gov/science/geography/CRSS2010/>) will be held in September 2010 at Cambridge's Scott Polar Research Institute. Prior to the conference (Monday, 20 September 2010), there will be a one day UK Polar Network Workshop on Circumpolar Remote Sensing.

The conference deals specifically with remote sensing applications in the polar environments, both Arctic and Antarctic. It will provide an international forum for the discussion of work currently being carried out in the circumpolar regions. Topics that have been discussed at previous CRSS meetings have included environmental monitoring, the cryosphere, resource prospecting, vegetation measurement, LiDAR, RADARSAT, Polar GIS

applications, and many others. The deadline for abstract submission is 31 May 2010.

Prior to the conference, the UKPN Workshop is directed at graduate students and other early career researchers. Sessions in development include Open source remote sensing and GIS, Imaging climate change and Innovating new techniques; suggestions from potential participants are encouraged. The day will also feature a career mentoring panel and will culminate with the CRSS Icebreaker Reception.

Further details of the conference and workshop are under development – please contact Allen Pope at allen.pope@polarnetwork.org with questions and input.



Books received

Eicken, H., R. Gradinger, M. Salganek, K. Shirasawa, D. Perovich and M. Leppäranta, eds. 2009. *Field techniques for sea ice research*. Fairbanks, Alaska, University of Alaska Press. 588 pp, 218 graphs and figures, DVD. (ISBN: 978-1-60223-059-0, (Cloth) US\$65.00.)

Thomas, D.N. and G.S. Dieckmann, eds. 2009. *Sea ice, Second edition*. Oxford, Wiley-Blackwell. 640pp. (ISBN: 978-1-4051-8580-6, (Cloth) £89.99/ €103.50.)

Pellikka, P. and W.G. Rees, eds. 2010. *Remote sensing of glaciers; techniques for topographic, spatial and thematic mapping of glaciers*. London, CRC Press/Balkema (Taylor & Francis Group). 340pp. (ISBN: 978-0-415-40166-1, (Cloth) £89).

Bennett, M.M. and N.F. Glasser, eds. 2009. *Glacial geology: ice sheets and landforms, Second edition*. Oxford, Wiley-Blackwell. 400 pp. (ISBN: 978-0-470-51690-4, (Cloth) £85.00 / €97.80, ISBN: 978-0-470-51691-1, (paperback) £ 29.95 / €34.50).



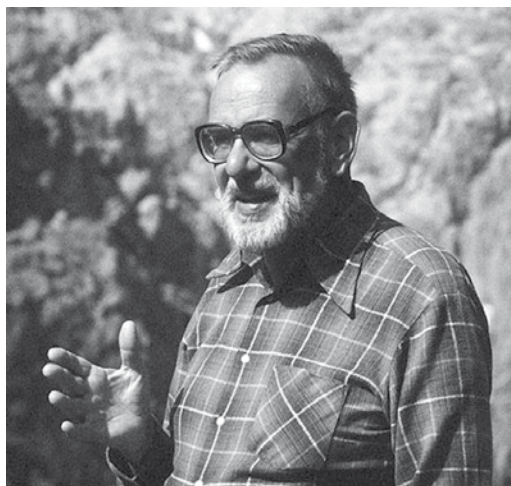
Obituary: Hans Röthlisberger

Dr Hans Röthlisberger, professor emeritus at ETH (Swiss Federal Institute of Technology) Zurich, and 9th president of the International Glaciological Society, died at his home in Uerikon, Zurich, on 10 September 10 2009. Hans, who used jokingly to call himself 'Tschoon' in a Swiss German pronunciation of his Anglicized name, had a rich life.

Hans was born on 1 February 1923 in Langnau in Emmental, the youngest of the three children of Johann and Marie Röthlisberger-Stucki, who were both teachers. Emmental, best known for the famous Swiss cheese, is a valley located in the middle of the tertiary pre-alpine uplifted terraces. These terraces are dissected by many small valley systems, forming a gently undulating hilly landscape covered with rich vegetation and pasture. At the southern end of the Emmental Valley the Alps soar abruptly to above 2000 meters.

Hans's father died when he was a year old, leaving his mother to raise three children and to support the family as a teacher. He spent his childhood in Emmental with his two older sisters, attending local primary and secondary schools, before moving to the Cantonal Seminar in Berne. In 1943 he entered the Faculty of Natural Sciences at ETH. Between university semesters, he was a substitute teacher at a primary school in Kalberhöni, a beautiful side valley of Saanen-Gstaad. It was there that he developed his life-long love of mountains. In 1947, he completed his 'Diplomarbeit' (equivalent to an MSc thesis) at the Department of Petrography with the theme 'Profile through Gotthardmassiv between Ulrichen and the Gries Pass with special reference to structural geology'. Prof. Paul Niggli, discoverer of the isotope/paleo-temperature principle, supervised him. In that year he became a member of the Academic Alpine Club of Berne. He grew into an accomplished rock and ice climber. Hans started his doctoral studies in the same year at the Department of Geophysics under the supervision of Prof. Fritz Gassmann, who was also the director of the Swiss Earthquake Service.

During his time as a doctoral student, Hans participated in three expeditions to the Arctic. In 1950 he spent half a year on the Barnes ice cap with the Arctic Institute of North America's



Baffin Island Expedition. In the summer of 1951 he worked in East Greenland, accompanying Dr Hans Rudolf Katz, a geologist. In 1953 he was back in Baffin Island, on Penny Highland. During these expeditions, his contributions were centered on seismology. His doctoral thesis, completed in 1954, was entitled 'On seismic and petrographic characterization of several Molasse rocks, including a description of the methods for determining grain size in solid material'. Upon completion of his doctoral thesis, Hans obtained a position as a research fellow at the Institute of Water and Foundation Engineering at ETH. Here Hans came in contact with Prof. Peter Kasser and Robert Haefeli, who influenced his future interest in glaciers.

Hans met a young woman named Miss Doris Baechli in Zurich and led her to the altar in 1954. Two years later their first daughter, Annelis, was born. In 1957 the young family moved to Wilmette, IL, USA, where Hans worked at the US Army Snow, Ice and Permafrost Research Establishment (SIPRE, the predecessor of CRREL). He was engaged in seismological applications in the northwestern region on the Greenland ice sheet. In Wilmette he shared an office with Prof. Ukichiro Nakaya. Hans spoke of their stimulating discussions on the deformation of single crystal ice, a lesser-known part of Nakaya's work. In 1958, their second daughter,

Susan, was born, so that when the Röthlisbergers returned to Switzerland and Hans to ETH in 1961, they were now a family of four.

At ETH Hans's work was very much concerned with the engineering side of glaciology, in particular of the safety and risk issues of ice. He was engaged in the decision-making process on the safety of the frozen Lake of Zurich in 1962/63; the catastrophic collapse of Allalingsletscher in 1965; an estimation of the risk of glacier collapse near Mauvoisin and Les Diableret in 1966; the danger of a glacier collapse in Gasterentales in 1967; the flood from the moraine-dammed lakes of the Grubengletscher; an ice avalanche problem above Felskinn in 1969; the breaking-off of Biesgletscher on Weisshorn in 1972/73; safety considerations of water intake facilities of the hydroelectric company Oberhasli in face of a glacier advance in 1982/83; and the danger posed by an ice-dammed lake at Austdalsbreen in 1987. He closely cooperated with the Swiss Federal Institute of Snow and Avalanche, Weissfluhjoch, Davos, especially with the late Prof. Marcel de Quervain and Dr Bruno Salm. In many problems presented above, his often technical solutions to actively mitigate dangers are pioneering works in engineering glaciology. Hans did not draw any sharp lines between these highly applied fields and the basic research for which he is better known.

In 1972 after completing his Habilitation (post-doctoral) thesis, which was concerned with flood and ice catastrophes related to glaciers, he began his two year lecture series 'Physical and technical glaciology', a title which aptly describes how he viewed glaciology. Each of the four semesters covered a theme: first semester, basic physics of ice; second semester, physics of glaciers; third semester, physics of lake ice, river ice, sea ice and permafrost; forth semester, prospect and sounding of ice bodies. The lectures were extremely demanding, requiring a sound knowledge of mathematics and physics. Students who attended these lectures gained a deep appreciation for glacial processes.

At the same time as preparing his lectures, Hans was making significant advances in his research area. One of his most prominent achievements, the hydraulics of glacier channels, was published in 1972 (*J. Glaciol.*, Vol.11, No. 62). This work opened a new chapter in glaciology, by introducing the opening and maintaining mechanisms of the sub-glacier channel. This was probably the most important step after the earlier lubrication mechanisms had been proposed. Theoretical estimations

of sub-glacier channel conditions had never been made in such a comprehensive manner; many of the theoretical assumptions in his model were based on Gornergletscher, whose Gornersee made occasional bursts through the sub-glacier channel to flood the village of Zermatt. Following this paper Hans made significant and valued contributions to research whenever water in glaciers was involved. One of the later tasks he personally took in hand was the study of the flow of Jakobshavn Isbrae on west Greenland, a rare ice stream in the Northern Hemisphere.

Owing to his significant and numerous accomplishments in research and teaching, the Swiss Federal Council bestowed on him the title of Professor in 1984. He was the president of the International Glaciological Society from 1984 to 1987, receiving many honors including the Seligman Crystal in 1992, and was elected an honorary member of the society in 2008. Even after Hans's retirement from ETH in 1988, he actively participated in glaciology seminars, sharing his extensive knowledge and experience with young scientists. In discussions Hans was always extremely modest and respected the ideas of others.

Throughout their marriage, Doris cared for the family and her excellent organization and tireless support created the ideal environment for Hans to make his significant and unique contribution to glaciology.

In 2007 Hans was diagnosed with cancer. While he fought the disease, he never allowed his illness to rule his life. He continued to attend glaciology seminars, took part in symposia, and attended lectures in other scientific disciplines. He enjoyed an active social life with family and friends. He never lost his wonderful sense of humour. I visited Hans on Sunday 6 September to deliver a bottle of wine from Tramin. He said cheerfully, 'Oh, we should open the bottle now, so that Atsumu can also enjoy it', knowing that I could not drink a drop of wine. This was just four days before he left us, and three days before he fell into a coma. We will deeply miss this genuine, optimistic and warmhearted man, but the courage he showed to the end is an invaluable gift to all of us.

Hans is survived by his wife, Doris, his two daughters, Annelis and Susan, and his three granddaughters, Esther, Kathrin and Miriam, and both sisters, Klara and Verena.

Atsumu Ohmura



Glaciological diary

** IGS sponsored

* IGS co-sponsored

2009

1–3 October 2009

**International Forum for Research into Ice Shelf Processes (FRISP)/
West Antarctic Ice Sheet Initiative (WAIS)
Joint Workshop**

Pack Forest Conference Center, WA, USA
Contact: Adrian Jenkins [ajen@bas.ac.uk]

7–10 October 2009

Polar Science and the Chemistry of Climate Change

Northeast Regional Meeting, American Chemical Society
Hartford, Connecticut
Website: <http://membershship.acs.org/N/nerm/>
Contact: Kathy Gorski [kmgorski@concentric.net]

12–13 October 2009

UK Polar Network Arctic Marine Sciences Workshop

Plymouth, UK
Website: http://www.polarnetwork.org/new/index.php?option=com_content&view=article&id=93&Itemid=88
Contact: Claudia Halsband-Lenk [clau1@pml.ac.uk]
or Angelika Renner [angelika.renner@polarnetwork.org]

23–24 October 2009

Northwest Glaciologists' Meeting

Vancouver, BC, Canada
Website: <http://www.sfu.ca/~gflowers/nwg2009>
Contact: Gwenn Flowers [gflowers@sfu.ca] or Christian Schoof [cschoof@eos.ubc.ca]

28–31 October 2009

Environments, Movements, Narratives in the Circumpolar North

Rovaniemi, Finland
Website: <http://www.arcticcentre.org/?Deptid=28867>
Contact: Karl Mertens [karlmertens@u.boisestate.edu]

27–31 October 2009

**International Colloquium –
Climate Change in Magellan and Antarctic Regions: Evidence and Challenge for the Future**

Punta Arenas, Chile
Website: <http://www.umag.cl/cambioclimatico/en>

29–31 October 2009

***Nordic Branch meeting of the International Glaciological Society**

Höfn in Hornafjörður, Iceland
Contact: Sverrir Guðmundsson, Helgi Björnsson, Tómas Jóhannesson at nigs2009@vedur.is
Website: <http://www.raunvis.hi.is/NIGS-09/>

3–5 November 2009

Northern Governance Policy Research Conference

Yellowknife, Northwest Territories, Canada
Contact: Stephanie Irlbacher-Fox [stephaniefox@theedge.ca]

4–6 November 2009

UK Polar Network Cryospheric Science Workshop

University of Sheffield, UK
Contact: cryoworkshop@polarnetwork.org

7–9 November 2009

Arctic in Rapid Transition Initiation Workshop

International Arctic Research Center
Fairbanks, Alaska
Website: <http://www.aosb.org/art.html>
Contact: Carolyn Wegner [cwegner@ifm-geomar.de]

10–12 November 2009

Acqua Alta: International Conference and Exhibition on Consequences of Climate Change and Flood Protection

Hamburg, Germany
Website: <http://www.acqua-alta.de/>

10–13 November 2009

International Workshop on Glacier Hazards, Permafrost Hazards and GLOFs in Mountain Areas: Processes, Assessment, Prevention, Mitigation

Vienna, Austria
Website: <http://www.geo.uio.no/remotesensing/gaphaz/>

13–14 November 2009

17th Arctic Conference of the Institute of Arctic and Alpine Research (INSTAAR)

Boulder, CO, USA
Website: <http://instaar.colorado.edu/ArcticConference>
Contact: Craig Lee [craig.lee@colorado.edu] or John Hoffercker [John.Hoffercker@colorado.edu]

30 November–3 December 2009

Antarctic Treaty Summit: Science – Policy Interactions in International Governance

Smithsonian Institution, Washington, DC

Website: <http://www.atsummit50.aq/>

Contact: Michael Lang [Langm@si.edu]

4–8 December 2009

IPY International Early Career Researcher Symposium

Victoria, BC, Canada

Website: <http://www.apecs.is/victoria09>

Contact: Amy Wiita [cinzaresearch@alaska.net]

14 December 2009

Second Annual Open Meeting: International Study of Arctic Change

San Francisco, CA, USA

Website: <http://www.arcticchange.org/>

Contact: Maribeth Murray [murray@arcticchange.org]

2010

5–8 January 2010

**Quaternary Research Association (QRA) – Annual Discussion Meeting
Sea-Level Changes: the Science of a Changing World**

Durham, UK

Website: <http://www.geography.dur.ac.uk/conf/sealevelchanges>

Contact: Sarah Woodroffe [s.a.woodroffe@durham.ac.uk]

13–15 January 2010

EUREKA 2010: Canadian Arctic Science at 80N

Ottawa, Ontario, Canada

A flier with complete information can be downloaded by clicking on the 'EUREKA 2010: Canadian Arctic Science at 80N' link on <http://www.candac.ca/candac/index.php>

18–22 January 2010

2010 Alaska Marine Science Symposium

Anchorage, Alaska, USA

Website: <http://www.alaskamarinescience.org/>

Contact: Carolyn Rosner [carolyn.rosner@nprb.org]

24 January–3 February 2010

Marine Biodiversity Under Change Workshop

For PhD students interested in the pan-Arctic region – registration at the Arctic Frontiers conference also required.

Tromsø, Norway

Website: <http://tinyurl.com/ARCTOS-wkshp>

Contact: Matias Langgaard Madsen [matias.madsen@uit.no]

27–29 January 2010

Arctic Frontiers 2010

Tromsø, Norway

Website: <http://www.arcticfrontiers.com/>

Contact: Arntraut Götsch [arntraut.gotsch@akvaplan.niva.no]

1–3 February 2010

***International Glaciological Conference
Ice and Climate Change: A View from the South**

Valdivia, Chile

Website: <http://www.cecs.cl/VICC2010/>

Contact: Claudia Flores [vicc2010@cecs.cl]

1–3 February 2010

Polar Climate and Environmental Change in the Last Millennium

Torun, Poland

Website: <http://www.zklim.umk.pl/nowa/polarna> – for information in English, please click on the 'english_torun-1-circular.doc' link

Contact: Rajmund Przybylak [rp11@umk.pl] or Andrzej Arazny [andy@umk.pl]

21–24 February 2010

Western Regional Science Association 49th Annual Meeting: Remote Regions/Northern Development sessions

Sedona, Arizona

Website: <http://www.u.arizona.edu/~plane/wrsa.html>

Contact: Lee Huskey [aflh@uaa.alaska.edu]

22–26 February 2010

Climate Change Impacts On the Bering Sea and Related Polar Seas:

From Observation to Prediction

American Geophysical Union Ocean

Sciences Meeting

Portland, Oregon

Contact: Rodger Harvey [harvey@cbl.umces.edu] or

Michael F. Sigler [mike.sigler@noaa.gov]

7–10 March 2010

Workshop on the dynamics and mass budget of Arctic glaciers/GLACIODYN (IPY) meeting

University of Innsbruck, Obergurgl, Austria

Arranged by the International Arctic Science Committee – Network for Arctic Glaciology (IASC-NAG).

Contact: Andreas P. Ahlstrøm [apa@geus.dk];

9–10 March 2010

2010 Alaska Weather Symposium

University of Alaska Fairbanks, Fairbanks, AK

Website: <http://weather.arsc.edu/Events/AWS10/>

Contact: Don Morton [morton@arsc.edu]

10–12 March 2010

40th Annual International Arctic Workshop

Winter Park Mountain Lodge, Colorado

Website: <http://instaar.colorado.edu/AW>

Contact: ArcticWS@colorado.edu

13–20 March 2010

Dissertations Initiative for the Advancement of Climate Change Research

(an interdisciplinary climate change research symposium)

Mesa, Arizona

Website: <http://www.dissccrs.org/>

Contact: organisers [info@dissccrs.org]

15–17 March 2010

AGU Chapman Conference on the Exploration and Study of Antarctic Subglacial Aquatic Environments

Baltimore, Maryland, USA

Website: <http://www.agu.org/meetings/chapman/2010/ccall/>

16–19 March 2010

2010 State of the Arctic Conference

Miami, Florida

Website: <http://soa.arcus.org/>

Contact: Helen V. Wiggins [helen@arcus.org]

or (for questions about abstract submission)

Judy Fahnestock [judy@arcus.org]

25–26 March 2010

6th Annual Polar Technology Conference

Boulder, Colorado, USA

Website: <http://polartechnologyconference.org/>

Contact: register@

PolarTechnologyConference.org

25–26 March 2010

The 14th Alpine Glaciology Meeting

Milan, Italy

Website to be announced

8–9 April 2010

UK Polar Network Workshop – Investigating variability in polar climates: Past, present and future

Monte Verita, Ascona, Switzerland

Website: http://www.polarnetwork.org/new/index.php?option=com_content&view=article&id=122

Contact: leedspolarnet@polarnetwork.org

11–16 April 2010

Triggering of rapid mass movements in steep terrains – mechanisms and risks

Monte Verita, Ascona, Switzerland

Website: <http://www.cces.ethz.ch/projects/hazri/tramm/conference>

14–18 April 2010

Annual Meeting of the Association of American Geographers

Washington, DC, USA

Sessions (co) sponsored by the Cryosphere Specialty Group include: State and Fate of Frozen Ground and Periglacial Environments; Glaciers & changing environments; Land, Ocean, and Atmosphere in a Changing Arctic; Hydroclimatology; Re-exploring the North
Website: <http://www.igsoc.org/www.aag.org/>

15–18 April 2010

Arctic Science Summit Week 2010

Nuuk, Greenland

Website: <http://www.assw2010.org/>

28–30 April 2010

Workshop on Cold Regions Hydrology

Innsbruck, Austria

Organized by the Network of Climate and Cryosphere Research at the University of Innsbruck, the European Space Agency (ESA) and ENVEO IT

The Climate and Cryosphere (CliC)

Programme of WCRP and ICSIH-IAHS are scientific co-sponsors

Website: <http://www.congrex.nl/10c06/>

29–30 April 2010

****SPIRIT (Spot 5 stereoscopic survey of Polar Ice: Reference Images & Topographies) workshop**

Toulouse, France

Website: <http://etienne.berthier.free.fr/SPIRIT/Home.html>

2–7 May 2010

EGU General Assembly

Session ‘Modeling the Spatial Dynamics of Permafrost and Seasonally Frozen Ground at Diverse Scales (CR4.2)’

Vienna, Austria

Website: <http://meetingorganizer.copernicus.org/EGU2010/session/2662>

Contact: Stephan Gruber [stephan.gruber@geo.uzh.ch]

Session ‘Climate of the Polar Regions (CL2.1)’
Website: <http://meetingorganizer.copernicus.org/EGU2010/session/1868>

Contact: Peter Wadhams [p.wadhams@damtp.ac.uk] or Steve Piacsek [piacsek@nrlssc.navy.mil]

Session ‘Boundary Layers in High Latitudes: Physical and Chemical Processes, Observational and Monitoring Programs, Modeling, and Analysis (AS2.4)’

Website: <http://meetingorganizer.copernicus.org/EGU2010/session/1853>

Contact: William Neff [william.neff@noaa.

gov], Gunther Heinemann [heinemann@uni-trier.de], Anna Jones [AEJO@bas.ac.uk], Stefania Argentini [s.argentini@isac.cnr.it] or Philip Anderson [PSAN@bas.ac.uk]
Session 'Sea Ice and Sea Ice-Climate Interactions (CR9.1)'
Website: <http://meetingorganizer.copernicus.org/EGU2010/session/1890>
Contact: Daniel Feltham [dlf@cpom.ac.uk]

17–20 May 2010

Seventh International Workshop on the Micromorphology of Glacial Sediments

Queen Mary University of London, London, UK
Contact: Jaap JM van der Meer [j.meer@qmul.ac.uk]

20 May–4 June 2010

Arctic in a Changing Climate: Physical and Biological Linkages to Permafrost

Summer School program organized by the International Arctic Research Center at the University of Alaska Fairbanks
Fairbanks, Alaska, USA
Website: http://www.iarc.uaf.edu/education_outreach/summer/2010/
Contact: Tohru Saito [saito@iarc.uaf.edu]

18 May–11 June 2010

Summer Field Course in Arctic Science

University of Alaska Fairbanks and Toolik Field Station
Contact: Anja Kade [ankade@alaska.edu]

30 May 2010

SCAR/AGCS Antarctic Sea Ice Workshop II

Tromsø, Norway
Contact: Stephen Ackley [Stephen.ackley@utsa.edu]

31 May–4 June 2010

International Glaciological Symposium: Ice and Snow in the Climatic System

Kazan, Russia
Website (address to be announced) will open on 15 December 2009

31 May–4 June 2010

****International Symposium on Sea Ice in the Physical and Biogeochemical System**

Tromsø, Norway
Contact: Secretary General, International Glaciological Society

4–11 June 2010

4th International Workshop on Ice Caves

Obertraun, Austria
Workshop theme: meteorology, glaciology and paleoclimatology in ice caves
Website: <http://www.iwic2010.info/>
E-mail: office@iwic2010.info

8–12 June 2010

International Polar Year open science conference

Oslo, Norway
Website: <http://www.ipy-osc.no/>

8–19 June 2010

Advanced Climate Dynamics Course on Ice-Sheet Ocean Interactions

MIT FabLab, Lyngen, northern Norway
Website: <http://www.bccr.no/filer/318.BYQIE.pdf>

13–17 June 2010

Third European Conference on Permafrost (EUCOPP2010)

Longyearbyen, Svalbard
Website: <http://www.eucop2010.no/>

5–11 June 2010

4th International Workshop on Ice Caves (IWIC-IV)

Obertraun, Austria
Website: <http://www.iwic2010.info/>
Contact: [office@iwic2010.info]

8–10 June 2010

67th Eastern Snow Conference: Here today gone tomorrow, the Eastern North America Cryosphere

Jiminy Peak Mountain Resort, Hancock, MA USA
Website: http://www.easternsnow.org/annual_meeting.html
Contact: Mauri Pelto [mspelto@nichols.edu]

8–12 June 2010

IPY Oslo Science Conference

Session T2-3: Snow and ice dynamics and processes
Oslo, Norway
Website: <http://www.ipy-osc.no/>
Contact: Jon Ove Hagen [joh@geo.uio.no]

14–18 June 2010

The 20th IAHR International Symposium on Ice

Lahti, Finland
Website: http://www.geo.physics.helsinki.fi/IAHR2010/IAHR2010_2.html

21–24 June 2010

24th international Forum for Research into Ice Shelf Processes (FRISP)

Evangelisches Bildungszentrum, Bad Bederkesa, Germany
Website: <http://www.gfi.uib.no/forskning/frisp/>
Contact: Adrian Jenkins [ajen@bas.ac.uk]

21–25 June 2010

****International Symposium on Snow, Ice and Humanity in a Changing Climate**

Sapporo, Japan

Contact: Secretary General, International Glaciological Society

22–23 July 2010

6th Antarctic Peninsula Climate Change workshop

Leeds, UK

Contact: Noel Gourmelen [n.gourmelen@leeds.ac.uk]

A follow-up announcement will appear shortly on the 2010 APCC workshop website

3–6 August 2010

4th SCAR Open Science Conference: Witness to the Past and Guide to the Future

Buenos Aires, Argentina

A session titled 'An interdisciplinary approach to understanding Antarctic ice shelf disintegration' will be convened by Eugene Domack [edomack@hamilton.edu] and Amy Leventer [aleventer@colgate.edu]

Website: <http://www.dna.gov.ar/scar2010/>

8–13 August 2010

AGU Meeting of the Americas: Dynamic Cryosphere session

Foz do Iguaçu, Brazil

Convened by Drs. Paul Winberry & Audrey Huerta (CWU) and Slawek Tulaczyk (UCSC)

Website: <http://www.agu.org/meetings/ja10/>

12–14 August 2010

Cryospheric Changes and Influence – Cryospheric Issues in Regional Sustainable Development

International Joint Conference by CLIC/IACS Lijiang, Yunnan Province, China

Website: <http://www.casnw.net/>

Contact: Xie Aihong [xieaih@lzb.ac.cn]

16–20 August 2010

****International Symposium on Earth's Disappearing Ice: Drivers, Responses and Impacts: A celebration of the 50th Anniversary of Byrd Polar Research Center**

Byrd Center, Ohio State University, USA

Contact: Secretary General, International Glaciological Society

5–10 September 2010

12th International Conference on the Physics and Chemistry of Ice

Sapporo, Japan

Contact: Chairperson Yoshinori Furukawa (Hokkaido University)

Website: <http://www.lowtem.hokudai.ac.jp/PCI-2010/>

12–16 September 2010

6th Canadian Conference on Permafrost

Calgary, Alberta, Canada

Website: <http://ninja.pro.net/disk2/geocalgary10/index.php?lang=en>

Contact: Jim Henderson [permafrost@geo2010.ca]

14–25 September 2010

Karthus course on Ice Sheets and Glaciers in the Climate System

Karthus, Italy

Website: http://www.phys.uu.nl/~wwwwimau/education/summer_school (coming soon)

20–23 September 2010

HydroPredict'2010

2nd International Interdisciplinary Conference on Predictions for Hydrology, Ecology, and Water Resources Management: Changes and Hazards caused by Direct Human Interventions and Climate Change

Prague, Czech Republic

Website: <http://www.natur.cuni.cz/hydropredict2010/>

20–24 September 2010

11th International Circumpolar Remote Sensing Symposium

Cambridge, UK

Website: <http://alaska.usgs.gov/science/geography/CRSS2010/>

26–30 September 2010

International conference: Global Change and the World's Mountains

Perth, UK

Website: <http://www.perth.uhi.ac.uk/mountainstudies/2010>

27–30 September 2010

Remote Sensing in Hydrology 2010 Symposium

Jackson Hole, Wyoming, USA

Website: <http://www.remotesensinghydrology.org/>

Contact: Christopher Neale (VP ICRS) [christopher.neale@usu.edu]

8–9 October 2010

Northwest Glaciologists Meeting 2010

University of Alaska Fairbanks, Fairbanks, Alaska, USA

Further details to be announced. Please note that the date agreed on at the 2009 meeting has had to be changed

15–17 October 2010

4th Graduate Climate Conference

Pack Experimental Forest, Mount Rainier, Washington, USA

Website: <http://uwppcc.washington.edu/gcc>

24–27 October 2010

Northern Research Forum 6th Open Assembly – Our Ice Dependent World

Oslo and Kirkenes, Norway

Website: <http://www.nrf.is/>

2011

29 March–2 April 2011

Arctic Science Summit Week 2011

Coex Center, Seoul, South Korea

ASSW 2011 will have an integrated Science Symposium covering the theme: ‘The Arctic: The New Frontier for Global Science’. Further details to be announced

5–10 June 2011

****International Symposium on Interactions of Ice Sheets and Glaciers with the Ocean**

Scripps Institution of Oceanography, La Jolla, California, USA

Contact: Secretary General, International Glaciological Society

27 June–8 July 2011

International Union of Geodesy and Geophysics

IUGG XXV General Assembly

Earth on the Edge: Science for a Sustainable Planet

Melbourne, Australia

Website: <http://www.iugg.org/assemblies/2011melbourne/>

Contact: Regine Hock (Regine.hock@gi.alaska.edu)

24–28 October 2011

World Climate Research Programme Open Science Conference: Climate Research in Service to Society

Denver, Colorado

Website: <http://www.wcrp-climate.org/conference2011>

2012

22–27 April 2012

IPY From Knowledge to Action Conference

Montreal, Québec, Canada

See news release at: <http://www.ainc-inac.gc.ca/ai/mr/nr/s-d2009/23301-eng.asp>

June 2012

****International Symposium on seasonal snow and ice**

Helsinki, Finland

Contact: Secretary General, International Glaciological Society

25–29 June 2012

****International Symposium on Glaciers and Ice Sheets in a Warming Climate**

Fairbanks, Alaska, USA

Contact: Secretary General, International Glaciological Society

Late summer 2012

****International Symposium on Ice Core Science**

Location to be determined

Contact: Secretary General, International Glaciological Society



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