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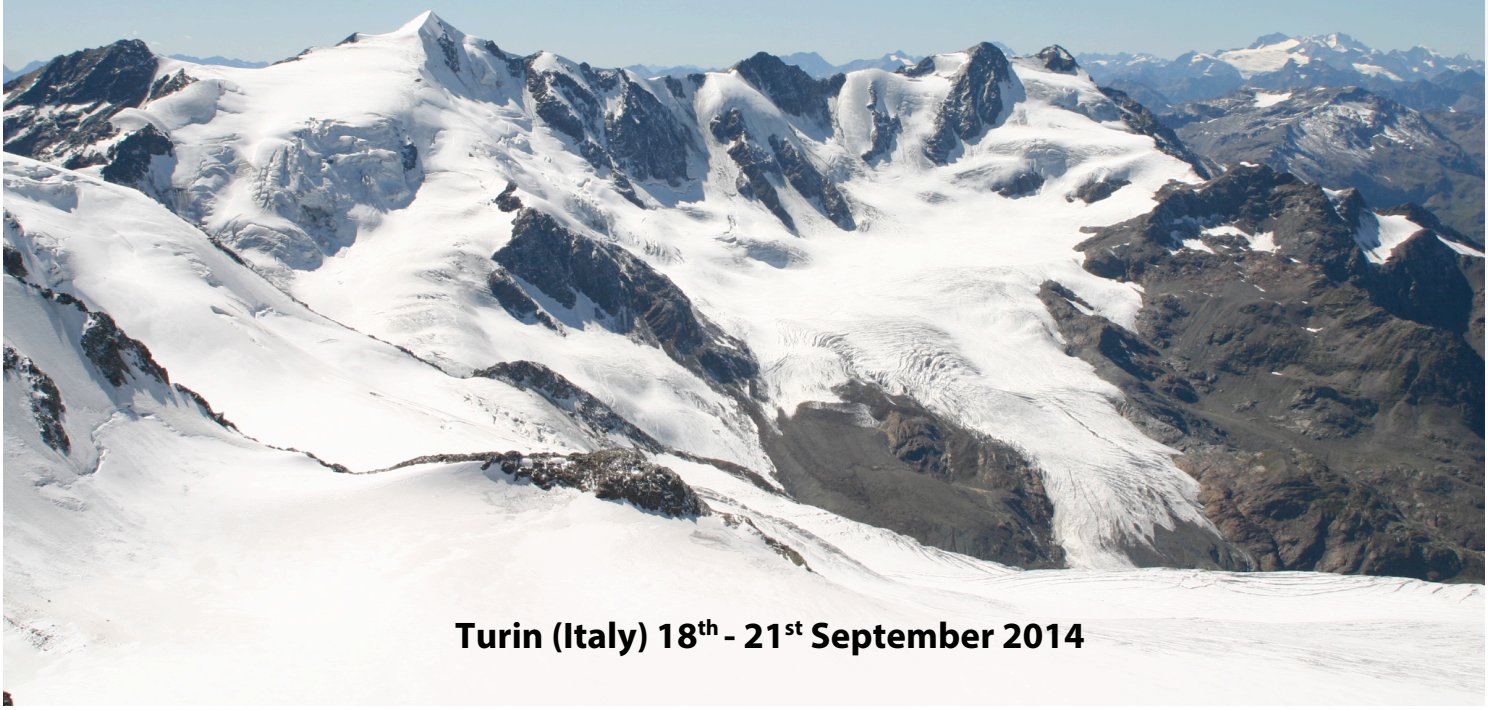
'The Future of the Glaciers: from the past to the next 100 years'



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"THE FUTURE OF THE GLACIERS – FROM THE PAST TO THE NEXT 100 YEARS"
Turin, Italy, September 18th-21st 2014

THE FUTURE OF THE GLACIERS. FROM THE PAST TO THE NEXT 100 YEARS
THE ACTIVITY OF THE ITALIAN GLACIOLOGICAL COMMITTE

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The Italian Glaciological Committee (Comitato Glaciologico Italiano)

The Italian Glaciological Committee (CGI) has been working in Italy since 1895, with the task to promote and to coordinate research in the field of glaciology. Originally the CGI was a commission for the study of Italian glaciers within the Italian Alpine Club (CAI). Since 1915, it became independent organism with the support of the National Research Council (CNR) and of other organizations and agencies interested in glaciological research.

Glacier monitoring

Glaciers are extraordinary natural archives of the climate history. In addition to being a strategic resource of fresh water usable for agricultural, civil, and industrial purposes, glaciers are valuable climate proxy, very sensitive to climatic and environmental changes, as they react to external forcing by changing shape and size. Alpine glaciers, in particular, being made up almost entirely of ice at a temperature close to the melting point (temperate glaciers), are very sensitive sentinels of global changes.

Since its origin, the CGI recognized the importance of systematic monitoring of Italian glaciers and, in particular, of measurement of frontal variations. Every year, at the end of the ablation season, the glaciological survey is carried out on selected Italian glaciers: measures and photographs from fixed points, observations of the snow cover and of the front morphology are also taken. This activity is regularly conducted since the end of the 19th Century and has never been interrupted since 1911, except during war periods, supplying therefore one of the longest series of observations of the glacial front variations in the world. The annual glaciological surveys allowed acquiring a large amount of data and a precious photographic documentation.

A section of the CGI Bulletin is dedicated, since 1927, to the results obtained in the framework of the glaciological campaigns (http://gfdq.glaciologia.it/issues/). At present, approximately 150 glaciers are monitored every year by a large number of voluntary surveyors, also linked to other associations.

Mass balance of selected Italian glaciers is measured since 1967 (e.g. the Careser Glacier). About a dozen of glaciers are presently monitored for measuring the glaciological mass balance. All the collected data related to the monitoring of frontal variations and annual mass balances measured in the Italian Alps contribute to the World Glacier Monitoring Service (WGMS) database (www.geo.uzh.ch/microsite/wgms/).

The glaciological archive (Photographs collection, historical maps, unpublished surveys)

The annual glaciological surveys allowed the CGI to acquire a large amount of data for the establishment of an archive of original documents, mainly (but not only) related to the Italian

glaciers. Thanks to the collection of a valuable photographic documentation, the CGI has acquired a huge mass of data relating to variations in the shape and size of glacial fronts, but also extremely useful to reconstruct the areal and volumetric variations of many glaciers.
Federico Sacco, a founding member of the Commission for the study of glaciers and CGI, particularly supported the irreplaceable value of multi-temporal photographic collection in glacier monitoring. His work on glaciers of the Western Alps, published nearly a century ago for the first issues of the Bulletin of CGI, are accompanied by stunning photographic plates that compare shots taken at different times from survey markers.
The photographic archive of the CGI holds tens of thousands of images related to Italian glaciers (but not only) imprinted on various media (negatives, black and white, and colour print, slides, DVDs and precious as delicate glass plates). The large amount of images, the partial decay of the paper and the fragility of the glass plates pose many problems of preservation, cataloguing, rational consultation and preservation of this important iconographic heritage. The CGI has recently launched an ambitious program of systematic scanning and computerization of the photographic heritage, based on the valuable contribution of volunteers and young students who apply for stages at the CGI (i.e. Educational University Internship).
In the 19th Century, the first glaciologists stressed the need for accurate mapping of glacial bodies so that, since the beginning, the Bulletin of the CGI hosted monographs on individual glaciers particularly relevant, accompanied by detailed photogrammetric surveys. The first volume of the Italian Glaciological Bulletin (1914), for example, opens with the publication of the topographic survey at a scale 1: 10,000 of the front of Miage Glacier, based on the first Italian application of the stereo-autograph Zeiss. Subsequently, the tradition of the photogrammetric surveys of major glaciers, such as those of the Lys executed the Military Geographic Institute in 1920 and 1925, consolidated between 1955 and 1975, also in response to positive cultural and scientific context that accompanied the International Geophysical Year 1957-58. All the maps have been scanned and will be available to all the interested researchers. In addition, to complete the picture of cartographic heritage, certainly deserve to be mentioned the unpublished surveys that accompanied the monitoring of glacier fronts and which are kept in the archive of the CGI.

The Glacier Inventory – A basic tool to be built, maintained updated, and freely available

Glacier inventories represent important tools, which allow the quantification of glaciers extension and volumes. Porro (1925) compiled the oldest inventory of the Italian glaciers: 774 glaciers are represented in 4 maps at the scale of 1:500.000 (Atlas of the Italian Glaciers; Porro and Labus, 1927; http://www.glaciologia.it/pubblicazioni/?lang=en). This systematic work on the Italian glaciers is amongst the first examples of glacier inventories in the world: 773 glaciers were identified in the Alps whereas only 1 glacier (Ghiacciaio del Calderone in the Gran Sasso Massif) was reported in the Apennines, at the southernmost glacierization limit of Europe.
On the occasion of the International Geophysical Year in 1957-1958, the CGI surveyed a new inventory, published in four volumes (CGI-CNR, 1959; 1962). The CGI-CNR inventory include 838 glaciers, which existed at the end of the 1950s; 190 glaciers that disappeared from the previous inventory are also reported. In total 1028 glaciated units were documented (http://www.glaciologia.it/ghiacciai.html). Glaciers of the Italian Alps are grouped in three main sectors: 322 glaciers are hosted in the Western Alps, 185 glaciers in Central Alps, 330 glaciers in the Eastern Alps. The melt water generating from these sectors was also summarized. 534 glaciers contributed to the hydrological regime of Po River (the main Italian River), 255 glaciers to the Adige River and the remaining 48 glaciers belonged to other hydrological basins. The southernmost Italian glacier, the Ghiacciaio del Calderone was still the only glacier in the Apennines.
Data collected by the CGI also contributed to the **World Glacier Inventory (WGI 1981-84), in which are reported** 1397 glaciers of the Italian Alps, covering a total extension of 608 km^2 (531 glaciers in Western Alps, 305 in Central Alps, and 560 in Eastern Alps).

The more recent updating of the Italian glaciers inventory refers to 1988-'89. Based on an aerial photogrammetrical survey conducted across the entire Italian Alps, the inventory was supported by the Italian Minister of the Environment. This inventory considers 787 glaciers with dimensions greater than 0.05 km^2, which covered a total area of 474 km^2 (about 20% of the total extension of the glaciers in the Alps). The comparison between the two CGI inventories evidences a drastic reduction of the glacierized areas in the Italian Alps from 1950s and 1988-89.
The largest glacial complex of the Italian Alps is the Adamello Glacier, a composite summit glacier (about 17.8 km^2 in 1950s, 18.5 km^2 in 1983, 16.4 km^2 in 2006, 15.8 km^2 in 2012), while the larger valley glacier is the Forni Glacier in the Ortles-Cevedale Group (less than 15 km^2 in 1950s, 13.2 km^2 in 1980s, 12.9 km^2 in 1991, 12 km^2 in 2003, 11.4 km^2 in 2006). Over 80% of the Italian glaciers, however, consist of glaciers very small in size. The Gran Sasso Massif hosts the remnant of the last Apennine glacier, the Calderone Glacier, now reduced to little more than a debris-covered glacieret.
The Italian glaciers, since the end of the maximum Holocene advance (occurred during the Little Ice Age, in the first half of the 19th Century) have experienced a phase of generalized retreat, accentuated in the 50s of the 20th Century, which was followed by a slight advancing stage culminated in the late '70s and early '80s. Since the '90s there was a general withdrawal of almost all the Italian glaciers. Since the second half of the 19th Century the Italian glaciers lost more than 40% of their areal extension. The mean annual snow line rose about 100 m, as a mean. Many of the wider glaciers subdivided originating minor glacial bodies. Several small glaciers disappeared or are presently reduced to glacierets, while many others are almost completely debris-covered.
In recent years, almost 100% of the Italian glaciers are retreating; numerous alpine glaciers have repeatedly found entirely below the snowline, recording significant frontal retreat, contractions of the accumulation basins, thinning of glacial bodies and tongues. Only the inertia of the ice has allowed glaciers to overcome these critical steps: the strong imbalance that seems to characterize the glaciers compared to current climatic conditions suggests that if this situation will last, further dramatic areal and volume reductions must be expected.

A new database for reconstructing the spatial-temporal evolution of the glacial resource in the Italian Alps over the last 100 years

An updated picture of the glacial resource in the Italian Alps is being realized through the acquisition of the most up to date available information on glaciers, including location, main geometric and morphologic parameters, also for their use in numerical simulations, and taking into account the existing international standards. The project focuses on the collection, validation, storage and analysis of glaciological data from the Italian Alps, referred to the last 100 years. A dedicated system will be realized for the management of these data, in line with the requirements of NextData Portal, and in agreement with the GeoNetwork architecture – like that of the SHARE Project. The project also aims to update and make easily available to the scientific community and to the stakeholders multitemporal data on the Italian glacial resource, through an integrated information management system made for this purpose. The system will represent a validated and reliable information base for quantitative modeling of glaciers response to climatic forcing. It will be a valuable tool for further research projects on glacial/periglacial environments.
The promotion of a free, distributed use of information on Italian glaciers, to be implemented within the NextData project, but also updatable in the future, is a specific responsibility of the Italian Glaciological Committee. This database will represent a breakthrough in the availability of glaciological data from the Italian Alps and will also satisfy the rising demand of open source availability of environmental data in the mountain regions.

Keywords: alpine glaciers, glacier monitoring, glacier inventory, cryosphere, global changes, Italian Alps

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LIST OF ABSTRACTS

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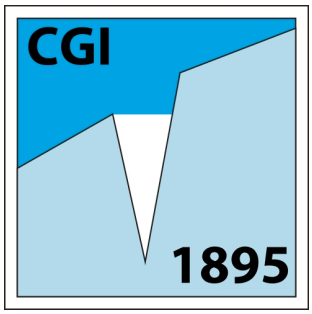

Evaluation of the performances of empirical regressions for the calculation of bulk snow density

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ABSTRACT

Snow covers are a seasonal reservoir of water in the solid form. Water mass accumulates during winter, and is released during spring and summer as basal runoff, feeding streamflow of many catchments in temperate areas. The amount of water mass in a snow cover is usually accounted for using the Snow Water Equivalent (*SWE*, in kg m^{-2} or $mm_{w.e.}$), which estimates the mass of liquid water which wold result from the complete melting of the snow cover itself. To calculate this quantity, evaluations of snow depth and bulk snow density are needed. A widely applied solution in conditions of data scarcity implies the measurement of snow depth, and the prediction of bulk snow density using multiple empirical regressions involving, as predictors, weather, climatic or temporal variables, such as air temperature, wind velocity, elevation, snow depth, or the age of the snow cover. Here, we reviewed the relations used in the Literature to estimate mean bulk snow density, and defined a preliminary dataset of 18 different equations. We compared the evaluations of these regressions versus continuous-time measurements of daily bulk snow density collected in western US by the SNOTEL network, by means of snow pillows. This simple analysis shows that the average percentage difference between predictions and data is rather high (around 25%-45%). In addition, this difference increases with elevation. This shows that particular care is due when using these regressions, especially at high elevations, where snow plays a relevant role in the local hydrologic regime.

Keywords: *SWE*, bulk snow density, regression, estimation, snow depth.

An innovative image-analysis protocol to evaluate the effects of dust on ice albedo: applications on Italian and Turkish glaciers

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ABSTRACT

In this work we investigated the characteristics of sparse and fine debris coverage at the glacier melting surface and its relation to ice albedo. In spite of the abundant literature dealing with dust and black carbon deposition on glacier accumulation areas, few studies that describe the distribution and properties of fine and discontinuous debris at the melting surface of glaciers are available. Furthermore, guidelines are needed to standardize field samplings and laboratory analyses, thus permitting comparisons among different glaciers. We developed a protocol to: (i) sample fine and sparse supraglacial debris, (ii) quantify its surface distribution and the covering rate, (iii) describe its composition and sedimentological properties, (iv) measure ice albedo, and (v) identify the relationship between ice albedo and fine debris coverage. The procedure was tested at the Forni Glacier surface (Italian Alps) in summer 2011, 2012 and 2013 and applied in summer 2014 on glaciers of the Mount Ararat (Turkey) as well, in order to better evaluate the effects of debris on ice albedo in different environmental settings (e.g., lithology, elevation, topography, latitude, climate). The fine debris and dust presence had marked variability in space and time influencing ice albedo. In particular, the natural logarithm of albedo was found to depend on the percentage of glacier surface covered by debris. The analyses on the sampled detritus generally indicate a local origin for its mineral fraction. Further, the identification on the Forni glacier of some cenospheres suggests an anthropic contribution to the formation of superficial debris cover. Moreover, the effect of liquid precipitation on ice albedo was not negligible, but short lasting, thus indicating that also other processes affect ice albedo and ice melt rates and then some attention has to be spent analyzing frequency and duration of summer rainfalls for better describing albedo and melt variability.

KEYWORDS: supraglacial dust, ice albedo, image-analysis, Italian Alps, Mount Ararat (Turkey)

The Adamello – Presanella Group (Rhaetian Alps): a key site for understanding recent glaciers variations

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ABSTRACT

The Alps are a sensitive environment towards the ongoing climate changes, to which they are reacting with variations in the extension of glaciers and permafrost and with an increasing in the frequency and magnitude of mass-wasting processes. The Alps have been referred in the Mountain Agenda as the "water tank of Europe" representing the source area of many important rivers. To focus the glaciers behaviour as response to recent global changes we investigated more than one hundred glaciers of the Adamello-Presanella Group. Present day glaciers of the this group, including the widest glacier of Italian Alps the Ghiacciaio dell'Adamello, extend for more than 50 km^2. We reconstruct LIA glacial limits through geomorphologic and glacial geologic field surveys; areal variations occurred in the 20th and 21th Centuries have been inferred from historical maps and multitemporal aerial photographs. Since the Little Ice Age (LIA), whose climax was reached in the Alps around 1850 AD, alpine glaciers experienced a period of manifest reduction, with a strong reduction in thickness and areal extension, broken by very few brief and weak advances. More than 140 glaciers developed during the LIA covered an area almost the double of their present surface..
The elevation of the Equilibrium Line Altitude (ELA), areal and volume variations underline a strong reduction since the LIA. The notable frontal regression is marked by withdrawals ranging from several hundred meters to more than 2000 m.
Considering the maximum LIA and 1983 AD glaciers extension of the Presanella Group, they lost about 55% of the total area while the mean value for the entire Adamello– Presanella Group is about 50%. An additional reduction of about 25% occurred between 1983 and 1999 AD. More recently, several glaciers of the group remained below the annual snowline and show dramatic areal and volumetric reductions.

Keywords: Adamello-Presanella Group, Climate Change, Glacial variations, Little Ice Age, Rhaetian Alps.

DATAGRALP – A new database for reconstructing the spatial-temporal evolution of the glacial resource in the Italian Alps over the last 100 years in the framework of the NextData Project

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ABSTRACT

An updated picture of the glacial resource in the Italian Alps is being realized through the acquisition of the most up to date available information on glaciers taking into account the existing international standards. In particular, the project aims to: i) make available to the scientific community and disseminate to all stakeholders multi-temporal data on the Italian glacial resource, by developing and populating a knowledge management system of validated glaciological data; ii) quantify glacial parameters, for specific time periods, needed by quantitative models aimed to simulate the response of glacial bodies to changing climatic scenarios; iii) reconstruct the recent (last 100 years) spatial-temporal evolution of the Italian glaciers, as terrestrial indicators of climate fluctuations, in consideration of the extreme sensitiveness of glacial bodies to climatic parameters.
A dedicated system is under construction for the management of these data, in line with the requirements of NextData Portal, and in agreement with the GeoNetwork architecture – like that of the SHARE Project.
The project also aims to update and make easily available to the scientific community and to the stakeholders multitemporal data on the Italian glacial resource, through an integrated information management system made for this purpose. The system will represent a validated and reliable information base for quantitative modeling of glaciers response to climatic forcing. It will be a valuable tool for further research projects on glacial/periglacial environments.
Promotion of a free, distributed use of information on Italian glaciers, to be implemented within the NextData project, but also updatable in the future, will represent a breakthrough in the availability of glaciological data from the Italian Alps and will also satisfy the rising demand of open source availability of environmental data in the mountain regions.

Keywords: Alpine glaciers, glacier monitoring, glacier inventory, cryosphere, aerial photographs, Italian Alps

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http://nextdata.sharegeonetwork.evk2cnr.org

Avalanche hazard evaluation in the Ligurian ski resorts (Italy)

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ABSTRACT

Liguria is characterized by a coastal arc extended up to 240 km. It is a largely mountainous and hilly region, with about two thirds of the area exceeding an elevation of 1,000 m a.s.l..
Consequently, the characteristic climate of the region, famously known for the Mediterranean-type climate, is far from being uniform. It reflects some fundamental morphological factors, such as S-exposures and the presence of a mountain ridge between the French border (to the W) and Tuscany (to the E).
Higher elevation mountains have suitable climatic conditions for winter sports, although the permanence of snow on the ground is related to local factors, such as exposure, slope steepness, air temperature and wind intensity.
The highest Ligurian peak is the Saccarello Mount (2200 m) at the borders with Piedmont and the French Department of the Alpes Maritimes, while the highest mountain in the Ligurian Apennines is the Maggiorasca Mount (1804 m), in the upper Aveto valley, at the border between the Genoa, Piacenza and Parma provinces. Near to these areas there are two "historical" ski resorts established in the mid-60s: Santo Stefano d'Aveto, bordering the ski areas of Emilia, and Monesi di Triora to the West, in the province of Imperia; both resorts have been subject to significant investment in the development of tourist activities and accommodation.
The unique climatic conditions of Liguria and the established trends in climate, however, require careful assessment of avalanche hazard, considering the increased flow of tourists and the poor perception of the associated risk in a region traditionally linked to "marine" leisure activities. During 2011, an avalanche in Santo Stefano d'Aveto caused the loss of a human life.
The paper presents a preliminary contribution aimed at assessing avalanche hazard in the two ski areas of Liguria: starting from the analysis of historical avalanches several parameters have been analyzed, such as hazardous nature of the terrain, the weather, the profile of the snowpack and the interaction with human activities and infrastructures.

Keywords: Avalanche, snow cover, hazard, climate change, Liguria.

Analysis of long-term mass balance series of the glaciers in the Italian Alps

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ABSTRACT

Mass balance measurements on glaciers are a key source of quantitative information for early detection of environmental changes, process understanding, model development and prediction of possible future developments. The Comitato Glaciologico Italiano and the World Glacier Monitoring Service regularly collect standardized observations on glacier mass balance, based on the 'direct glaciological' method.
We analyzed mass balance series of the glaciers in the Italian Alps which are still being regularly measured and which have at least ten years of continuous data. The longest series started in 1967 on Careser glacier. Measurements began on Fontana Bianca and Sforzellina in the 1980s, and on Ciardoney and Pendente in the 1990s. Other observation series started in the 2000s on Grand Etret, Lunga, La Mare and Malavalle. Two glaciers are located in the Western Alps, the other seven in the Eastern Alps.
Measurements results indicate that average mass balances agree well with a sample of glaciers representative of the entire European Alps. Among the longest series, however, Careser and Ciardoney glaciers are losing mass at significantly higher rates. However, given the high correlation of their series with the other Italian glaciers, they enable recognizing mountain-range-scale temporal trends in the seasonal components of mass balance. In particular, the Careser series shows a sharply negative trend in the annual mass balance, almost entirely due to increasing summer ablation.
Most monitored glaciers display strongly imbalanced conditions and nearly complete absence of accumulation area, with the exception of few years in the last two decades. Consequently, as their survival and the prosecution of mass balance measurements are at risk, there is the need to i) evaluate their spatial representativity by means of regional-scale geodetic mass balance assessments based on DTM differencing, and ii) start parallel measurements on neighboring larger and higher-reaching glaciers, which should replace them in the future.

Keywords: glacier monitoring, mass balance measurements, strategies for the future

Permafrost mapping in a high-altitude catchment of the Ortles-Cevedale using spring water geochemistry

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ABSTRACT

The most commonly-used geomorphological evidences of the spatial distribution of permafrost in high-altitude catchments of mountain regions are the rock glaciers, whose activity and permafrost content are however not easy to define without geophysical and/or dynamic investigations. On the other hand, temperature measurements of the soil surface (GST and BTS) and sub-surface generally require multi-year monitoring and their interpretation is not straightforward.
Spring water flowing from areas with permafrost has a distinct physical signature, in particular for temperature which is generally lower than 2°C. Since springs are widespread in headwater catchments characterized by impermeable bedrock, the chemical-physical monitoring of spring water looks attractive for the investigation of permafrost occurrence. In this work we present the chemical-physical characterization of spring water for the assessment of permafrost distribution in a high-altitude catchment of Ortles-Cevedale (Eastern Alps).
Water temperature, electrical conductivity and isotopic composition (δ^2H and $\delta^{18}O$) were measured in 45 springs, collecting water samples in summer 2007, 2010, and 2012. Geomorphological evidences of permafrost and ground surface temperature data enabled the classification of springs upslope areas into two categories of permafrost occurrence (probable and no permafrost) and were used to determine the most suitable tracer for permafrost mapping.
Results showed that springs from probable-permafrost areas have a specific water temperature signature. Therefore, water temperature of springs was used as response variable in multiple linear regression while the mean elevation and clear sky radiation of springs upslope areas were used as predictors. The multiple regression models were statistically significant and were used to map the spatial distribution of spring water temperature, which was reclassified in three permafrost categories (probable, possible, unlikely). Independent validation by GST data provided evidence that the spring water temperature can be used alone for the assessment of catchment-scale permafrost distribution in this type of alpine catchments.

Keywords: Ortles-Cevedale, permafrost mapping, rock glaciers, springs water temperature.

Multitemporal analysis of the Southern Sabbione Glacier (Formazza Valley, Arbola Group) by geomatics techniques.

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ABSTRACT

In this work the evolution of the Southern Sabbione Glacier, during the last Century was studied, by means of Geomatics techniques.
The reconstruction of the glacier's terminus trend in time and the volumetric changes, expressed in terms of mass balance, were obtained by data processing in GIS and use of photogrammetric techniques.
Digital Elevation Models (DEM), referred to different years, were used to obtain volumetric changes.
Bibliographic, cartographic, iconographic and aerophotographic data were used for the reconstruction of the glacier's terminus trend.
For the photogrammetric analysis, Piedmont Region's DEM (1992) and 2000 digital orthophotos were used, as volumetric and planimetric references .
With the digitizing of historical maps in GIS, DEM 1940 was generated, while DEM 1988, and 2000 were obtained using a digital photogrammetric station (LPS 9.3).
Through the comparison between the rebuilt DEMs (1940, 1988, 2000) and the DEM of Piedmont Region, volume differences in glacial masses were calculated, for the different time intervals.
In addition, the digital orthophotos processing, from DEM 1988 and 2000, allowed us to visualize and digitize the glacier's terminus position in their respective years.
For the 1940-2009 period the glacier's terminus is set back approximately 1850 m.
The calculation of volumetric changes was limited, due to the lack of a complete overlap between the DEMs, to some areal intervals: - 519 · 10^6 m^3 ± 24% for the 1949-1988 overlapping area (1.5 · 10^6 m^2); - 557 · 10^6 m^3 ± 6.1% for the 1988 -1992 area (5.7 · 10^6 m^2); -712 · 10^6 m^3 ± 4.1% for the 1992 - 2000 area (4.8 · 10^6 m^2).
The fluctuations of the glacier terminus and the volumetric variations had suggested a marked downward trend of the Southern Sabbione Glacier.

Keywords: Southern Sabbione Glacier, Geomatics, glacier fluctuations, Italian Alps

GLACIERS ONE-TIME. The Society Protagonist of the Research

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ABSTRACT

Glaciers one-time involves the citizenship in the development of a popular scientific project, which, among its objectives, aims to make the society conscious of the glacial retreat in action and to quantify the changes in the mountain landscape. All are invited to take photographs of the modern Italian glaciers with the exact points of view of historical photographs, and to make photographic comparisons. Glaciers one-time is carried out in collaboration with institutions that carry out glaciological activities. The institutional network so has the goal to cooperate together for the promotion of research within the society and the understanding of the landscape changes due to retreat of the glaciers. With the active participation of citizenship, it was possible to do a picture of glaciation to publicize the awareness of the state of health of the glaciers.

The involvement of the society has been without to suggest pointers, mountains, glaciers and valleys depicted in the photograph. The project allowed the discovery of the territory retracing the paths attended from the ancient photographer to take, in the same place, the same photograph. This was useful for promoting the development, attendance and re-discovery of the mountain, starting a process of socialization for the identification of the place from which to take the photo. It gave the opportunity to take photographs during the entire summer 2012. The photographic material product was then sent to Museo delle Scienze who filed the photos with information on the author's photo, date and place of capture. The Scientific Committee conducted the appropriate assessments to extrapolate the best pictures and, the changes in landscapes and portraits of the glacial retreat. All the best pictures shared within the network and posted online to make them available to the entire community that can see and rediscover the importance of their work.

Keywords: photographic comparison, glaciers, research and society, enhancement mountain environment.

Accounting for air temperature distribution in glacier mass balance modeling

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ABSTRACT

The distributed modelling of snow and ice mass balance enable a better understanding of processes involved in glacier hydrology and the prediction of glacier runoff under possible future climatic scenarios. The complexity of the modelling approach must fit with the purposes of its application and with the temporal and spatial resolution required in simulations. The so-called 'Enhanced Temperature-Index' (ETI) melt models constitute a good compromise between model simplicity, parsimony of input data, and the capability to account for dominant processes in snow and ice mass balance. We illustrate a general-purpose model (EISModel - Energy Index Snow-and-ice Model) for the simulation of snow and ice accumulation and melt processes. Given the key role of air temperature in modeling ablation and accumulation processes, further emphasized in ETI models, accurate spatial calculation of temperature input data is crucial. Compared to ambient conditions, lower temperatures (the so-called glacier cooling effect), and temperature variability (the so-called glacier damping effect) generally occur over glaciers, complicating the extrapolation from off-glacier weather stations. Using a dataset from portable and permanent weather stations, we analyzed the air temperature distribution and wind regime on La Mare and Careser glaciers (Ortles-Cevedale), in order to characterize the katabatic boundary layer (KBL) processes over these glaciers. The impact of different calculation methods proposed in the literature for calculating on-glacier temperatures from off-glacier data was assessed using EISModel. Comparisons with model runs using measured temperatures revealed that none of the proposed methods fully accounts for the actual temperature distribution, and that even small deviations in air temperature calculations strongly impacted the results from the mass balance model.

Keywords: cooling effect, enhanced temperature-index model, glacier mass balance, katabatic boundary layer.

Hazard and risk in high glacierized mountains

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ABSTRACT

Glacierized alpine environments are among the most sensitive on Earth to the warming of climate that has happened over the past century. Geomorphic processes that operate in high mountains are affected directly by changes in temperature and precipitation and indirectly by a reduction in snow and ice cover. Amplified warming at high elevations is destabilizing slopes by thawing permafrost. Water accumulating in fractures and other discontinuities in rock and soil lowers stability, exacerbating the loss of support of slopes due to glacier downwasting and retreat.

Lakes dammed by glaciers and moraines are draining catastrophically in our warming climate, with considerable destructive downstream impacts. Ice-dammed water bodies can drain either via enlarging subglacial tunnels or by overtopping or mechanical collapse of the glacier dam. New dangerous lakes will develop higher within glaciersheds later in this century. Most lakes dammed by lateral and end moraines formed in the twentieth century when valley and cirque glaciers retreated from advanced positions reached during the Little Ice Age. Moraine dams are susceptible to failure because they are steep and relatively narrow, they comprise loose poorly sorted sediment, and they may contain ice cores or interstitial ice. These dams generally fail by overtopping and incision. Outburst floods from glacier- and moraine-dammed lakes typically entrain, transport, and deposit large amounts of sediment. If the channel is steep and contains abundant loose sediment, the flood likely will transform into a debris flow. Such debris flows may be larger and more destructive than the flood from which they formed.

Areas in which either the amount of precipitation or the frequency of severe storms increases are likely to experience more frequent landslides, especially debris avalanches, debris flows, and lahars. Sediment delivery to streams in these areas will increase, possibly heightening flood risk in populated areas.

Keywords: Climate change, glaciers, hazard, high mountains, risk

Positive mass balance of the very small glaciers of Prevala and Eastern Canin (southeastern italian Alps) in the hydrological year 2012-2013

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ABSTRACT

In the hydrological year 2012-2013 a mass balance calculations were performed in two very small glaciers of the southeastern Alps: the Prevala and the Eastern Canin, in the Julian Alps. We used a 12 m long avalanche snow probes and ground penetrating radar (GPR) to measure the winter snow accumulation. Detailed density estimation has been evaluated directly from GPR, and the results have been verified with some dedicated 4 m to 5.5 m deep snow pits. Summer ablation have been interpolated over the entire surface of the glacierets thanks to a number of ablations stakes inserted in the winter snow pack between the half of May and the end of October. Complementary repeated GPR surveys along two transects over the Prevala glacieret, allowed to image the internal changes during the ablation season and to compare the obtained results with the direct measures given by the ablation stakes. We observed a positive mass balance both for Eastern Canin (+0.21 m w.e.) and for Prevala (+0.35 m w.e.). This results are ascribable to the higher and longer winter snow accumulation of the winter season 2012-2013, which was able to counteract the 2013 summer heat.

Keywords: very small glaciers, glacierets, mass balance, GPR, Julian Alps

The Istituto Mosso LTER site (Aosta Valley, Italy): an integrated research - monitoring in an alpine permafrost area. Site instrumentation and techniques

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ABSTRACT

Rock glaciers are the most prominent geomorphic features related to the presence of permafrost in mountain areas. Climate warming is likely to have strong impacts on permafrost status, making cold areas at high altitudes especially vulnerable. Therefore, climate evolution and its impact on abiotic and biotic components of permafrost environments is a research topic of increasing importance.
In this work the active *Col d'Olen* rock glacier, located in the Istituto Mosso LTER (Long Term Ecological Research) site, in the Aosta Valley Region (NW-Italian Alps), is the object of an interdisciplinary investigation. Instrumentation and techniques are described below.
Climatic data from automatic weather stations have been collected in the study area and they will be updated and analysed. Moreover, a network of portable instruments will be established (during the summer 2014) on the rock glacier for collecting meteorological data, after a dedicated calibration procedures to assess the uncertainties of the measures, in the framework of MeteoMet2 project.
The physical and chemical characteristics of the rock glacier outflow are under investigation by using temperature dataloggers and a multi-parametric probe spectro::lyser^{TM} **(NO3-N and DOC)**. Regular sampling of water on weekly basis has been also established for investigating major ion concentrations (e.g. Ca^{2+}, Mg^{2+}, etc.), trace elements (e.g. Ni, Si, etc.) and isotopic analyses ($\delta^{18}O$). Moreover, the chemical characteristics of snow and fine-grained material are under analysis.
The ground surface temperature monitoring will be conducted using Maxim iButton® DS1922L mini-thermocrons and Hobo TidbiTv2 temperature loggers, regularly distributed on the rock glacier's surface and in a few selected surrounding sites. Total station and differential GNSS instruments will allow an accurate grid distribution and to acquire the coordinates of the dataloggers. In addition, high resolution digital terrain models (DTM's) and thermal images of the rock glacier area will be obtained from terrestrial laser scanner and *unmanned aerial vehicle* (*UAV*). Finally, ground-dwelling arthropod colonisation of the rock glacier's body will be studied.

Keywords: Climate, Italian Alps, Periglacial environment, Permafrost, Rock glacier.

Electrical tomography surveys to study the internal structure of a rock glacier and a debris covered glacier in the Chilean Andes: comparative analyses and genetic implications

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ABSTRACT

In March 2012 several electrical tomography (ERT) were performed over the rock glacier (RG) and the debris covered glacier (DCG) Pyràmide, in central Chilean Andes. The twenty one electrical resistivity tomographic profiles over the RG, especially in the frontal and apical sectors, permitted a deep understanding of the internal structure, useful for interpreting the genesis and assess the present water supply. ERT were performed both with 2 m and 5 m span, in order to also achieve more detailed information of the active layer. The active layer thickness ranged between 1 and 8 m, while a core of massive ice is present in the whole sectors of the RG although is more superficial on the southern side. Over the DCG, five longitudinal 2 m spaced profiles have been carried out in the median part of the glacier. The debris cover thickness is quite regular (from 1.5 to 3.5 m) in the steepest surveyed sector, and apparently lie above a 1.5 m thick portion of ice, rich in debris. Debris cover is thicker where the compression is higher due to marked slope variations. The comparison between the two landforms allows to clearly recognize some structural similarities. The observed high values of resistivity (>1 million ohm) both in the upper part of the RG and in the DCG are referred to massive glacial ice. Ice topography of both landforms appears sub-parallel to the topographic surface. Also the thickness of the debris cover and the active layer of the RG and DBG are similar. Based on the above presented results we can assume a common origin of both the RG and DCG.
Project "*Plan de Acciòn para la conservacion de glaciares ante el cambio climatico*". Coordination G. Diolaiuti; managing Ev-K2-CNR (Italy); Scientific and technician collaboration Dirección General de Aguas (MOP, Santiago, Chile).

Keywords: Rock Glacier, Debris Covered Glacier, Chilean Andes, electrical tomography, electrical resistivity.

Present state of the cryosphere in the italian and slovenian southeastern Alps

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ABSTRACT

The Julian Alps, in the southeastern most sector of the alpine chain, still preserve some very small glaciers and glacierets. The peculiar local climate characteristics, enhanced by topo-climatic and morphological effects, allow the existence of these glacial evidence at a very low altitude respect to the rest of the Alps. In the very last years the study of such very small glaciers and glacierets received a renewed interest, especially thank to the ongoing development of geophysical and geodetical techniques. The eastern and western branches of *Canin* glacier and the *Prevala* glacieret were surveyed for the first time with ground penetrating radar (GPR) between 2011 and 2014. In autumn 2013 a GPR survey was also performed on *Zeleni Sneg* glacieret (Triglav, Slovenia). Dedicated LiDAR surveys and geodetical campaigns allowed to obtain accurate DTMs, crucial for a correct estimation of thickness, areal extension and volume of the glacial bodies, and for the understanding of their recent evolution. Glaciological campaigns conducted between 2011 and 2014, all together allowed the calculation of the first mass balances for this alpine sector. The thickness of some of the very small glaciers of the southeastern Alps is close to 30 m. Generally they are characterized by repeated layers of ice, firn, snow and debris, often equally distributed. The additional analysis and acquisition of archive non-metrical images were used to reconstruct the area's evolution of Canin and Triglav glaciers from 1893 and 1897 respectively. Following the period of intense glacial reduction between the half 1980s and the early 2000s, we observed a general stabilization, or even increase, both in area extension and volume in the last ten years. This is mainly due to an increase in the winter precipitation which counteracted the observed general warming trend of the summer months.

Keywords: very small glaciers, Julian Alps, DTM, LiDAR, GPR.

Evolution of Dolomites glaciers in the last 100 years and recent mass balances in three glaciers

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ABSTRACT

The aim of this work is to provide quantitative data on changes occurred in the little Dolomite glaciers in the past century and show the recent mass balance data of three glaciers, among the largest ones in the Dolomites. Today there are approximately 75 glaciers in the Dolomites; they are generally of little size, often in form of glacierets, and some of them were unknown in the past. Owing to that, a sample of 27 glaciers was taken, for which historical data are available. Furthermore, the mass balance was calculated for Marmolada, Antelao Superiore and Fradusta glaciers, where GPR and GPS measures were taken in 2004 followed by Lidar survey from helicopter in 2009. These surveys show an average surface loss of 4.48 km^2 in 100 years, amounting to -49%, of which approximately 30% in the last 30 years. Calculation of mass balance, in the 2004/2009 period, showed an average annual loss of respectively 1.05 m w.e a^{-1} for Antelao Superiore, 1.16 m w.e a^{-1} for Fradusta and 1.01 m w.e a^{-1} for the Marmolada Glacier.

Keywords: Dolomites, Glaciers area, Front variation, Mass balance.

A web 2.0 platform for a century of glaciological observations in the Italian Alps

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ABSTRACT

More than 100 years of systematic glacier monitoring in the Italian Alps have produced one of the longest and most valuable series of observations of this kind in the world. The collection is relevant not only for its value as historical archive, but also as an important reference for analyzing past trends and for modeling the future of the cryosphere and the hydrology in Europe.
The format of the reports and the instrumentation used by the operators have widely changed over the century, from paper notes to spreadsheets, from slides to digital photos, from tape readings to GPS, and this evolution is still in progress. It follows a great heterogeneity in the collection, making extremely onerous both storing and consulting all the documents.
It is a crucial objective to preserve this heritage, to make it available to scientists for analysis, and to ensure its continuation over time.
Recent information technology advancements let foresee scenarios in which mobile smart devices and sensors will assist operators in recording field measurements, while web processes and applications will facilitate the automatic storage and display of data. User-friendly interfaces and interactive tools could then help non-experts to collect, map and handle additional glaciological information.
The geo-web offers effective ways to manage the most varied contents on a single multipurpose platform: while supporting spatial and temporal analysis, it will also facilitate a collaboration respectful of local practices and intellectual property rights. Moreover, the use of standard web services guarantees for the sharing, the re-use and the maintenance of the collections over time.
Following these criteria a web platform has been designed and implemented in a prototype form. It assimilates existing modules in a comprehensive framework and complement them with new services, tools and interfaces, with the aim to foster collection and consultation of heterogeneous glaciological observations.

Keywords: glacier monitoring, Spatial Data Infrastructure, Volunteered Geographic Information.

A monitoring plan for glaciers evolution and glaciers-related risk in Aosta Valley, IT

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ABSTRACT

Glaciers-related risk represent a major concern in civil protection and land-use planning in mountain areas. Actually, glaciers dynamics can trigger sudden, fast, far-reaching and destructive processes, such as ice avalanches, floods and debris flows. Forecasting of instabilities is mostly difficult or impossible due to a poor knowledge of processes and to remote location of glaciers. Uncertainty is enhanced by changes in climate that strongly affect glaciers evolution.
Aosta Valley region (NW Alps, Italy) is a highly glaciarized region, since more than 50% of the territory is above 2000 m asl and many peaks exceed 4000 m asl altitude. About 200 glaciers are inventoried, covering 135 km^2 (5% of the territory). A regional glacier inventory, field surveys and mass balance are carried out in order to monitor glaciers state and evolution.
Human settlements and infrastructures often reach high-mountain environment, mainly because of tourism development. Hence, glaciers dynamics can often affect settlements, thus generating risk.
Regional Geological Service, by means of Fondazione Montagna sicura, set up a Glaciers-related Risk Monitoring Plan (GRMP), in order to inventory glaciers hazards, detect new hazards arising from glaciers evolution and survey and monitor cases involving risk.
GRMP starts from an historical analysis of past instability events (icefalls, glaciers break-off, GLOFs), implemented by a geomorphologic analysis of the present glaciers state, to detect whether hazards are still actual. Potential runoff areas have been evaluated and crossed with vulnerabilities, to select dangerous glaciers. A photographic survey is carried out every year to evaluate glaciers evolution and detect potential arise of new hazards. So far, three cases required a specific monitoring system, as they can represent an actual risk for inhabited areas or infrastructures. These cases (Grandes Jorasses Glacier, Planpincieux Glacier and Lys Glacier) comprehend the three main types of glaciers-related hazards, i.e. icefalls from cold hanging glaciers, break-off of temperate or polythermal glaciers, and glacial lakes outburst.

Keywords: Glaciers-related risk Glaciers evolution, monitoring, Aosta Valley .

“100” YEARS of Glaciers and Glaciology in South Tyrol

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ABSTRACT

The Hydrographic Office of the Autonomous Province of Bolzano is a permanent member of the Italian Glaciological Committee and has been instituted in 1976 with the aim to collect and coordinate all the hydrographical, meteorological and glaciological observations in South Tyrol.
Since the LIA an evident retreat of glaciers has been observed and documented in this area with a reduction in surface of about 70% until now. This poster shows the main results of the most important studies about the glaciers of this part of the Italian Eastern Alps and their evolution in the next century. The available data extend from the “traditional” local glacier inventories, mass balances and front variations to some historical maps and documents as well as the recent surveys, papers and modelling results.

Keywords: fluctuations of glaciers, glacier inventory, glacier mass balance, Hydrografic Office of the Autonomous Province of Bolzano - South Tyrol.

Comparing weather station and isotopic data in the new Alpine ice core drilling site of Mt. Ortles (South Tyrol, Italy)

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ABSTRACT

The oxygen and hydrogen isotopic composition of ice cores has been widely used to reconstruct the climate of the past. However, the conditions in which snow layers are formed, and the effects of post-depositional processes, need to be taken into account when using stable isotopes as climate proxies, especially at medium and low latitude sites. During autumn 2011 four ice cores were drilled (three down to bedrock) in the top part of the Alto dell'Ortles glacier (3859 m a.s.l., South Tyrol, Italy), where the mass balance is still largely positive; it was the first time an ice core project reached the bedrock of an eastern Alpine glacier. At the same time, an automatic weather station (AWS) was installed in proximity of the drilling site, at 3830 m a.s.l. Several snow pits samples and two 10 m deep shallow cores were also retrieved in the same area between 2008 and 2013. Air temperature, wind speed and direction, and snow height data provided by the AWS with hourly resolution since 2011 enable the estimation of the snowpack evolution, and can be compared to the isotopic profiles determined in the snow pits, which were dug at the end of the typical accumulation (June/July) and ablation seasons (August/September). The analysis aimed at better understanding the mechanisms driving the isotopic composition variations at this site, in order to estimate the feasibility of a past climate reconstruction in this Alpine region. Based on the results from the two-year period (2011-2013) of overlap between isotope profiles and AWS data (and also using additional meteorological data from weather stations located at lower altitudes), an attempt has been made to reconstruct the snowpack evolution, in order to interpret the isotopic signal coming from deep and shallow cores.

Keywords: Alps, Glacier, Ice core, Isotopes, Temperature.

Wet-snow and glide-snow avalanches risk management in ski resorts: the support of the Mountain Risk Research Team to the Monterosa Ski in Aosta Valley (NW Italian Alps)

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ABSTRACT

Wet-snow and glide-snow avalanches are highly dangerous due to the large uncertainty related to their release, in term of volume and timing, and due to the high impact pressure they can develop on buildings, forest and infrastructures, such as for example a lift mast. In ski resorts, artificial avalanche release is commonly used as a protection measure for lifts and ski runs. But wet and glide-snow avalanches do not react positively to such measure and therefore are more difficult to manage than dry snow avalanches.
Moreover, in a context of climate change, they gain importance as in the future the snow cover might become wetter and the frequency of wet avalanches might increase, though no clear trend has been identified yet.
To improve our knowledge on the formation of this type of avalanches, four test sites have been installed within the Monterosa Ski resort in Aosta Valley (NW Italian Alps) during Summer 2013. Two of them are set up to monitor the snow gliding of the entire snowpack, which can possibly result first into the formation of glide cracks and then to avalanche releases. At the snow/soil interface glide shoes, temperature and humidity sensors are placed to monitor the gliding process and its most influencing driving factors. A web-cam is also continuously monitoring the possible glide cracks formation and evolution. Close to these, a third test site is devoted to the test of innovative sensors for snow humidity and density measures, important variables for these phenomena. The last test site is dedicated to the evaluation of the effectiveness of different protection measures, such as for ex. innovative defense structures and artificial release measures with respect to the risk related to wet-snow avalanches.
This work describes the test sites, the objectives of the research and some preliminary data.

Keywords: experimental test sites, glide-snow avalanches, monitoring, snow/soil interface, wet-snow avalanches

Characterization of two permanent ice cave deposits in the southeastern Italian Alps by means of ground penetrating radar (GPR)

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ABSTRACT

In the Natural Park of the Prealpi Giulie, Mount Canin represents a peculiar case study in terms of relationships between climate and environment. This massif is characterized by glacial and periglacial environments and by a large number of karst caves. In many of this high altitude caves permanent and layered ice deposits are reported. Although the area is interested from several decades by an intense research caving, the study of the underground cryosphere started only at the end of summer 2010 when two karst cave (Leupa and Vasto), partially filled by permanent ice, has been identified to be suitable for a geophysical and environmental monitoring.
In order to assess the thickness and the inner structure of such ice deposits, we performed several multi frequency Ground Penetrating Radar (GPR) surveys. We acquired several profiles using a GPR equipped with 500, 800 and 1600 MHz bistatic shielded antennas. GPR sections were combined in order to obtain volumes, therefore allowing a pseudo 3D interpretation. We imaged several intra ice horizons and the contact between ice and rocks reaching a maximum depth of about 5m and 9m for Leupa and Vasto ice caves, respectively.
The acquired data in the Leupa ice cave show an air-filled void (verified also by direct inspection) characterised by the typical EM phase inversion due to the contact between ice and air. Some features highlighted by the GPR traces have been furthermore interpreted as evidence of dynamic within the ice mass in the small glacieret existing at the entrance of the Vasto cave, probably driven by the presence of karstic voids within the rock mass.

Keywords: Ice caves, GPR, karst, Julian Alps, underground cryosphere

Geophysical potentials in glacial and periglacial environments in the Alps

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ABSTRACT

The understanding of the geometry and of the physical properties of the alpine glaciers as well as of the frozen sediments represents a major breakthrough to support detailed reconstruction of the recent and of the past climate changes. The utilization of geophysical imaging techniques to address these issues became fairly popular and in the last decade several authors reported successful cases of exploration.
The modern instruments deliver better and cheaper resolving power although in many cases severe logistical problems should be faced to collect the data in such extreme environments. Robust data interpretation is still somewhat lacking as the complexity of elastic, electrical and magnetic settings of the subsurface is often beyond geophysical resolution. Numerical modeling of the physical properties and of the associated response could be a valuable tool in the interpretation of such complexities.
We report here about several cases of integrated geophysical exploration of alpine glaciers (Adamello, Cevedale, Agola, Montasio, etc), of debris-covered glaciers and of areas characterized by permafrost. Different geophysical methods, using 2D and 3D geometry, were combined in all these experiments in order to constrain interpretation. Furthermore forward modeling was often utilized to gain a better insight in possible data processing artifacts and as a primary aid to assist the interpretation process.

Keywords: glaciers, gpr, passive seismic, resistivity, tomography.

A synthesis of the Antarctic surface mass balance

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ABSTRACT

Anthropogenic climate change is likely to cause continuing global sea level rise, but some processes within the Earth system may mitigate the magnitude of the projected effect. The present snowfall in Antarctica is equivalent to 6.0 mm/yr of the sea level increase. Regional and global climate models simulate enhanced snowfall over Antarctica, which would provide a direct offset of the future contribution to global sea level rise from cryospheric mass loss and ocean expansion. During the past decade, the Antarctic Ice Sheet has lost volume at a rate comparable to that of Greenland. Several processes affect surface mass balance, introducing large uncertainties in past, present and future ice sheet mass balance. To provide an extended perspective on the past surface mass balance of Antarctica, we used firn/ice core records to reconstruct the temporal variability in the surface mass balance over the past centuries. The surface mass balance reconstructions indicate that the changes over most of Antarctica are statistically negligible and that the current surface mass balance is not exceptionally high compared to the last 800 yr. However, a clear increase in accumulation of more than 10% has occurred in high surface mass balance coastal regions and over the highest part of the East Antarctic ice divide since the 1960s. To explain the differences in behaviour between the coastal/ice divide sites and the rest of Antarctica, we suggest that a higher frequency of blocking anticyclones increases the precipitation at coastal sites, leading to the advection of moist air in the highest areas, whereas blowing snow and/or erosion have significant negative impacts on the surface mass balance at windy sites.

A novel firn/ice-core melter system for continuous ICP-QMS trace element analysis

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ABSTRACT

Impurities trapped in snow and ice provide precious information on the past-atmosphere and past environmental variations. In particular, the study of trace elements and ionic compounds contributes to the understanding the changes in the past atmospheric circulation and the estimation of the relative contribution of different sources.
A new melting device for on-line decontamination and continuous analysis of firn/ice cores was used to analyse an alpine firn/ice core drilled at Colle Gnifetti (M. Rosa, 4450 m a.s.l.), covering a time period of 10,000 years. Melt water from inner part of ice core section was pumped to an ICP-QMS and a conductivity micro-cell for trace elements and continuous conductivity measurements, respectively. High resolution profiles of 24 elements were obtained. Pronounced seasonal variations were observed for both crustal (eg. Mg, Al) and anthropogenically enriched (eg. Cd, Pb) elements, with higher concentrations during summer. While the long-term profiles of crustal trace elements didn't show significant variations, for anthropogenic enriched metals a widespread increase is reported from 18th century, reflecting changing emissions. Discrete samples were also collected for trace elements, Pb isotopes and ^{239}Pu determinations by ICP-SFMS and ICP-OES.
To determine if changes observed in Colle Gnifetti core faithfully reflect changes in emissions from nearby European countries, we have compared snow/ice data with emissions data present in the literature. For example, from 1800 AD to the first decade of 20th century Pb concentrations progressively increased, reaching a maximum in the 1920s. During the 1920s Pb concentrations suddenly halved and remained low for the next two decades. After the Second World War, Pb depositions increased dramatically with the introduction of Pb additives in gasoline, peaking in the mid-1970s. From 1975, Pb concentrations in Colle Gnifetti ice began to decrease in accordance with the first environmental policies in Europe which started to limit pollutant emissions.

Recent glacier changes in the Val Venosta region

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ABSTRACT

Val Venosta is an inner-alpine dry valley with exceptionally low annual precipitation amounts. Hence, local glaciers may represent an important part of the seasonal water cycle of the region as their runoff during the melt season feeds the Adige-river which is the main water source for the intensive fruit production in the valley. Like everywhere else in the European Alps, glaciers in this area have been subject to substantial mass losses during recent decades.
The current study focuses on the glacier changes in the northern Part of the Ortles-Cevedale Alps and the southern Ötztal Alps during the period 2004 to 2014. We present the results of detailed mass and energy balance observations at Langenferner, a new benchmark glacier in the Ortles-Cevedale massive. Those direct observations are related to the regional glacier changes derived from three airborne laser-scanning (ALS) campaigns in 2005, 2011 and 2013. A quantification of areal and volumetric glacier changes in the Val Venosta region during the investigation period is provided, as well as the corresponding geodetic mass balances of the single glaciers. The results of the mass-balance calculations are interpreted with respect to their spatial distribution, taking topographic parameters such as altitudinal distribution of glacier area into account. Furthermore, the volume changes were used to cross-check the direct mass balance observations on Langenferner and to evaluate the representativity of these measurements for other glaciers in the region..

Keywords: airborne laser-scanning, glacier mass balance, surface energy balance

Definition of a methodology to map the suitability of mountain glaciers for ice core drilling using morphometric and climatic indicators.

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ABSTRACT

Mountain glaciers and non-polar ice core are very important sources of paleo-proxy data which are essential to achieve a complete overview of climate change in the last centuries. The glaciers melting, which rapidly increased in the last years, could lead to loss information affecting the possibility to predict how the climate will evolve. In this context, the need to develop a methodology to identify the suitable glaciers for ice core drilling is a current challenge. In the framework of the NextData project a method for mapping suitable areas at global scale has been defined by exploiting morphometric and physical parameters. The criteria governing the choice of a drilling site were identified according the literature of ice cores and by exploiting experts knowledge. Selected criteria mainly concern: i) the quality of glaciological reconstruction, ii) the technical feasibility and logistics, iii) the climatic interest.
The suitability of mountain glaciers for ice core drilling is herewith defined as the probability to drill a glacier to retrieve an ice core with preserved stratigraphic information and high temporal resolution.
Ice core drilling sites (from Ice core Data Base created by Geomatic Laboratory, DISAT UNIMIB) both for European Alps (n = 23) and Himalayan (n = 39) were initially overlaid on the Digital Elevation Model (DEM) and global inventories of glacier (i.e. GLIMS and RGI). Several geo-morphometric indicators (e.g. slope, flow accumulation, local relief, etc.) were then extracted from the ASTER GDEM (30 meters spatial resolution). Both for drilling site and glacier area, the cumulative distribution function was represented and classified. A weighting scheme was defined using both a data- and knowledge-driven approach in order to estimate a suitability of drilling based upon geo-morphometric indicators.
Results are currently integrated with climatic record (e.g. temperature, precipitation) and accessibility indicators in order to produce a mid-latitude glaciers map of suitability for ice drilling.

Keywords: Mountain glaciers, Ice core drilling, Classification, Suitability of drilling.

Multitemporal geomorphological analysis of avalanche events in the Miage Glacier Basin, Mont Blanc Massif.

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ABSTRACT

Glacier mass balance models usually do not take into account the input given by snow avalanches, but are based mainly on air temperature and precipitations. However in some cases, the input given by the snow avalanche deposits are important and their contribution to the glacier mass balance might be relevant.
In this work we address the above-mentioned issue with an empirical approach to a case study in the Mont Blanc massif, (NW-Alps, Aosta Valley Region, Italy). In the glacial basin of the Miage, a debris covered glacier, due to the high rate of snowfalls and the rugged topography, avalanches are so much frequent and their deposits remain on the glacier surface all the year.
Thanks to a rich database of historical aerial photos and to field surveys on the summer 2013 avalanche deposits, it was possible to analyze the evolution of snow avalanche deposits along the glacier surface. During fieldwork, control points have been established and information about the avalanches on the Miage Glacier have been collected, by GPS positioning and using camera and compass. Afterthat, data have been elaborated in a GIS system to produce digital results. The multitemporal reconstructions have been achieved thanks to seven digital orthophotos, produced from respective aerial photos covering the years between 1952 and 2003. Orthophotos have been analyzed to draw avalanche deposits. Deposits of different years have been compared in order to recognize some differences and relationships. Moreover, snow and weather data have been analyzed to find possible correlations with the avalanche data.
Some preliminary results:

- Larger deposits were found on North-facing slopes, compared with the South ones;
- The size of the avalanches deposits in summer on the glacier was found to be strictly related to the accumulated snowfall during the previous winter.

In order to summarize the information, multitemporal geothematic maps have been created.

Keywords: Avalanches, GIS, Glacier, Mass Balance, Multitemporal.

DATAGRALP – A new database for reconstructing the spatial-temporal evolution of the glacial resource in the Italian Alps over the last 100 years in the framework of the NextData Project - The Western Italian Alps

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ABSTRACT

In the framework of the CNR-NextData project, the DataGRALP working groups aim to improve the knowledge on Italian glacial resources, by developing an adequate system for the management of numerical, textual, iconographic and spatial glaciological data.
The Western Alps team focuses on the collection, validation, storage and analysis of glaciological data from the Piemonte and Valle d'Aosta regions. Glaciers of the Western Alps contribute significantly to the Italian glacial resource by means of a diversity of glacier types: valley glaciers and debris-covered glaciers (Miage, Belvedere), large (e.g. Lys, Verra) and small (e.g. Ciardoney, Breuil) mountain glaciers, hanging glaciers (Grandes Jorasses, Signal). They spread over a large area, but major glaciers concentrate in the most relevant massifs (Monte Bianco, Monte Rosa and Gran Paradiso) or elevated mountains (e.g. Monviso, Ciamarella and Punta del Sabbione).
A dedicated information system has been used to store basic glaciological parameters extracted by the CGI inventory (1959-62), such as: extension, length, width, slope, orientation, elevation, coordinates, but also information about glacier type and form, source nourishment.
An updated picture (2006) of the glaciers of the Western Alps has been drawn from most recent available ortophotos: glacier outlines have been associated to attribute tables for glacier parameters (area, length, width, slope, max and min elevation, exposure, latitude and longitude of the glacier centroid).
As a result, preliminary comparison data and statistics are outlined here for the glacial resource of the Western Alps: about the 34% of the glaciers existing in the inventory of CGI (1959-1962) are extinguished in 2006. Almost 1/4 glaciers were dismembered in more little glacial bodies and the present day total glaciated area is about 67% of the previous inventory.
Research by the team is in progress for more detailed quantification of glacial parameters in order to feed numerical models targeted to the simulation of the response of glaciers to climate change scenarios.

Keywords: Alpine glaciers, glacier monitoring, glacier inventory, cryosphere, aerial photographs, Western Italian Alps

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http://nextdata.sharegeonetwork.evk2cnr.org

A field monitoring network strategy to evaluate ablation and displacement rates of some selected Chilean glaciers

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ABSTRACT

Chile is characterized by a not negligible ice resource, mainly located in the Andes and in Patagonia. In the austral summer 2012 a field monitoring network strategy has been developed in order to survey the short-term evolution of a selection of Chilean glaciers. Then several glaciers featuring different size, geographical and climate setting were selected in the Andes (i.e. Piramide and San Francisco) and in Patagonia (i.e. Exploradores and Tyndall) thus being representative of the whole Chilean glaciation. On these glaciers ablation stakes were installed by steam drill and their position was acquired through differential GPS measurements as well.
After the installation of the monitoring network, measurements were periodically repeated in order to quantify ablation and displacement rates. In the Andes, for example, the Piramide glacier, a debris covered one, were 7 stakes have been located, was characterized by up to 130 cm of ice loss in the period 18/01-05/12/2012-xx at an elevation of 3.490,9m a.s.l. and featured a daily ablation of 0.41 cm and a surface displacement of 10 m over the whole summertime. In the Patagonia instead the Exploradores glacier featured a daily ablation of 2.37 cm in the period 08/02-28/11/2012 and surface displacement of 69.166 m.
All the collected data have been managed and processed in a GIS and a geomatic approach was applied to produce thematic maps.

The described activities were carried out in the framework of the Project "Plan de Acción para la Conservación de Glaciares ante Cambio Climatico", a scientific cooperation project funded by IDB - Inter-American Development Bank. The project, coordinated by G.A. Diolaiuti and managed by EvK²CNR committee, involved, as a technical and scientific partner, the Chilean Dirección General de Aguas (DGA - Ministerio de Obras Públicas).

Keywords: Ablation measurements, DGPS survey, Chilean Andes, Chilean Patagonia, geomatic approach.

Snow cover and soil monitoring in Sagarmatha National Park (Nepal): an integrated approach

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ABSTRACT

Since 2012, in the Sagarmatha National Park, a monitoring project (SHARE–RIVERS) has been carried out with the main purpose of studying the water cycle, with a special focus on the influence of climate change. Project activities include a wide variety of in-situ (water and soil sampling) and remote analyses.
Two expeditions have been carried out (2012 and 2013) for a soil and water survey in the area. In particular the measurement of soil temperature (Maxim I-Button) along an altitudinal transect (2660-5320 m asl) was carried out during winter 2012-2013 in order to gather data about patterns of ground surface temperature and the snow cover duration. The soil temperature measurement is still going on (HOBO U23 Pro v2). Moreover, in the last expedition, the occurrence of Pahilin cyclone (65 cm of snowfall at sites higher than 4615 m asl in three days) in the valley allowed the performing of several snow sampling along an altitudinal transect for a chemical characterization. Snow cover duration has been assessed by computing soil daily temperature amplitude and comparing the obtained results with threshold values derived from literature (e.g. 2° C).
These data have been compared with long time series of snow depth data obtained from weather stations located in the Sagarmatha valley and with remote sensing analyses carried out using MODIS satellite scenes.
Preliminary results showed an high variability in snow cover duration among the time series and an abrupt change at elevation greater than 5000 m asl. Concerning soil temperature, in the investigated season, a 0.47°C/100 m gradient was computed, a result comparable with air temperature one. At higher elevation the prevalent pattern of ground surface temperature, according to Ishikawa et al. (2003), was "*Direct atmospheric cold heat penetration throughout winter*". This pattern didn't always allow the detection of the snow cover duration, which, for example, during the winter 2011-2012 ranged between 21 and 329 days.
This integrated approach will provide a medium term assessment of snow cover dynamics and soil temperature in the park and a ground work for further analysis on environmental variables influenced by this phenomena e.g. water cycle, nutrient cycling, plant phenology.

Keywords: Climate, High elevation, Himalaya, Remote sensing, Soil temperature.

Belvedere glacier (Monte Rosa – western Italian Alps), a century of monitoring

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ABSTRACT

The Belvedere glacier (WGI code I4L01211009) is located in the Anzasca valley, Macugnaga, in the north-eastern sector of Piemonte (Italy). It is a debris covered glacier situated at the base of the high Monte Rosa east face. Its length is about 6 km and its maximum width is up to 500 m, with a surface of 5.58 km² and an average slope of 10°. The glacier main body is connected, in its upper part, with the Northern Locce, Signal and Monte Rosa Glaciers and it ends with a forked snout, reaching a minimum of altitude of 1770 m a.s.l..
Since the end of the XIX century, it has been studied and explored for the particular aspects of geodynamic phenomena of its glacial basin, connected with the overlying east face of Monte Rosa. Several phenomena of special interest occurred: at least seven outbursts and moraine collapse from August 1868 to July 1979, ice avalanches from above glaciers, a surge-type movement that had its culmination in the early 2000s and the formation of several glacial lakes, the largest of which was the supra-glacial lake "Effimero", formed during the summers from 2001 to 2009, that reached its maximum in July 2002 (volume of about 3 million m³ and depth of 57 m).
After the observed movement of surge and the formation of the "Effimero" lake several monitoring surveys have been carried out in order to check glacier dynamics during and after the event phase. Ablation, displacement, height loss and past dynamics were investigated by geomatic techniques, including differential GPS, terrestrial laser scanning and photogrammetry, allowing to quantify the monitored phenomena and help to better understand current glacier state. Moreover data were collected and computed by the employment of Geographical Information Systems which also allowed to represent glacier evolution in time.

Keywords: Alps, Differential GPS, Geomatic, Historical reconstruction, Terrestrial Laser Scanning.

Alpine glaciers as a climate proxy in a changing world

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ABSTRACT

The perception of mountain glaciers has strikingly changed from a strong symbol of an intact human-environment relation in romantic paintings and in advertisement for tourism to a unique demonstration object of climate change and of an increasingly disturbed global environment. Everybody can observe ongoing glacier changes and the physical processes involved – the melting of ice under warming conditions – are understandable to a wide public. For more than a century, internationally coordinated glacier monitoring has contributed to our quantitative knowledge and qualitative understanding of the evolution. The Commissione Glaciologica del Club Alpino Italiano, later the Comitato Glaciologico Italiano, participated from the very beginning in this climate-related long-term global observation programme.
Modern integrative strategies of worldwide glacier monitoring bridge the gap between detailed local studies for process understanding and model development with regional to global coverage primarily based on digital terrain information and high-resolution satellite information. As air temperature relates to all components of the glacier mass and energy balance, worldwide glacier evolution since the end of the Little Ice Age documented by long-term measurement series closely agrees with global warming trends. Both, the shrinking of glaciers as well as the rising temperatures are expressions of growing energy contents in the global climate system with human influences, especially through increasing atmospheric greenhouse gas concentrations, probably having become the primary driver.
The rapid developments in nature and technological innovation represent considerable challenges for the future. While space-born sensors provide an enormous flood of important data, many rather small mass balance glaciers tend to vanish and must be replaced by larger glaciers in order to avoid the danger of interrupted long observational series. An emerging research field concerns the modelling of new landscapes – e.g., the formation of new lakes - for de-glaciating mountain ranges.

Keywords: Alpine glaciers, climate change, cold mountains, glacier monitoring, landscape evolution.

Hydrological modelling in the Inylchek glacier region, Central Tian Shan

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ABSTRACT

A spatially distributed conceptual runoff model able to reproduce melt below supraglacial moraine was developed. Sub-debris ablation was calculated based on empirical equations derived from field observations. The model was applied at the Inylchek glaciers. While runoff from Southern Inylchek flows directly into the Inylchek River, runoff from Northern Inylchek is blocked by Southern Inylchek and forms Lake Merzbacher. This lake is drained frequently by outburst floods which reach the vast irrigation system in the Tarim basin downstream. To calibrate the model, a multialgorithm, genetically adaptive multiobjective method (AMALGAM) was used. Daily runoff observations from Inylchek River as well as glacier mass balance gradients from other glaciers in the Tien Shan were used as objective functions in three split samples. Runoff simulations yielded Nash-Sutcliffe coefficients mostly higher than 0.9, and the mass balance gradients were simulated in an acceptable range. The comparison of calculated lake volumes with outburst volumes reported in the literature gave insight into the hydrological system of Lake Merzbacher: the lake seems to have permanent runoff, also during the filling process. The good match between simulated and observed hydrographs further indicates that after the outburst, the enlarged drainage channels are closed rapidly and the system quickly transforms intmodelo pre-outburst conditions. Our research contributes to a better understanding of the glacio-hydrological regime of this highly glacierised catchment and helps to improve future scenarios on water availability in this arid region.

Keywords: sub-debris melt, runoff modeling, glacier mass balance, ice-dammed lake.

Uncertainties of meltwater modeling to runoff at a range of spatial and temporal scales – scopes of the hiSNOW project

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ABSTRACT

The cryopsheric contribution to mountain hydrological resources is likely to change with progressive changes in climatic conditions and glacier extents. Therefore there is a keen interest in examining the best tools for measuring these changes and developing the most appropriate model systems for enabling the highest quality projections of hydrological resources.
The goals of the hiSNOW project are to explore the relative performances of a range of methods of determining cryospheric runoff that are applicable at various spatial and temporal scales, and in particular to examine the sources and scale of uncertainties associated with each application.
The project area of interest is in the Ötztaler Alps, where assessments of the glacier mass balance of Hochjochferner will be undertaken simultaneously for 2014-2015 using (i) glaciological methods, (ii) geodetic methods using high resolution terrestrial laser scanning and (iii) remote sensing methods based on determining accumulation area ratios from the late summer snow line (LSSL) determined from LANDSAT imagery. Over a wider area of the glaciated upper catchments of the region for the period 2003-2014 the AMUNDSEN snowcover and hydrology model driven by INCA meteorological inputs will be used to compute snowcover and runoff. The outputs of this activity are finally also compared to snow cover maps derived from MODIS for the respective time period.
Validation data from extensive field measurements and available river gauge data will be used to evaluate the performance of each of these approaches of investigating cryospheric water stores and the derived meltwater release will be compared at a range of possible temporal and spatial scales in order to assess their relative performance for various hydrological applications.

Keywords: glacial runoff, mass balance, modeling, remote sensing, field measurements.

Glacier evolution of the last decades in the Nepal Himalaya, from repeat pictures and from own glaciological observations.

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ABSTRACT

After 50 years, a series of repeat photographs of glaciers were made in the Khumbu region Nepal in October 2006. The early photographs were taken mainly in 1956 by glaciologist Fritz Müller who was a scientific member of the Swiss Everest Expedition. The qualitative results show that very often the main valley glaciers did not change much in length nor in shape at the front, due to a substantial coverage of debris. Considerable thinning of glaciers was found at higher elevations of the valley glaciers. This could be recognized also by the strong destabilization of the moraines due to the absence of ice back-pressure to the morainial flanks. Several small glaciers without mass gain from high elevations have disappeared. Steep small glaciers with an accumulation area reaching to high elevations have not changed much in shape. This is probably due to higher snowfall amounts at high altitudes during monsoon seasons since the early 1990s. This increase in monsoon-precipitation has also been observed analyzing firn stratigraphy on glacier cliffs, in regions more to the west: in Lang Tang (2011) and Annapurna region (2012), as well as in Garwhal (2014). This little mass gain observed above 6000m compensate only to some degree the general ice loss of the glaciers of the mentioned regions of Central Himalaya, due to climate warming with an increase in the equilibrium line altitude (ELA).

Keywords: Glacier, Himalaya, firn stratigrafy, repeat photographs.

100 Years Glacier-Climate Studies at Claridenfirn Worldwide Longest Glacier Mass Balance Series 1914-2014

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ABSTRACT

Seasonal components of the mass balance provide the best insights to analyze climate-glacier interactions. Point observations at fixed locations directly reflect climatic conditions and are not biased by interpolation effects or the dynamic behavior of the glacier. An uninterrupted time series of mass balance observations of seasonal resolution since 1914 exist at two locations on Claridenfirn in the central Swiss Alps. This dataset represents the far longest available direct mass balance observations world wide. The stakes are located near the equilibrium line and the measurements act as index to reveal climatic fluctuations. The long term variations in mass balance are mainly driven by changes in summer ablation. An overall trend of decreasing mass balance is superimposed by a positive trend between the mid-1960s and the mid1980s and two distinct periods of recession in the 1940s and since 1985. We find evidence of significant changes in precipitation and melting conditions.

Keywords: Claridenfirn, long term mass balance.

Scenarios of glacier mass balance and runoff in alto Adige and Tirol, 2040 - 2060

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ABSTRACT

Based on records of runoff and climate and on glacier inventories of 1969, 1997, 2006 models of the water balance of 80 glacierized basins in the Alps of Alto Adige and North Tirol have been calibrated. Results show a systematic change of basin precipitation and of glacier mass balance from the central to the exterior parts of the Alps. The possible future runoff has been modelled with climate scenarios GFDL CM3 45 and CCLM ECHAM5 for 2040-2060. The presentation emphasizes the changes in glacier mass balance and equilibrium line altitude and the seasonal shift of glacier runoff and Pardé coefficients.

Keywords: climate driven glacial change, glacial runoff, mass balance changes.

The Global Cryosphere Watch : a WMO's programme for the monitoring of the cryosphere

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ABSTRACT

The cryosphere, its changes, and its impacts have received increased attention in recent years. It receives constant coverage by the media, creating a demand for authoritative information on the state of the world's snow and ice resources from polar ice to glaciers, based on data from the paleoclimate record, current observations, and future projections. The World Meteorological Organization (WMO), with the co-operation of other national and international bodies and organizations, and using its global observing capability, is in a position to provide an integrated, authoritative, continuing assessment of the cryosphere – a Global Cryosphere Watch (GCW). GCW will provide, directly or indirectly, data, information, products and analyses that will help Members and partners provide needed services to the wider user community. GCW will help us understand, assess, predict, mitigate, and adapt to climate variability and change and improve weather forecasting and hazard warnings, thus helping reduce the risk of loss of life and property from natural and human-induced disasters. In its fully developed form, GCW will include observation, monitoring, assessment, product development, prediction, and research. It will provide the framework for reliable, comprehensive, sustained observing of the cryosphere through a coordinated and integrated approach on national to global scales to deliver quality-assured global and regional products and services. The first phase of the GCW is the Development and Implementation Phase, that started in 2012 and will end in 2019. One of the core activity of this phase is the establishment and subsequent operations of the core GCW surface-based observational network, called CryoNet. It will define the types of sites in cold climate regions, on land or sea, operating a sustained, standardized programme for observing and monitoring as many cryospheric variables as possible. The GCW and Cryonet initiative will be presentend in detail at the conference.

Keywords: Climate Changes, Cryosphere, Global Monitoring, WMO.

The glaciological, stratigraphic, and isotopic contexts of the Great War site of Punta Linke (Ortles-Cevedale Group).

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ABSTRACT

The recent period of retreat of alpine glaciers is characterised by a marked reduction in the thickness of the glaciers also at higher altitudes, where there are emerging not only large portions of the bedrock, but also trenches and military constructions of the "White War", as is happening in Punta Linke . After the end of the Great War, the military structures were abandoned and progressively covered by snow and ice, thus preserving climatic environmental information related to this site from the end of World War I to the present. During the archaeological excavation campaign conducted in 2010, samples of ice have been collected from different contexts, for analysis at the EuroCold Lab of the University of Milan-Bicocca. The glaciological context of Punta Linke (made by the Italian Glaciological Committee in collaboration with the Provincia di Trento - Soprintendenza per i Beni Librari, Archivistici e Archeologici - Settore Beni Archeologici) includes also the reconstruction of the areal and volumetric variations of the glacial area near the archeological site, starting from the Holocene glacial maximum (Little Ice Age, culminated around the half of the 19th Century).
Four pillar were sampled in different stratigraphic context (bare glacier, eternal of structure, internal of structure, in the rock tube), and subsampled for visual stratigraphy, stable isotopes, chemistry and archive. A continuous thin sections (9x9 cm) from each pillar were done for provide visual stratigraphy by single and crossed polarised images; samples from 5 to 7 cm were done for the δD and δ18O stable isotopes measurements; samples from 5 to 10 cm were done for major ions measurements. For dating purpose an aliquot by the archive were used for 136Cs measurements.
The results permit to evaluate the snow filling history of the military structures from the end of the War World I.

Keywords: Glaciology; Global change; World War I; Archaeology; Ortles-Cevedale Group.

Aspect and slope angle as source of spatial variability in physical and chemical properties of Alpine snowpacks, Monte Rosa Massif (NW Italian Alps)

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ABSTRACT

In Alpine regions, snowpacks are characterized by both spatial and temporal variability, as a function of topographical and meteorological factors. In particular, the spatial variability of Alpine snowpacks is caused by a variety of parameters such as deposition, wind erosion, melting, radiation and metamorphism of the snow. This study addresses the snowpack spatial variability issue at the slope scale aiming at quantifying the influence of aspect and slope angle on the evolution of the snowpack physical and chemical properties.
Three sites were chosen in the Monte Rosa Massif (NW Italian Alps) at an elevation of 2600 m ASL, characterized by different slope angles and aspects: North and 25°, South and 25°, flat. In winter 2007-2008, physical and chemical (pH and Electrical Conductivity) snow parameters were periodically recorded. The structure and composition of snow displayed significant differences among sites: (1) in term of physical properties, the snowpack at the flat site was comparable to the North-facing site in the lower part of the profile, while it was similar to the South-facing site in the upper part of the profile; (2) concerning chemistry, the nutrient release started at the end of February at the South-facing and flat sites, occurring through different ionic pulses during the winter, on the contrary, at the North-facing site, the release occurred with a unique relevant ionic pulse at the end of April. This study confirms that the physical properties of a snowpack can vary broadly as a function of plot-scale topography, and that also the chemical properties are influenced by slope angle and aspect. The same topographic conditions play a role in the process of solute release, with different consequences in the nutrient input from snowmelt to subnivian mountain soils.

Keywords: field measurements, ionic pulse, snow chemistry, snowpack variability, topography

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Ten years of glaciological observations at Baltoro Glacier, Pakistan

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ABSTRACT

Baltoro Glacier is one of the largest valley glaciers in the world and a prominent representative of large debris covered glaciers in the Karakoram. Observations on this glacier have a long history, dating back to the first scientific visit during the Italian expedition to the Karakoram of the Duke of Abruzzi in 1909. Since then the glacier was regularly visited by Italian researcher and since 2004 a more focused investigation started on Baltoro glacier. Especially two unanswered scientific questions are investigated on this glacier: i) what is the effect of extensive supra-glacial debris cover on the ablation conditions of glacier and ii) is it possible to determine the high elevation accumulation in the Karakoram? Beginning in 2004, extensive ablation observations have been carried out across the lower parts of Baltoro glacier in combination with investigations of ice dynamic changes. The terminus position of Baltoro Glacier has been more or less stable during the last 100 years. However, surface profiles show that the surface elevation in the ablation zone has decreased considerably during this period. Model calculations demonstrate that the debris cover in the lower parts of the glacier effectively protect the ice body and mitigate the influence of high melt rates on the glacier mass balance. Mass balance calculations, on the other hand are complicated due to the lack of information about the accumulation conditions in the entire mountain region. A series of new measurements now allows us to close this gap and to develop a well based characterization of accumulation in the high basins of Baltoro glacier.

Keywords: Debris covered glaciers, Karakoram, Mass balance.

Remote sensing investigations to describe snow cover area (SCA) variability over 18 watersheds of the Central Chile in the time window 2008-2011

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ABSTRACT

We analyzed MODIS snow data to describe snow cover area (SCA) variability over 18 watersheds of the Central Chile in the period 2008 -2011. In particular, we used the MOD10A2-V5 snow product, consisting in data fields for maximum snow cover extent over an eight-day compositing period. The study area was divided into three different zones (North, Central, and South), due to its extent (~192,000 km^2) and following previous works performed by the Direccíon General de Aguas for the period 2000-2007.
After georeferencing our data to the WGS84 Datum (UTM Projection, zone 19S), the scenes were mosaicked and cropped to fit the study area (*i.e.* our three zones). Then we set a threshold for cloud coverage (30%) as the clouds can hide land features. So doing we only lost 2% of our sample. The hypsographic and aspect analyses were performed using the SRTM3 elevation model (http://www.cgiar-csi.org).
Our study reveals the overall mean SCA for the period 2008-2011 was 3832 km^2 (~2% of the entire study zone), with a maximum value reached in the hydrological year 2008 (*i.e.* April 2007 to September 2008). The maximum $SCA_{2008\text{-}2011}$ is reached in the Central Zone (7317 km^2), while the geographic and topographic features (*i.e.* low altitudes in the South Zone and the presence of the desert and the plateau in the North) seem to limit snow deposition elsewhere. For the same reason, snow is found higher in the North and its altitude decreases as we go southwards. In the North Zone the minimum SCA is reached sooner than elsewhere, lasting for a longer period (November to March). West aspects are dominant in each zones throughout the study period.
The present work represents an effort to extend the dataset of SCA in the Central Chile over time, adding precious information for any trend analysis of snow cover in this area.
The presented results were carried out under the umbrella of a scientific collaboration project named "*Plan de Acciòn para la conservacion de glaciares ante el cambio climatico*". This project was supported by an international announcement of Inter-American Development Bank and was coordinated by G. Diolaiuti and managed by Ev-K2-CNR (Italy). The scientific and technical collaboration was provided by the Dirección General de Aguas (Ministerio de Obras Pùblicas, Santiago, Chile).

Keywords: Snow cover area (SCA), Remote sensing, MODIS, Chile.

GIS analysis to apply theoretical Minimal Model on glacier flow line and to assess glacier response in climate change scenarios

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ABSTRACT

Development of theoretical work about glacier dynamics has given rise at the construction of mathematical models to assess their response in climate scenarios. Glacier are sentinels of climate condition and the Project of interest NextData will favour new data production about the present and past climatic variability and future climate projections. The aim of our project is to develop theoretical models to understand, evaluate and reproduce glacier response in different climate scenarios. These models try to reduce the complexity of a glacier dynamics in a simple description based on physics laws. To investigate glacier evolution has been used Minimal Glacier Model: this models does not explicitly describe spatial distribution of ice thickness, basal water pressure, sliding velocity. The glacier evolution is calculated from an integrated continuity equation over the entire volume, based on the perfect plasticity principle. The state variable is glacier length. The analysis is composed also by theoretical equation to estimate the mean thickness of a glacier, that starts from the evaluation of the elevation range and slope. For setting minimal model the glacier geomorphology has been studied by Digital Elevation Model using a GIS. Through DEMs, it is possible reconstruct the evolution of glacier with a multitemporal analysis and draw the flow lines that follow the accumulation-ablation dynamic, on which the model is applied. During this work an algorithm were developed to extrapolate from DEMs all the features to run model. The model input data set are given by the mass balance and the Equilibrium Line Altitude. A theoretical fit is the transfer function between the climate forcing (winter precipitation and summer temperature) and the glacier behaviour. First the model is validated on historical real series of glacier parameter and dimension, followed by the run of this models to estimate the evolution of glacier in future scenarios.

Keywords: Glacier, Minimal Model, GIS, DEMs.

Characterization and dynamics of bacterial community of cryoconites in two temperate glaciers

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ABSTRACT

Cryoconite holes are small depressions filled with water that occur on glacier surfaces. These holes form when dark debris, mainly constituted by mineral and microbial airborne particles (the cryoconite), lay down on the glacier surface, is heated by solar radiation, and melts the glacier. In the last decades, interest has increased in understanding the hydrology, biogeochemistry and ecology of cryoconite holes because they are considered the most biological active environments on the glaciers.
We collected 110 samples of cryoconite from two different temperate glaciers. Forni glacier (Italy) is the widest valley glacier (11.36 km^2) in Italy despite its extent largely decreased in the last years. Samples were taken at different times: July 2012, July 2013, August 2013 and September 2013. Baltoro glacier (Pakistan) is one of the largest Karakoram glaciers (62 km long) and its extent has been constant over the last century. Total DNA was extracted from all the samples and the Illumina sequencing of the V6 hypervariable region of 16S rRNA gene was performed to describe the bacterial community in each cryoconite hole. The data showed that the bacterial communities of Baltoro cryoconites are dominated, at order level, by *Burkholderiales* that constituted more than 60% of the communities and were completely different from those of the Forni cryoconites, where communities were dominated by *Sphingobacteriales*, *Burkholderiales*, *Sphingomonadales* and *Cyanobacteria*. Analysis of Forni samples collected in 2013 also showed that the microbial community structure also changed over time. Indeed, samples collected in July, immediately after the melting of the snow coverage, presented higher abundances of *Cyanobacteria* and *Clostridiales* than those collected in the following months, which conversely showed higher abundance of heterotrophic bacteria. Our results therefore represent a first insight into the ecology of the most productive ecosystems of mountain glaciers.

Keywords: Baltoro, Forni, Illumina sequencing.

The Arguerey and Breuil glaciers (Graian Alps, Italy)

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ABSTRACT

In this work we analyze the evolution of the Arguerey and Breuil glaciers (La Thuile, Aosta Valley), from the end of the Little Ice Age (LIA) to the years 2000s.
For this purpose, the glacier areas at specific time steps (1850, 1929, 1961, 1975, 1999, 2005) have been derived from topographic maps, from data collected by the Italian Glaciological Commettee, and from the outputs of the GlaRiskAlp Alcotra project. Using GIS techniques, it was possible to identify clearly the glacial areas and estimate their reduction through time.
At the end of the LIA the Arguerey Glacier had an areal extent of about 2.26 km^2, in 2005 this area had become about 0.44 km^2, with a reduction of 81%. At the end of the LIA the Breuil Glacier had an areal extent of about 3.39 km^2, and in 2005 this area had become about 0.69 km^2, with a reduction of 80%. A detailed reconstruction of glacier change through time will be provided.
During the last glaciological survey (September 2013), the signals used since the 1920s for the measurements of the snout distance and for the photographic surveys were precisely located, by means of a GPS receiver. Thanks to this information, we'll be able to transform the numerical information relating to snout distance in geo-referenced data.
This work aims to contribute to the knowledge of glacier evolution in the northwestern Italian Alps, also in support of studies on the impacts of climate change in high-altitude environments in the southwest sector of the Greater Alpine Region.

Keywords: GIS, glacier fluctuation, GPS, historical documentation, Italian Alps

Paraglacial processes in a recently deglaciated Antarctic environment (Elephant Point, Livingston island)

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ABSTRACT

Elephant Point is a small ice-free environment of only 1.16 km² in the SW fringe of Livingston Island (South Shetland Islands, Antarctica). The retreat of Rotch ice cap during the Holocene has exposed the land surface in this peninsula.
The northern tip of the Antarctic Peninsula has seen one of the strongest temperature increases in Earth during the second half of the XX century. In response to this climate trend, the retreat of the Rotch Dome has accelerated: up to 17.3% of the total ice-free surface in this peninsula has appeared between 1956 and 2010.
A detailed geomorphological mapping in the field was conducted in Elephant Point in January 2014. Four main geomorphological units were identified: proglacial environment, moraine complex, bedrock plateaus and marine terraces. The first two are affected by intense paraglacial dynamics as a readjustment to the new environmental setting. Several types of slow (solifluction) and rapid (slumps, debris flows, landslides) mass wasting processes have been observed in the moraine system. These processes are particularly active in the northern slope of the moraine, mainly through slump activity. In the active slumps ice-rich permafrost is exposed at surface. A significant percentage of 9.6% of the slopes of the moraine is affected by this type of mass movement. Thermokarst processes have been also observed in the proglacial environment and in the moraine plateau.
The degradation of this ice-rich permafrost terrain in the recently deglaciated area in Elephant Point is expected to continue during the following years, more or less pronounced depending on the rate and magnitude of climate change.

Keywords: deglaciation, Elephant Point, Maritime Antarctica, paraglacial processes, permafrost.

Preliminary results of the research on permafrost and periglacial environment in Piedmont Alps and future perspectives.

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ABSTRACT

Landslides and debris flow occurred in recent years in Piedmont sometimes were triggered in high altitude areas involving touristic resorts reaching even the urbanized valley areas. These paroxysms highlighted the need to expand towards higher mountain areas the climate and ground monitoring in order to analyse the potential relationships among climate change, periglacial environment and permafrost degradation, which could cause an increase in geological hazard of large mountain areas.
With this aim, ARPA Piemonte (Regional Agency for Environmental Protection) in collaboration with the University of Insubria, launched since 2006 a series of activities designed to enhance and deepen the knowledge on these issues, by establishing a network of permafrost monitoring stations distributed throughout the regional Alps. The activities, which enjoyed of a strong impulse during the European Alpine Space project *"PermaNet - Permafrost long-term monitoring network"* in the 2008÷2011 period, are now integrated in the institutional objectives of the Agency. The main results obtained are represented by: the updated regional inventory of permafrost morphological indicators, maps and models of the potential distribution of alpine permafrost, thermal monitoring stations in vertical boreholes (5 to 100 m deep) and in ground surface (steep rockface, debris and soil). Moreover, BTS (Bottom Temperature of the Snow Cover) measurement campaigns, geophysical surveys and some detailed studies (in collaboration also with Torino University) aimed to evaluate the relationship among atmosphere, geosphere, cryosphere and biosphere have been carried out.
In this work a synthesis of all activities conducted so far are presented with preliminary results at regional level, and the next future research on the topic of Piedmont Alps cryosphere will be delineated.

Keywords: permafrost monitoring, periglacial environment, Piedmont Alps.

PERMACLIM model implementation in QuantumGIS software: a new open source tool to simulate the spatial distribution of alpine permafrost

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ABSTRACT

Permafrost is defined as ground that remains at or below 0 °C for at least two consecutive years, for natural climatic forcing. It is very common in high latitude areas but it is also present in the mid-latitudes mountain range, such as the Alps. The detection of alpine permafrost is difficult due to complex geology and morphology. Measurement campaigns and the installation of monitoring stations are often not easily carried out, and the interpretation and spazialization of punctual data are very problematic. Therefore, an approach based on modeling allows the evaluation of permafrost distribution in mountain regions, in order to address more accurate direct or indirect analyses.
Many empirical and physical models already exist for estimating the spatial distribution of mountain permafrost, often requiring many complex input data. However none of these models have been implemented in open Geographic Information System (GIS) software yet.
In this work, the simplified physical-based model PERMACLIM (Guglielmin et al., 2003) has been implemented and developed as a plug-in for the QuantumGIS application (QGIS), an open source GIS environment. PERMACLIM model uses the energy balance equations and it needs as input data a Digital Elevation Model (DEM), climatic data (air temperature and snow thickness) and physical data (snow thermal conductivity and sensible heat flux). As output, PERMACLIM provides a permafrost map based on mean biennial ground surface temperature for each cell point of the DEM.
The PERMACLIM plug-in (implemented in collaboration with Faunalia) is an extremely versatile open source cross-platform application, using the Python language. It consists of four modules finalized to the calculation of: the distribution of snow based on slope, the ground surface temperature (GST) and the monthly and annual means of GST.
To sum it up, the PERMACLIM is a physical model with a simplified approach that is well suited for a regional application and that requires essentially two variables (air temperature and snow depth) which are often available in spatialized form. Moreover, the plug-in for an open source GIS is a free and open tool, to be freely used and developed by the scientific community.

Keywords: Geographic Information System, Open source, QuantumGIS, Permafrost.

Glacier fluctuations and forest limits changes in the Central Italian Alps

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ABSTRACT

Glacier history in mountain regions is strictly related to vegetation dynamics since both of them are directly influenced and driven by the climatic conditions. During a phase of climate change characterized by ameliorated temperature conditions the equilibrium line altitude rise over a region is usually followed by a generalized glacier shrinkage phase and by the glacier tongues retreat. As regards vegetation, the glacier-free proglacial areas of large valley glaciers typically undergo vegetation primary successions followed by forest invasion and the treelines are in general characterized by shifts towards higher altitudes. The study was performed in the highly-glacierized area of the Central Italian Alps, focusing on the forest invasion of the Forni Glacier forefield and on the treeline in Valfurva.
We found that the forest invasion of the Forni Glacier forefield is accelerating over time, with the lagtime between glacier retreat and tree establishment passing from a mean of 64 years at about 2540 m from the glacier front position (post Little Ice Age period), to a mean of 7 years at about 420 m close to the glacier front. Currently the most advanced portion of forest in the glacier forefields is characterized only by very young trees, which is in contrast to the evidences of a buried log found under the slope colluvium at an altitude of 2385 m a.s.l. and dating 4201-4031 cal. yr BP: this reveals that during the Sub-Boreal much older specimens of stone pine were present on the valley slopes. From the regional assessment of the treeline altitude performed by means of a GIS-based approach, over the 360 km of treelines analyzed we found that the mean altitude of the climatic treelines was 2531 m a.s.l., whereas the treelines constrained by geomorphological factors and human-influenced ones were meanly at 2356 m and 2331 m a.s.l. respectively.

Keywords: Central Italian Alps, Climate change, Glacier fluctuations, Glacier forefields, Treeline shift.

Solar activity, inter-annual climate variability deduced from Antarctic snow studies

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ABSTRACT

The cosmogenic nuclide beryllium 10 (10Be), recovered from ice cores, is often used to study solar activity on long timescales. In polar snow, the 10Be concentration is influenced by various factors other than the Sun. In order to identify and quantify various contributions to the 10Be signal, two Antarctic snow records spanning the last 60 years from Vostok and Concordia stations located on the central Antarctic plateau sites were analysed at a sub-annual resolution. Three factors that contribute to the 10Be signal were identified. First, a significant period of approximately 11 years, was detected on both records, and can be associated with the modulation of 10Be production by solar activity Second, two peaks in 10Be concentrations are associated to the stratospheric volcanic eruptions of the Mount Agung (in 1963) and the Pinatubo (in 1991), respectively. This indicates that powerful input of volcanic sulfates can impact the 10Be transport and deposition from the stratosphere. Third, an inter-annual variability of ~4yrs is present in 10Be records which are associated to that of sodium of marine origin. This 4yrs variability is interpreted as a tropospheric signal from the lower latitudes that could be associated with atmospheric circulation inherited from the coupled Southern Ocean ocean-atmosphere system. The study from sites within the high Antarctic plateau opens perspectives for ice cores dating over the last few centuries, for documenting the past climate variability over the Southern Ocean, as well as for the reconstruction of past solar activity in relation to climate.

Keywords: Antarctic, dating, ice cores, solar activity, climate variability.

Late Glacial to Holocene deglaciation of the Piave basin: new insights from an ombrotrophic peat bog

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ABSTRACT

Paleoclimate and paleoenvironmental studies in the North-Eastern Italian Alps are hampered by the scarcity of well-preserved high-altitude deposits and by the lack of high-resolution multi-proxy records with adequate chronological control. Records from peat bogs have been demonstrated to be among the best tools in paleoenvironmental studies to reconstruct past climate conditions and variations in atmospheric composition and here we present the first complete Late Glacial to Holocene peat succession from the Dolomites (Danta di Cadore, Belluno, Italian Alps). We collected a 7 m core and evaluated the potential of the ombrotrophic Val di Ciampo peat deposit (1400 m a.s.l.) as an archive of environmental and climate changes.
Chronological constraints on the course of deglaciation in the Southern Alps are fewer than those available for the Northern slope of the Alps. For the Piave basin, the mode and timing of deglaciation are well-defined only for its mid-part, while no data are available for the upper section. In such a context of very limited information, our new data represent a very valuable result, providing clear evidence that, during the Bölling-Alleröd interstadial, the upper part of the Piave Glacier was ice-free, and that the retreat process of the Piave Glacier from the Last Glacial Maximum was very rapid.
Pollen assemblages at the transition from the Late Glacial to the Early Holocene were studied at high resolution. In this time frame, pollens show that thicker forests of Gymnospermeae were present during the Bölling-Alleröd interstadial, and were reduced by the climatic cooling of the Younger Dryas, when a more open type of vegetation spread. Then, with the beginning of the Holocene, forests developed again with the expansion of warmth-requiring trees.

Keywords: Holocene, Late-glacial, Piave, peat bog, pollen analysis.

A 1D model of snow-gliding: the case study of Mont de la Saxe (NW Italian Alps)

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ABSTRACT

Snow-gliding is complex to predict and to model, and yet tremendously important as it may have negative effects on forest stands and soil erosion and could drive snowpack dynamics in the pre-glide-avalanching phase. Notwithstanding some advancements have been done hitherto in this area, but only little concerning the modelling of the process. This study aims to contribute to the understanding of the snow-gliding process by presenting a data driven, distributed, physically based and time-dependent 1D model, able to predict the gliding movement of snowpack along a flow line at daily scale.
The analysis pursues a number of objectives, namely i) to create a practical model requiring few, relatively easily available input data, ii) to reconstruct the snowpack physical evolution starting from measured precipitation, considering each single layers (thickness, density, thermal conductivity, temperature and SWE), and iii) to evaluate the rate and extent of movement of the snowpack in gliding phase, and iv) to provide a potentially useful tool for the risk assessment in areas subject to gliding, and subsequent avalanching.
In the proposed gliding model several simplifying assumptions were introduced, including absence of traction stress, wetting and water percolation through the snow, and micro topography of soil is schematized as a sinusoid in absence of soil erosion.
The model is applied to the avalanche site called "Torrent des Marais - Mont de la Saxe" in Aosta Valley, during the winter seasons 2010 and 2011, featuring different snow and weather conditions, when the site was equipped with specific sensors to measure snow gliding and soil and snow parameters.
The results displayed good capacity of the model to reproduce time patterns and final displacement of the snowpack, despite the great differences in the occurrence of the two investigated events.
The present results represent a dependable starting point for future researches, that should be focused at including more complex modelling of the different processes affecting snow-gliding, in order to possibly consider also the glide cracks formation and glide-snow avalanche release.

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Keywords: snow-gliding, 1D model, snowpack, experimental test sites.

Thermofluidodynamic modelling of the Adamello glacier changes in the current climate

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ABSTRACT

A thermofluidodynamic model was applied to the study case of the Adamello glacier (17,24 km^2, after GLIMS 2003 data), located in the Central Alps. The behaviour of the glacier between 1996 and 2007 was simulated. Using the open source finite element code Elmer (http://www.csc.fi/elmer) the dynamic and mass continuity equations were solved for the velocity field and the free surface elevation. The glacier was modelled with a 3D mesh composed by 28050 nodes and subdivided into 10 vertical layers. Elevation of the free surface and bedrock recorded in 1991 and in 1996 were used as boundary and initial conditions. For each simulated year a top surface temperature of -7.5 °C was considered for the winter semester (no-slip condition prevailing); in the ablation season the glacier's temperature was set to 0°C. During melting a fixed bottom velocity was applied to simulate the slip behaviour. As a Neumann boundary condition on the glacier's top surface the mass balance estimated from the energy-balance over the 1995-2009 period was assumed. The maximum simulated surface velocity results to be 87 m a^{-1}, a value consistent with observations. In order to assess the validity of the results, the change in the thickness of the glacier observed between 1991, 1996 and 2007 (DEM difference) was compared to the simulated change in the free surface elevation. The model was able to reproduce reasonably well the observed change in average thickness, although the spatial pattern of depth changes is underestimated or overestimated in some areas.

Keywords: Adamello Glacier, Energy Balance, Mass balance, Thermofluidodynamic.

Ten years geomorphological evolution of Zebrù Valley (Italian Central Alps) after the Thurwieser rock avalanche

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ABSTRACT

On September 18th, 2004 a rock-slide of about 2.2 millions of m^3 detached from the southern flank of Punta Thurwieser, and propagated as a rock avalanche along the Marè Valley in the upper part of Zebrù Valley, 30 Km East from Bormio (Sondrio, Italian Central Alps).
A portion of the Zebrù glacier, located right below the source area, has been mantled with a metric to sub-metric thickness of dark-grey dolostone debris, thus affecting the dynamic of the Zebru glacier. In this contribution, we aim to study the role of the rock avalanche on the mass balance of Zebrù glacier through Terrestrial Laser Scanner, airborne Lidar and GPS data collected since 2004.
Acting as a thermal insulation, the debris layer allowed to preserve a large amount of ice volume in the terminus of the glacier through reduced ablation process, resulting in a 13 m scarp in 2013 between covered and non-covered ice surfaces. Repeated measures in the displacement of rock avalanche accumulation induced by underlying ice flux enabled to calculate the mean ablation rate of the glacier and the retreat velocity, which shows an increasing trend of movement downvalley, due to topographical constraints.

Keywords: Differential ablation, flux velocity, Italian Central Alps, mass balance, Punta Thurwieser, Rock Avalanche.

Monitoring of the endoglacial caves position in Gorner Glacier (Switzerland)

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ABSTRACT

The importance of the exploration of endoglacial cavities in the glaciers has recently opened new challenge for scientific research due to a need for observational data to understand the effects of global warming on ice masses. As cryo-karstic phenomenon is directly related to the study of hydrology and physics of glaciers, intensive surface melt and massive decrease in elevation since the 1980s together with ice movement could affect not only the ice mass balance but also the glacial deep drainage. In fact, on glacier surface with relatively flat and compact, the meltwater feed epiglacial streams with a discharge of a few cubic meters per second that make up a complex network of surface drainage that after short distances disappear in pits (moulins) created by water falling in the mass of ice.
In the last 15 years, the monitoring of the position of several endoglacial caves have been performed in the Gornergletscher, the most interesting glacier in the Alps (South West of Switzerland), with the aim to distinguish local factors from global processes in the annual evolution of its moulins. Since 1999 the study took place with multiple field campaigns for morphological and location data compilation, rendered by maps. All field items have been inventoried with corresponding spatial position and compared with the previously existing information.
The preliminary data elaboration shows that, even though the Gorner glacier has not yet adapted its size to the new climate and are still far away from a steady-state, moulins still form at the same spot year after year, surviving at the surface ice movement toward the margins as observed during events triggered by intensive surface melt.

Keywords: endoglacial cave, moulins, glaciospeleology, Gorner glacier, Switzerland.

DATAGRALP - a new database for reconstructing the spatial-temporal evolution of the Glacial Resource in the Italian Alps over the last 100 years in the framework of the NextData Project - The Central Italian Alps

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ABSTRACT

In the framework of the CNR-NextData Project, the DataGRALP working group aims to improve the knowledge on Italian glacial resources, by developing an adequate system for the management of numerical, textual, iconographic and spatial glaciological data.
The Central Alps team focuses on the collection, validation, storage and analysis of glaciological data from the Lombardy region. The method adopted will furnish an updated picture of the glacial resource referred to 2006-2007 as well as of existing data related to the 1950s (CGI-CNR Inventory) and to the 1980s (WGI). Updating of data 2006-2007 is based on photointepretative analysis of orthophotos available via WMS (http://www.pcn.minambiente.it/GN/).
All data have been managed in GIS environment for constructing a glaciological database. All glacier outlines have been associated to attribute tables for glacier main parameters taking into account the existing international standards (WGMS).
The Central Alps hosted 185 active glaciers while 86 were extinct at the date of CGI–CNR Inventory (1959-1962). These glaciers covered an area of about 11.68 km^2 (including the Mandrone Glacier as part of the Adamello Glacier).
The WGI indicates in 1981-1983 305 glaciers covering an area of about 117 km^2. Preliminary data derived from 2006-2007 orthophotos, indicate the existence of more than 250 glacial bodies and 45 glacierets, covering 88.65 km^2 and about 26 km^2 respectively. Since 1950 about 30 glacial bodies disappeared and, on the contrary, about 60 newly formed glaciers derived from the fragmentation of wider glaciers.
Comparing data derived from the CGI-CNR Inventory and the new updated data for the 2006, glaciers of the Central Alps show an areal reduction of about 24%. The amount of areal reduction varies from 7% in the Orobie to 54% in the Tambo-Stella Group. The maximum glacial reduction was registered in the Ortles Cevedale Group where about 13.5 km^2 were lost since 1950s.

Keywords: Alpine glaciers, glacier monitoring, glacier inventory, cryosphere, aerial photographs, Lombardy.

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http://nextdata.sharegeonetwork.evk2cnr.org

Accelerated retreat of Italian Glaciers: the case of the Lobbia Glacier (Adamello Group, Rhaetian Alps)

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ABSTRACT

Glaciers in the Italian Alps as well as in other regions are withdrawing due to the effects of global warming. As documented in most alpine regions, alpine glaciers reached their maximum Holocene extent during the Little Ice Age (LIA, around 1850 AD).
In the Adamello-Presanella group (Rhaetian Alps) more than 140 glaciers developed during the LIA covering an area almost double compared to the present surface. Starting from the middle of the 19th century there was an important reduction in thickness and area of glacier bodies, broken by brief and weak advances, the most recent of which was around the 1980 AD. The Lobbia Glacier, a wide high-plateau glacier located in the Adamello Group, recorded in the last twenty years the fastest areal and volumetric variation since the end of the Little Ice Age. Trough multitemporal analisys of cartographic documents and aerial photos as well as geomorphological surveys, we reconstructed the glacier fluctuations in the last 150 years. Our data show that Lobbia Glacier experienced a relevant areal shrinking with a reduction of about 40% compared to its maximum Holocene extent as well as a frontal retreat of about 2350 m and 650 m of the northern and southern tongues respectively. Begging from the 1950s, we recorded a relevant contraction of the glacial body also in the highest portions of the accumulation area, highlighted by the formation of rocky windows, which are progressively widening. A relevant thinning of the glacier surface is also evidenced by hystorical photos of the First World War, showing a local thickness reduction of more than 80 m. The comparison between Digital Elevation Models confirms a consistent thickness reduction over the entire glacial body and documents a volumetric loss exceeding 60% from the LIA maximum to 2006 AD.

Keywords: areal and volumetric fluctuations, glacier monitoring, Lobbia Glacier, Rheatian Alps.

Fluctuations and recent variations of Pisgana Glacier (Adamello Group, Central Italian Alps) during late Holocene

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ABSTRACT

Two distinct glacial bodies (both North facing) presently constitute the Pisgana Glacier, in the Adamello Group, Raethian Alps. The western body (Ghiacciaio di Pisgana Occidentale) is a well defined valley glacier with compound accumulation basin, while the eastern one (Ghiacciaio di Pisgana Orientale) is a simple valley glacier. During the Little Ice Age (LIA), the Pisgana Glacier advanced to its maximum Holocene position and fed three distinct lobes reaching the minimum elevation of 2125 m. We evaluated areal and volumetric variations since the LIA through both direct and indirect investigations. Quantitative analysis of glacier variations was carried on by mean of aerial photographs, orthophotographs, and cartographic material (since 1885 AD) while the maximum Holocene extension was reconstructed by means of geomorphological mapping and glacial geological survey. All the data were processed in GIS environment (Arcmap 9.3, Ilwis 3.3). Volume variations expressed in terms of mass balance from Little Ice Age to 2012 were calculated by comparing different Digital Terrain Models (LIA-1983-2006) and by applying empirical formulas largely used in glaciological research (all the other years). A definitely negative trend, reflecting strongly negative mass balance, brought Pisgana Glacier to halve its area from the Little Ice Age maximum extension to 1983 and further accelerated the contraction later on (to 2012). The general negative trend was interrupted by minor phases of expansion that occurred at the start of 1900 and during the ’80s. Volume reduction exceeds 180 millions of m^3 from 1850 to 1983 and the loss further increased until 2006.
Results obtained are in agreement with the trend recorded by most glaciers of the Alps since the Little Ice Age, reflecting the strong response that glaciers show respect to the ongoing climate warming.

Keywords: Holocene, Italian Alps, Little Ice Age, Mass Balance, Pisgana Glacier.

Seasonal air circulation model and topographic survey of the "Grotta del Gelo" (Mount Etna, Italy)

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ABSTRACT

The "Grotta del Gelo" (literally Cave of Ice), which is located at 2043 m a.s.l on the north flank of Mount Etna volcano (Sicily, Italy, 37°48'27.3"N 14°58'19.9"E), is the southernmost ice cave over Europe. Alike other caves at Mount Etna, the "Grotta del Gelo" is a lava tube resulting from the volcanic activity. Specifically, it formed during the historic long-lasting eruption of 1614-24. Despite its position in terms of latitude and geological setting, peculiar conditions of thermal equilibrium started to develop (e.g., temperature fluctuation around zero, cold-air trap, etc.) after about twenty years from the end of eruption, leading to the gradual process of subterranean freezing inside the cave. Ice occurs in several forms in the cave, namely: seasonal lake ice, stalactites, stalagmites and columns close to the entrance, perennial ground ice in the deepest zone. The surface covered by the glacier reaches about 240 m^2, with an estimated ice volume of 220-260 m^3.

In order to develop an air circulation model, a network of data loggers was installed on May 2013. These have recorded the air temperature, with steps of 15 minutes, inside and outside the cave. Furthermore to evaluate variations of the ice block from morphological and volumetric standpoints, topographic surveys using a digital theodolite have been performed in different periods. Following this systematic method, the final result will be the development of a 3D model of the cave and of the ground ice, showing hypogeal ablation and variations of the volume over the years.

Keywords: Cold-Air Traps, Grotta del Gelo, Ice Cave, Lava Tube, Mt. Etna.

Post-LIA glacier changes along a climatic transect in the Central Italian Alps

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ABSTRACT

The variability of glacier response to atmospheric temperature rise in different topo-climatic settings is still matter of debate. To address this question in the central Italian Alps we compile a post-LIA (Little Ice Age) multitemporal glacier inventory (1860-1954-1990-2003-2007) along a latitudinal transect that originates north of the continental divide in the Livigno mountains, and extends south through the Disgrazia and Orobie ranges, encompassing continental-to-maritime climatic settings. In these sub-regions we examine area change of 111 glaciers. Overall, total glacierized area has declined from 34.1 to 10.1 km^2, with a substantial increase in the number of small glaciers due to fragmentation. Average annual decrease (AAD) in glacier area has risen of about an order of magnitude from 1860-1990 (Livigno: 0.45; Orobie: 0.42; and Disgrazia: 0.39 % a^{-1}) to 1990-2007 (Livigno: 3.08; Orobie: 2.44; and Disgrazia: 2.27 % a^{-1}). This ranking changes when considering glaciers < 0.5 km^2 only (i.e., we remove the confounding caused by large glaciers in Disgrazia), so that post-1990 AAD follows the latitudinal gradient and Orobie glaciers stand out (Livigno: 4.07; Disgrazia: 3.57; and Orobie: 2.47 % a^{-1}). More recent (2007-2013) field-based mass balances in three selected small glaciers confirm post-1990 trends showing consistent highest retreat in continental Livigno and minimal area loss in maritime Orobie, with Disgrazia displaying a transitional behaviour. We argue that the recent resilience of glaciers in Orobie is a consequence of their decoupling from synoptic atmospheric temperature trends. A decoupling that arises from the combination of local topographic configuration (i.e., deep, north-facing cirques) and high winter precipitation, which ensures high snow-avalanche supply, as well as high summer shading and sheltering. Our hypothesis is further supported by the lack of correlations between glacier change and glacier attributes in Orobie, as well by the higher variability in ELA_0 positioning, post-LIA glacier change, and inter-annual mass balances, as we move southward along the transect.

Keywords: area change, climate setting, mountain glaciers, snow avalanche supply.

Micrometeorological conditions and melting distribution assessed at the Exploradores Glacier (Northern Patagonia Icefield, Chile)

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ABSTRACT

The Exploradores Glacier is part of the Northern Chilean Patagonian Icefield, around 46° 30′ S and 73° 10′ W. It's a maritime glacier located on the northeastern slope of Cerro San Valentín (i.e. it's not directly connected to the icefield), in the Aysen Region of Chile. In November 2011 a VAISALA Automatic Weather Station was installed on the tongue of Exploradores Glacier (at 180 m a.s.l.). It has been measuring all the meteorological parameters: air temperature and relative humidity, atmospheric pressure, wind speed and direction, incoming and outgoing shortwave and longwave radiation by a CNR4 net radiometer and liquid precipitation. We analyzed the meteorological data in the time frame 11th February - 22nd April 2012 to characterize the area at a micrometeorological level. In addition to distribute the melting over the whole glacier surface (using the 2000 SRTM DEM with a resolution of 90m x 90m), we applied an enhanced T-index approach based on the air temperature and the incoming solar radiation (see Carturan et al., 2012). This latter was distributed following Oerlemans (2001). From 12th February to 10th April 2012 at an altitude of 157 m we found a melt amount equal to -5.4 m w.e. and the melting rate resulted null at 1200 m. Moreover considering the whole area of 114 km2, a total melting amount of -0.19 km3 w.e. resulted with a mean ablation of -1.6 m w.e. In addition, regarding only the ablation area (73 km2 wide) the mean loss resulted -2.5 m w.e.

The presented results were carried out under the umbrella of a scientific collaboration project named "*Plan de Acciòn para la conservacion de glaciares ante el cambio climatico*". This project was supported by an international announcement of Inter-American Development Bank and was coordinated by G. Diolaiuti and managed by Ev-K2-CNR (Italy). The scientific and technician collaboration was provided by the Dirección General de Aguas (Ministerio de Obras Pùblicas, Santiago, Chile).

Keywords: Exploradores Glacier, Northern Chilean Patagonian Icefield, Enhanced T-index Melt Model, Micrometeorological Conditions, Supraglacial Automatic Weather Station.

A contribution to a better understanding of the alpine cryosphere: the new Italian Glacier inventory

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ABSTRACT

A new Glacier Inventory is an indispensable scientific and practical requirement in Italy due to the importance of evaluating the present glacier coverage and the recent changes driven by climate. The first Italian Glacier Inventory dates back to 1959-1962. It was compiled by the Italian Glaciological Committee (CGI) in cooperation with the National Research Council (CNR) and describes 824 ice bodies which altogether were covering 518 km^2. Moreover in the Eighties a new inventory was compiled to insert Italian data into the World Glacier Inventory (WGI). During the last decade the largest part of the Italian Alpine Regions have produced regional and local glacier inventories, moreover the actual need is an unique homogeneous glacier database. The new Italian glacier inventory includes the main fundamental parameters and features, such as glacier name, national inventory code, former WGI code, coordinates, surface area (minimum size 0.01 km^2), glacier type and aspect (following the guidelines of the World Glacier Monitoring Service summarized by Paul et al., 2010). The identification of the Italian glacier bodies and the evaluation of glacier area and main features have been performed by analyzing aerial orthophotos acquired in the time frame 2005-2011 (pixel size 0.5 m X 0.5 m) and processing high resolution satellite images.
The whole Italian glaciation consists in 900 ice bodies covering a surface area of 369.5 km^2. Considering the glacier surface, the Italian region featuring the widest ice coverage is Valle d'Aosta (133.7 km^2). Moreover the highest number of glaciers per region is found in Lombardy (230 ice bodies). Excluding the two glacieret split from Calderone glacier in the Apennines, the Italian glaciation is located on the Alps and mainly consists in small ice bodies (mean glacier area of 0.4 km^2) classified as Glacieret or Mountain Glacier. The dominant aspect is North and only a very small number of wide glaciers is still present (i.e. 3 glaciers >10 km^2) resembling the ancient huge Alpine glaciation.

KEYWORDS: Cryosphere evolution, Glacier inventory, Italian Alps

Ice thickness measurements with GPR on some Chilean glaciers (Central Chile and Northern Patagonia)

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ABSTRACT

Ground Penetrating Radar (GPR or Georadar) is a non-invasive geophysical technique using high-frequency EM pulses transmitted from a radar antenna to investigate the subsurface. The transmitted radar pulses are reflected from various interfaces within the ground separating materials with different dielectric properties (e.g. ice-rock interface) and their return is detected by the radar receiver. GPR has been extensively used for glaciological investigation during the last 30 years for mapping glacial bed morphology as well as detecting discontinuities in glacial ice (e.g. subglacial water-filled cavities). Ice thicknesses obtained from GPR surveys are generally used to estimate glacier volume and assessing water reserves stored in the investigated glacier. GPR surveys on some Chilean glaciers, located in Central Chile (Piramide Glacier, San Francisco Glacier, Echaurren Norte Glacier) and Northern Patagonia (Exploradores Glacier) were carried out during summer 2012. A GSSI SIR-3000 radar system and a RADARTEAM Subecho 40 antenna, with 35 MHz centre frequency were used. Georadar measurement were geo-referenced with geodetic GPS instrumentation, providing 3D coordinates along the GPR profiles with centimetric precision, very useful where no recent topographic surveys of the glacier surface were available. The main outcomes of the above investigations will be presented.

The presented results were carried out under the umbrella of a scientific collaboration project named "*Plan de Acciòn para la conservacion de glaciares ante el cambio climatico*". This project was supported by an international announcement of Inter-American Development Bank and was coordinated by G. Diolaiuti and managed by Ev-K2-CNR (Italy). The scientific and technician collaboration was provided by the Dirección General de Aguas (Ministerio de Obras Pùblicas, Santiago, Chile).

Keywords: Piramide Glacier, San Francisco Glacier, Echaurren Norte Glacier Exploradores Glacier, GPR, GPS, ice thickness.

Investigating debris covered ice in the Luseney Range, Aosta Valley.

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ABSTRACT

The glaciers of the Alps have been intensively observed and major glacier inventories exist in most Alpine countries. Airborne photography is a major tool for the outlining of glaciers in inventories. However detection can be difficult in some cases: first of all when ice becomes buried under debris, but also in areas where snow cover is abundant at the end of summer, or where even slight cloud cover or mountain shadows (mostly in old flights) makes airborne photography not suitable for detection. Further difficulties can be encountered in areas where, because of difficult access, remoteness, or isolated nature of glacial bodies, field glaciological observations have been discontinuous or absent. This research aims at detecting buried ice bodies, which have been often not included in glacier inventories. For that, a detailed study of a small area in the Aosta Valley region, in the surroundings of the Becca de Luseney (N 45°87' E 7°49'), has been carried out during this research. For this purpose at first literature and historical research has been carried out, coupled then with analysis of recent and historical othophotographs. Subsequently, the zones of interest have been studied by means of differential airborne radar interferometry (DinSar). This method shows a very good correlation between individuation of the areas delimited by detailed aerial photography analysis and those outlined by remote sensing.

Keywords: Aosta Valley, buried ice, debris covered ice, DinSar, glacier inventory.

A first approach to detect supraglacial vegetation coverage on debris-covered glaciers using aerial photographs and satellite images: the case study of Miage Glacier

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ABSTRACT

Debris-covered glaciers are becoming a new habitat for vegetation including trees, which germination and growth are controlled by debris layer thickness and grain size, by surface velocity and stability and by the altitude of the glacier tongue. The progressive colonization of debris-covered glacier surface performed by trees is a response to climatic and environmental changes that may be further investigated in trees located in crucial study sites, where the effects of these changes are evident. For this reason, the need for a method that allows the rapid detection of supraglacial trees is increasing.
In this study we present the first results of the identification of supraglacial tree coverage located on the Miage Glacier (Mont Blanc Massif), using aerial photos and satellite images.
Two methods were tested.
1) A semi-automatic method was attempted on aerial images from 2005. Two training classes of pixels were selected on the glacier terminus area, one corresponding to the debris and the other one corresponding to the vegetation, in order to perform a supervised classification using maximum likelihood algorithm.
2) The comparison between the areas characterized by the presence of vegetation, identified through the analysis of aerial images and the direct observation conducted in the study area, and the data of supraglacial temperature, altitude, moisture and thickness of debris, obtained from satellite images, was performed, in order to find a correlation between vegetation presence and these variables.
The main problems concerning the discontinuous distribution and the relatively reduced size of the vegetation (regarding both its height and its canopy) in the identification of supraglacial trees have been discussed in order to identify a rapid but accurate method of investigation.

Keywords: Aerial Images, Debris-covered glaciers, Miage Glacier, Satellite Images, Supraglacial Vegetation.

Inventory of lakes in glaciated and recently deglaciated areas of Piemonte Region (Northwestern Alps)

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ABSTRACT

This study concerns lakes located in glaciated and recently-deglaciated areas of the northwestern alpine chain. They are of considerable significance due to several reasons: they represent important elements for mountain environment, landscape and ecosystem; they are an economic resource for tourism (e.g. Miage Lake, Mount Blanc Massif, Aosta Valley) and for the production of hydroelectric power (e.g. Sabbione Lake, Val Formazza, Northern Piemonte); finally they can play as risk factors for enabling Glacial Lake Outburst Floods (e.g. Effimero Lake, Belvedere Glacier, Mount Rosa Massif).
In the Piemonte Region, large amount of information (reports of the yearly glaciological surveys, photos, maps, aerial imagery) are available on glacial lakes, but they are not systematically organized. This work aims to create an inventory of glacial lakes, to make a geographical and multitemporal analysis of the phenomenon and to deepen some case studies for increased knowledge on the relationship between the lake and its respective glacier.
Different methods and instruments were used: bibliographic research, database construction, aerial photogrammetry, orthophotos analysis and Geographic Information System (GIS).
An inventory of 55 glaciers affected by the presence of one ore more glacial lakes has been derived. Geographycal distribution of glaciers with lakes includes five sectors of western Alps (3 in Maritime Alps, 9 in Cottian Alps, 24 in Graian Alps, 6 in Pennine Alps and 13 in Lepontine Alps). For each glacier a short description is presented, focused on the evolution of related glacial lakes, and supported by photos and references. A morphometric evaluation was performed on: altitudinal distribution of glacial lakes, glaciers exposure, the slope of the areas where lakes are located and lakes size.
Data collected allows to deepen the knowledge of glacial environment, to understand spatial and temporal evolution of glacial lakes, but also related phenomena that happens in the cryosphere. This has recently become a need because of the global climate change.

Keywords: geomatics, glacial lakes, inventory, Northwestern Italian Alps.

DATAGRALP - a new database for reconstructing the spatial-temporal evolution of the Glacial Resource in the Italian Alps over the last 100 years in the framework of the NextData Project - The Eastern Italian Alps

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ABSTRACT

The Eastern Alps team focuses on the collection, validation, storage and analysis of data from the Triveneto region and from Calderone Glacier. The method allow us to have an updated picture of the glacial resource referred to 2006-2007 as well as considering the existing data related to the 1950s (CGI-CNR Inventory) and from data collected during the 1980s (WGMS). The methods we used for the more recent data is based on photointepretative analysis of orthophotos taken during the 2006s and 2007s available via WMS from the National Geoportal and of other territorial data (such as LiDAR data) if available.
All the data have been managed in GIS environment to construct a glaciological database through the development of an adequate system for the management of glaciological data. All glacier outlines have been associated to attribute tables for glacier main parameters (area, length, width, slope, max and min elevation, exposure, coordinates) taking into account the existing international standards (WGMS).
Here we present the preliminary data derived from the rielaboration of CGI-CNR Inventory and the comparison with the new data coming from photointerpretative analysis.
During the 1950s the Eastern Italian Alps + Gran Sasso d'Italia hosted 342 glaciers (175.5 km^2).
Preliminary data derived from the 2006-2007, indicate the existence of 411 glacial bodies (134.7 km^2). The newerly formed glaciers derived from the fragmentation of wider glaciers.
Comparing the data from the CGI-CNR Inventory and the new survey of 2006, glaciers of the Eastern Alps show an areal reduction of about 23%. The amount of areal reduction varies from 0% in the Alpi Giulie to 37% in the Alpi Dolomitiche. In any case the maximum value of glacial reduction was registered in the Alpi Venoste, Passirie e Breonie Group where about 17 km^2 have been lost since 1950s.

Keywords: Alpine glaciers, glacier monitoring, glacier inventory, cryosphere, aerial photographs, Italian Alps

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http://nextdata.sharegeonetwork.evk2cnr.org