

**Proceedings of the International Symposium**

**THE FUTURE OF THE GLACIERS  
FROM THE PAST TO THE NEXT 100 YEARS**

**Held in Torino (Italy) 18 - 21 September, 2014  
For celebrating 100 years of the Bulletin of the Italian Glaciological Committee**

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# THE FUTURE OF THE GLACIERS FROM THE PAST TO THE NEXT 100 YEARS FOREWORD

**International Symposium held in Torino (Italy) 18 - 21 September, 2014  
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**ABSTRACT:** Baroni C. & Salvatore M.C., *The future of the glaciers: from the past to the next 100 years*. (IT ISSN 0391-9838, 2015).

The International Symposium “The future of the glaciers: from the past to the next 100 years” was held in Torino (Italy) from 18 to 21 September, 2014 for celebrating the centenary of the Bulletin of the Italian Glaciological Committee. The “Bulletin”, published as *Geografia Fisica e Dinamica Quaternaria* (GFDQ), is currently in its third series. The topics of the meeting were focused on glacier mass balance, monitoring and observation, glacier geophysics, glaciological hazard, climate driven glacial change, glacier hydrology, periglacial/permafrost processes, and snow processes. A selection of the papers presented at the Symposium is published in this volume.

The centennial CGI activity represents the base of knowledge for prosecuting and improving Italian glaciological researches and for satisfying the increasing need for validated and reliable data for developing quantitative models of glaciers response to climatic warming.

**KEY WORDS:** Alpine glaciers, Glacier monitoring, Glacier inventory, Cryosphere, Global change

**RIASSUNTO:** Baroni C. & Salvatore M.C., *Il futuro dei ghiacciai: dal secolo scorso ai prossimi cento anni*. (IT ISSN 0391-9838, 2015).

Il Simposio Internazionale si è tenuto a Torino dal 18 al 21 Settembre 2014 per celebrare il centenario della pubblicazione del Bollettino del Comitato Glaciologico Italiano, oggi giunto alla terza serie con la rivista *Geografia Fisica e Dinamica Quaternaria*. I temi principali affrontati nel Simposio hanno riguardato i bilanci di massa, il monitoraggio dei ghiacciai, le ricerche geofisiche, la pericolosità glaciologica, la risposta dei ghiacciai ai cambiamenti climatici, l'idrologia glaciale, i processi glaciali e periglaciali e i processi nivali. In questo volume è pubblicata una selezione dei lavori presentati al Simposio.

La centennale attività del CGI rappresenta una solida base di conoscenza per proseguire e migliorare le ricerche glaciologiche italiane per soddisfare la crescente richiesta di dati validati e affidabili necessari allo sviluppo di modelli quantitativi della risposta dei ghiacciai al riscaldamento climatico in atto.

**TERMINI CHIAVE:** Ghiacciai alpini, Monitoraggio glaciale, Catasto dei ghiacciai, Criosfera, Cambiamenti globali

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## THE INTERNATIONAL SYMPOSIUM ON THE FUTURE OF GLACIERS

The International Symposium “The future of the glaciers: from the past to the next 100 years”, was held in Torino (Italy) from 18 to 21 September, 2014 following the wishes of the President of the Council of Ministry of Italy and under the Patronage of: i) the Ministero dell’Ambiente e della Tutela del Territorio e del Mare, ii) the President of the National Science Council (Consiglio Nazionale delle Ricerche, CNR), iii) the Club Alpino Italiano (CAI), iv) the Italian Association of Physical Geography and Geomorphology (AIGeo), and v) the Regione Piemonte. The

University of Torino hosted the Symposium, and the Universities of Pisa, Milano Bicocca, Padova and Politecnico of Torino co-sponsored the event.

The Symposium aimed to celebrate the centenary of the Bulletin of the Italian Glaciological Committee. The Bulletin, currently in its third series, is published as *Geografia Fisica and Dinamica Quaternaria* (GFDQ). GFDQ has been included in the Thomson Reuters ISI database beginning with Volume 30 (2007) and is now ranked by Thomson Reuters Web of Knowledge (<http://www.gfdq.glaciologia.it/>).

An Icebreaker on the evening of Thursday the 18<sup>th</sup> opened the International Symposium at the “Castello del Valentino”, where, in 1894, Francesco Porro first proposed to encourage the study of the “movements of glaciers” at the XXVI Congress of the Italian Alpinist, giving occasion to the Executive Committee of the Club Alpino Italiano (CAI) to nominate a “Commission for the study of glaciers” (1895) that later became the Italian Glaciological Committee (Comitato Glaciologico Italiano, CGI; <http://www.glaciologia.it/>).

Changes in mountain glaciers have direct impacts on human activities, especially in mid-latitude regions where high-altitude snow and ice contribute to the hydrological controls of human activity. Therefore, the symposium specifically included topics pertinent to the Earth’s ‘Third Pole’. To improve our understanding of the dynamics of cryospheric change, the interactions with the climate, and the impact on the living environment of mountainous regions, the Symposium aimed to provide a general discussion of the changes in these components of the global cryosphere, including broader issues from recent in situ observations, remote sensing measurements and modelling efforts.

In detail, the topics of the meeting were: glacier mass balance, monitoring and observations, glacier geophysics, glaciological hazard, climate driven glacial change, glacier hydrology, periglacial/permafrost processes, and snow processes.

The scientific programme included four keynote lectures by internationally renowned scientists who provided state of the art lectures on *Alpine glaciers as a climate proxy in a changing world* (Wilfried Haeblerli), *Hazard and risk in high glaciated mountains* (John John Clague), *Solar activity, inter-annual to monthly climate variability over the southern hemisphere deduced from Antarctic snow studies*, (Jean Robert Petit) and *A synthesis of the Antarctic surface mass balance* (Massimo Frezzotti).

The Symposium provided a mixture of oral and poster sessions, and included free time to facilitate interaction between participants for exchanging scientific information in an informal setting. The Symposium was attended by a number of Italian and international researchers, with a strong showing of young researchers who enthusiastically provided new results about the methodological study of the cryosphere. The numerous oral presentations and posters noted the results of several interesting research projects conducted both in Italy and abroad, providing an up-to-date view on the topics of the meeting.

A field excursion into Val Veny, Courmayeur, and Aosta Valley concluded the Symposium (Organizers: Philip De-

line, Marco Giardino, Gianni Mortara, Luigi Perotti, Carlo Baroni).

Complete information about the Symposium organization, the International Science Steering and Editorial Committee, the Local Organizing Committee, the Secretariat, and the abstracts book are available on the CGI website (<http://www.glaciologia.it/en/il-comitato/convegni-glaciologici/>).

The Proceedings of the International Symposium collects a selection of peer-reviewed papers spanning topics such as the state of Italian Glaciers in 2006-2007, the snow cover variability and hydrology of several glaciated basins of Chile, the relationship between glacial change and river discharge in Val Venosta (Italy), a geophysical survey of the World War I scenario at Punta Linke, an ablation model for debris covered glaciers, and the evaluation of the performance of empirical regression for the calculation of bulk snow density (Avanzi & alii, Bocchiola & alii, Francese & alii, Galos & alii, Migliavacca & alii, Minora & alii, Salvatore & alii).

## THE ACTIVITY OF THE ITALIAN GLACIOLOGICAL COMMITTEE

The Italian Glaciological Committee (CGI) has been working in Italy since 1895, with the aim of promoting and coordinating 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 has become an independent organization 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 climate history. In addition to being a strategic resource of fresh water that is usable for agricultural, civil, and industrial purposes, glaciers are a valuable climate proxy, and very sensitive to climatic and environmental changes because they react to external forces by changing shape and size (IPCC, 2007, 2013 and reference therein). Alpine glaciers, in particular, are composed almost entirely of ice at temperatures close to the melting point (temperate glaciers) and are very sensitive sentinels of global change.

The monitoring of Italian glaciers has been performed since 1895 by the CGI, which coordinates the national glaciological survey, additionally collecting data from regional and local groups of volunteers. Since its origin, the CGI recognized the importance of systematic monitoring of Italian glaciers and, in particular, of the measurement of frontal variations. This activity has been regularly conducted since the end of the 19<sup>th</sup> century, resulting in one of the longest-running observations of glacier frontal variations in the world (CGI, 1928-1977; 1978-2010; Desio, 1967; WGMS, 1988, 1989, 1993, 1998, 2005, 2008, 2012, 2015; Baroni & alii, 2011, 2012, 2013, 2014, 2015; Belloni & alii, 1985; Belloni, 1992; Citterio & alii, 2007; Carturan & alii, 2014; Pelfi-

ni & Smiraglia, 1988; 1997; Santilli & *alii*; 2002; Federici & Pappalardo, 2009; Zemp & *alii*, 2008, 2015; and references therein). At present, approximately 150 glaciers are monitored every year by a large number of voluntary surveyors who are also linked to other associations (Baroni & *alii*, 2011, 2012, 2013, 2014, 2015; WGMS, 1988, 1993, 1998, 2005, 2008, 2012, 2015; Zemp & *alii*, 2015; <http://www.glaciologia.it/en/i-ghiacciai-italiani/le-campagne-glaciologiche/>).

Since 1927, a section of the CGI Bulletin has been dedicated to the results obtained in the framework of these glaciological campaigns (<http://gfdq.glaciologia.it/issues/>).

The mass balance of selected Italian glaciers has been measured since 1967 (e.g., the Careser Glacier; Zanon, 1992; Giada & Zanon, 1991, 1996; Caruran & Seppi, 2007; Carturan & *alii*, 2013a). Approximately a dozen glaciers are presently being monitored for their glaciological mass balance. All of the frontal variation and annual mass balance data measured in the Italian Alps contribute to the World Glacier Monitoring Service (WGMS) database ([www.geo.uzh.ch/microsite/wgms/](http://www.geo.uzh.ch/microsite/wgms/)).

THE GLACIOLOGICAL ARCHIVE (PHOTOGRAPH COLLECTIONS, HISTORICAL MAPS, UNPUBLISHED SURVEYS)

The annual glaciological surveys provide the CGI with a large amount of data for the establishment of an archive of original documents that are primarily but not exclusively related to the Italian glaciers. These data allow estimation of variations in shape and size of glacial bodies and frontal margins.

A large number of historical documents are published in the 50 volumes of the Bollettino del Comitato Glaciologico Italiano (I-II series). The photographic archives of the CGI hold valuable documents and, furthermore, tens of thousands of images depicting Italian glaciers that are reproduced on various materials and media, including negatives, black and whites, colour prints, slides, DVDs and delicate

glass plates; (Lesca, 1971, Mortara pers. Comm.). The large number of images, and the partial decay of old cartographic and photographic documents as well as the fragility of the glass plates, have created serious problems relating to the conservation and preservation of this important iconographic heritage. The CGI has recently started an ambitious program of systematically digitizing the photographic heritage, with the valuable help of volunteers and students who intern at the CGI (Educational University Internship).

Since the beginning, the Bulletin has published monographs on individual glaciers that are considered to be particularly relevant, accompanied by detailed photogrammetric surveys and maps. The first volume of the Italian Glaciological Bulletin (1914), for example, published the topographic survey of the front of Miage Glacier at a scale 1:10,000, which represented the first Italian application of the stereo-autograph Zeiss. The CGI aims to digitally archive all the historical documents for their preservation and to make them freely available to all interested researchers.

THE GLACIER INVENTORY – A BASIC TOOL TO BE BUILT, MAINTAINED, UPDATED, AND FREELY AVAILABLE

Mapped glacier outlines are stored in both national and regional inventories using different acquisition dates and deriving from different methods of acquisition (field surveys, topographic maps, remote sensing).

The first initiative for inventorying glaciers is due to Porro (1925), who listed the glacial bodies in the Italian Alps and the Apennines: the glaciers were surveyed and described individually on record cards. In addition to the geographic location, glaciological quantitative data (e.g., maximum and minimum elevation, extension, aspect) were reported. Unfortunately, only a part of these records have been found and are presently preserved at the headquarters of the CGI in Torino. Porro & Labus (1927) later created an inventory that represented the first attempt to provide a snapshot of



FIG. 1 - The Mandrone and Lobbia Glaciers (on the right and on the left, respectively) in a historical photograph taken on 29th August 1904 (courtesy of G.B. Castiglioni).



FIG. 2 - The Miage Glacier with debris covered tongue and M. Bianco in background. Photo taken on 2<sup>nd</sup> July 2011 (C. Baroni).

the ice cover of the Italian Alps; 774 glaciers were mapped on four sheets at a scale of 1: 500,000. Unfortunately, the quantitative glaciological data were not reported. The small scale and the criteria adopted for mapping do not allow the data collected by Porro & Labus to be managed in the GIS environment. Nevertheless, this work represents the basis for the subsequent work of updating and expansion conducted by the CGI.

In fact, during the International Geophysical Year 1957-58, the Italian Glaciology Committee, supported by the National Research Council, produced a new inventory of Italian glaciers (CGI – CNR 1959; 1961a; 1961b; 1962).

Following activity conducted during the International Geophysical Year 1957-58, international efforts were devoted to creating and maintaining the collection of worldwide datasets on glaciers: the World Glacier Inventory (WGI, [http://nsidc.org/data/glacier\\_inventory/index.html](http://nsidc.org/data/glacier_inventory/index.html)) was launched in the 1980s by the World Glacier Monitoring Service (WGMS) and contains information on over 130,000 glaciers. The WGI was published at the end of the 1980s (WGMS, 1989) and is available on the National Snow and Ice Data Center website (NSIDC; [https://nsidc.org/data/glacier\\_inventory/](https://nsidc.org/data/glacier_inventory/)). In 1986, the World Glacier Monitoring Service (WGMS) started to collect information on glacier

changes when the two former ICSI services PSFG (Permanent Service on Fluctuations of Glaciers) and TTS/WGI (Temporal Technical Secretariat/World Glacier Inventory) were combined (FoG 1959 to 2010, available at <http://www.geo.uzh.ch/microsite/wgms/fog.html>; WGMS, 1988, 1989, 1993, 1998, 2005, 2008, 2012, 2015; Zemp & *alii*, 2015 and references therein).

Between 1980 and 1986 the CGI contributed to the realization of the WGI, using the experience acquired collaborating with the “World Inventory of Perennial Ice and Snow Masses” (Lesca, 1974). The outlines of glaciers and glacierets were mapped at a scale of 1:25,000 by the Istituto Geografico Militare Italiano (IGMI) and were mapped on regional technical cartography at a scale of 1:10,000 (Valle d’Aosta, Lombardia, and Trentino - Alto Adige p.p.). Multitemporal vertical aerial photographs at different nominal scales were used for defining the glacier borders (Belloni & *alii*, 1985; Secchieri, 1985; Pelfini & Smiraglia, 1988). The survey dates of the aerial photographs span from 1975-1977 for the Valle d’Aosta (Dora Baltea basin), 1980-1982 for the Alto Adige-South Tirol (Adige basin), 1983 for the Piemonte (upper Po basin), 1981-1983 for the Lombardia (Po basin), 1982-1984 for the Trentino (Adige basin), and finally 1983-1984 for the Veneto – Adriatic sea basin (WGMS,

1989; Serandrei-Barbero & Zanon, 1993). This time interval runs the ten years from 1975 to 1984.

In the early 1990 s, the CGI completed an update of Italian glaciers on behalf of the Ministry of the Environment (Ajassa & *alii*, 1994, 1997). The survey was based on photointerpretation of the “Volo Italia 1988-1989” aerial photos covering the entire Italian national territory (Biasini & Salvatore, 1993). The original data of this inventory are presently not available and need further elaboration before being inserted in the GIS environment. The CGI is working on validating and providing these data. The 1988-1989 inventory includes 787 glaciers with dimensions greater than 0.05 km<sup>2</sup>, which cover a total area of 474 km<sup>2</sup> (Ajassa & *alii*, 1994, 1997). The comparison between the two surveys highlights a drastic reduction of glacierized areas in the Italian Alps between 1957-1958 and 1988-89. Furthermore, the comparison of WGI and 1988-1989 data (WGMS, 1989; Ajassa & *alii*, 1994, 1997) underlines a strong reduction of Italian glaciers between 1975-1984 and 1988-1989, although a direct comparison between the two inventories will be possible only after a more accurate validation of the available data.

The CGI also contributed to GLIMS (Global Land Ice Measurements from Space), a project started in 2000 that was designed for inventorying glacial resources with

space-borne sensors and maintaining a geospatial database available via website, featuring interactive maps and an interoperable standard web mapping service (<http://www.glims.org>). The Italian contribution to the project is focused on producing a satellite-derived Atlas of Italian Glaciers (Ranzi & *alii*, 2013) containing quantitative glaciological parameters. So far, glaciers based in the Lepontine Alps, the Pusteresi Alps, the Dolomites, the Ortles-Cevedale and the Adamello-Presanella have been extracted from five Aster images (Ranzi & *alii*, 2010, 2013). The data are available on the GLIMS database maintained by the National Snow and Ice Data Centre and have also been organized into a geographic information system in KML format on the CGI website (<http://www.glaciologia.it/en/il-progetto-glims-it/>)

Many other glacier inventories have been produced at the regional scale since the early 1990s (Zanon, 1990; Comitato Glaciologico Trentino, 1994; Servizio Glaciologico Lombardo, 1992; Bombarda, 1996; Bonardi & *alii*, 2012; Secchieri, 2012), but they consist of limited portions of the Italian Alps within regional or provincial administrative limits. Regional inventories apply different standards for the collection, representation and analysis of data and refer to different chronological intervals that are not suitable for evaluating glacial evolution at the scale of the entire Italian Alps.



FIG. 3 - The Forni Glacier and Punta S. Matteo from Punta Linke (Ortles Cevedale Group). Photo taken on 2nd September 2010 (M.C. Salvatore).

Smiraglia & Diolaiuti (2015) and Smiraglia & *alii* (2015) present a new glacier inventory of Italian glaciers spanning a period of seven years (from 2005 to 2011). This inventory was assembled by the University of Milan in collaboration with “Levissima” and Everest-K2-CNR and with the scientific support of the CGI.

In this volume, Salvatore & *alii* (2015) furnish a snapshot of the state of Italian glaciers of the 2006-2007 hydrological period. The glacier boundaries and the glaciological data are freely available and downloadable on the website of the Italian Glaciological Committee (<http://www.glaciologia.it/>).

Continuous glacier monitoring and the updating of inventories (Haerberli, 2004; Haerberli & *alii*, 2007; Lambrecht & Kuhn, 2007; Fischer & *alii*, 2014; Gardent & *alii*, 2014) represent fundamental steps for defining glacier changes and modelling their future evolution in response to climate change.

As a consequence, the CGI aims to update and make easily available to the scientific community and stakeholders multitemporal data on Italian glacial resources through an integrated information management system made for this purpose. This system will be a valuable tool for further research projects on glacial and periglacial environments and will provide a validated and reliable information base for the quantitative modelling of glacier response to climatic warming.

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