SHARE

EvK2CNR

Stations at High Altitude for Research on the Environment

2013

AWS Rwenzori
(4750 m a.s.l., 0° 22′ 34.55″ (Lat N)
and 29° 52′ 43.24″ (Long E), Uganda - Africa)

REPORT, HIGHLIGHTS, FOCUS

Share 2013

REPORT, HIGHLIGHTS, FOCUS

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Presentation

The 2013 edition of SHARE report aims to show the main research activities and outcomes achieved in the framework of SHARE – Stations at High Altitude for Research on the Environment – project, whose goal aim is to contribute to the study of climate change and its impact on mountain regions, supplying unique information to the international scientific community and decision-makers on sustainable development and adaptation strategies.

The SHARE project is structured into four main Work Packages – Scientific Research and Climate, Technological Research and Climate, Information System and Capacity Building, each of which includes diverse activities. In particular, the part devoted to Scientific Research and Climate comprises five sub Work Packages: Atmosphere, Earth Sciences, Water Resources, Biodiversity and natural resources, Medicine and Human Health.
The WP 1.2, formerly named Glaciology, has been re-named as Earth Sciences, and now includes two sub Work Packages: WP 1.2.1. Glaciology, where new activities eg. the study of permafrost in the Alps and Karakorum, have been integrated, and WP 1.2.2 Geology/Geophysics/Risk Assessment, where all geological activities promoted by SHARE have been gathered. The latter include studies on metamorphic CO2 degassing from the Himalayan orogen and its influence on long-term global climate changes, and the data analysis of the GNSS Permanent Station, part of the Himalayan GNSS network and installed last year at the Pyramid International Laboratory.

The report is organized into three sections: the first summarizes through bulleted list the findings achieved in the different SHARE WPs, providing readers with a quick overview of the activities undertaken; the second gives an account of the Highlights, the key results identified for each thematic area in 2013, whicle the third concludes the report with the Focus section, where the results of the concluded Pilot Projects SHARE STELVIO and SHARE PAPRIKA are reported.


Elisa Vuillermoz

During 2013, Dr. Elisa Vuillermoz has been appointed as new scientific coordinator of the SHARE project. She succeeds Dr. Paolo Bonasoni, coordinator of SHARE since 2005.
Dr. Vuillermoz, PhD in Earth Sciences at University of Milan, has worked for the Ev-K2-CNR Committee since 2004.

In 2013, the Ev-K2-CNR Committee, thanks to its long environmental monitoring program, promoted in the framework of SHARE Project, was involved in different national and international initiatives, as reported below:

• **GEO**: appointment of Ev-K2-CNR Committee researcher, Dr. Antonello Provenzale, as GEO Ecosystems Coordinator (January 30, 2013)
GEO – Group on Earth Observations is a voluntary partnership of governments and international organizations which coordinates efforts to build a Global Earth Observation System of Systems, or GEOSS, on the basis of a 10-Year Implementation Plan for the period 2005 to 2015. The Plan defines a vision statement for GEOSS, covering its purpose and scope, expected benefits, and the nine "Societal Benefit Areas", of disasters, health, energy, climate, water, weather, ecosystems, agriculture and biodiversity.

• **UNEP – CCAC:** designation of Ev-K2-CNR Committee as non-State Partner in the Climate Clean Air Coalition to Reduce Short-Lived Climate Pollutants (February 15, 2013)

CCAC - Climate and Clean Air Coalition to Reduce Short Lived Climate Pollutants is an important initiative promoted by UNEP (United Nations Environmental Programme) in 2012, whose aim is to encourage action-oriented work to promote near-term reductions of SLCPs at a substantial scale worldwide and engage high level stakeholders.

• **CRUI – DOI:** participation of Ev-K2-CNR in the DOI project (February 25, 2013)

DOI is a project of the Conference of Italian University Rectors though which each institute affiliated to the project will be allowed to operate as a "Data Center" self-assigning an unlimited number of DOI.

• **SUSKAT:** participation of Ev-K2-CNR Committee in the Suskat-ABC field Campaign through the Ev-K2-CNR Paknajol and NCO-P sites (May 17, 2013)

SUSKAT – Sustainable Atmosphere for the Kathmandu Valley is a project led by the Institute for Advanced Sustainability Studies (IASS), Potsdam, Germany, coordinated by the International Center for Integrated Mountain Development (ICIMOD) and supported by the Ministry of Science, Technology and Environment, Government of Nepal. Its aim is to conduct a comprehensive assessment of various aspects of air pollution in the Kathmandu Valley.

• **WMO-SPICE**: participation of Ev-K2-CNR Committee in the Solid Precipitation Intercomparison Experiment (SPICE) through the SHARE automatic weather stations (AWSs) installed on the Forni Glacier (Italy) and at Pyramid International Laboratory Observatory (Nepal)

SPICE - Solid Precipitation Intercomparison Experiment is an international intercomparison project of the World Meteorological Organization studing the performance of modern automated sensors measuring solid precipitation.

SHARE project interacts with the Italian Project of strategic interest NextData, sharing the ground based observations carried out by the monitoring network operative in Himalaya and Karakorum. The core of the project, more focused on Italy, is the realization of a national portal for the retrieval, storage, access and diffusion of environment and climate data from mountain and marine areas.

Structure

ACTIVITY SECTOR	WORK PACKAGE		THEMATIC AREA
Scientific Research and Climate Coordinator **P. Cristofanelli** *(ISAC- CNR)*	**WP1**	Integrated Project for climatic, environmental and geophysical monitoring, on local, regional and global scales.	**WP 1.1** Atmosphere **P. Cristofanelli** *(ISAC-CNR)* **WP 1.2** Earth Sciences 1.2.1 **C. Smiraglia – G. Diolaiuti** *(University of Milan)* 1.2.2 **G. Poretti** *(University of Trieste)*, **F. Rolfo** *(University of Turin)* **WP 1.3** Water Resources **R. de Bernardi** *(Ev-K2-CNR)* **WP 1.4** Biodiversity and natural resources 1.4.1 **S. Lovari** *(University of Siena)* 1.4.2 **G. Rossi** *(University of Pavia)* **WP 1.5** Medicine **A. Cogo** *(University of Ferrara)*
Technological Research and Climate Coordinator **G.P. Verza** *(Ev-K2-CNR)*	**WP2**	Activities for development of systems technologically advanced and for environmental monitoring in remote area.	
Information System Coordinator **M.T. Melis** *(University of Cagliari)*	**WP3**	Multidisciplinary Information System and Geonetwork where metadata, environmental data and geographic information on mountain regions are achieved to be use by scientific bodies, governments and inter-governmental agencies.	
Capacity Building Coordinator **S. Proietti** *(University of Perugia)*	**WP4**	Program supporting government level decision-making processes regarding the environment; transfer of skills and technologies to promote and ensure sustainable development; technology transfer, promotion of business and institutional participation.	

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WP 1.1: Atmosphere and climate

Reference Person: **Paolo Cristofanelli**
Institute of Atmospheric Sciences and Climate - Italian National Research Council (ISAC-CNR), Italy

Objectives foreseen in 2013

1) Continuation of the observation activities undertaken at the measuring stations belonging to the SHARE network and data entry into reference databases (GAW-WMO, UNEP-ABC, SHARE Geonetwork, AERONET, ACTRIS).

2) Resumption of environmental monitoring in Uganda, through the installation of a new automatic weather station (AWS), in the western part of the Stanley Plateau.

3) Definition of the variability, on different time scales, of climate-altering and chemically reactive compounds in mountain areas, which represent the background conditions of the lower troposphere.

4) Study of processes and mechanisms of interaction among mountain ranges and atmospheric circulation.

5) Characterization of the physicochemical properties of aerosols in high altitude areas.

6) Definition of the influence of the transport of air-masses influenced by polluted or natural processes on climate-altering and reactive compounds in mountain areas.

7) Assessment of climate impacts linked to changes in climate-altering and chemically reactive compounds in mountain areas.

8) Support WP1.5 activities in the study of indoor pollution in Himalaya.

Results obtained in 2013

1) Publication of the following results:
a. *"3-year chemical composition of free tropospheric PM1 at the Mt. Cimone GAW Global Station – South Europe – 2165m a.s."* on Atmospheric Environment (Carbone et al., see List of Publications);
b. *"The GMOS cyber(e)-infrastructure: advanced services for supporting science and policy "* on Environmental Science Pollution Research (Cinnirella et al., see List of Publications);
c. *"Analysis of Summer Ozone Observations at a High Mountain Site in Central Italy (Campo Imperatore, 2388 m a.s.l"* on *Pure and Applied Geophysics* (Cristofanelli et al., see List of Publications) (see Fig. 1).

2) Long-term observations of atmospheric compounds (gas and aerosol), meteorological parameters and solar radiation fluxes are continuing at the global stations WMO-GAW "O.Vittori" at Monte Cimone (Italian Apennines, 2165 m a.s.l.) and Nepal Climate Observatory-Pyramid (NCO-P) (Himalayas, 5079 m a.s.l.). Observations by weather and radiometric Automatic Weather Station (AWS) belonging to the SHARE network are also on-going: a complete revision of the data recorded in the period 2010 – 2012 is currently on going, together with the upgrade of the guidelines for the meteorological data validation (with a special emphasis for snow level, rain precipitation and surface albedo). Moreover, in-situ calibration and check activities have been performed at the AWSs Lukla (Nepal, 2660 m a.s.l.) and Namche (Nepal, 3570 m a.s.l.) (see Fig. 2).

3) On March 2013, Italian technicians, in collaboration with local technicians and researchers of the Uganda Meteorological Department and University of Nairobi, installed the new AWS in Rwenzori National Park, at 4700 m a.s.l. Preliminary analysis of collected data began.
The first test was carried out on a climatic chamber installed at the Pyramid Laboratory, for the in-situ calibration of air temperature and atmospheric pressure sensors.

4) Observations continued of total gaseous mercury (TGM) at the NCO-P, following the Global Mercury Observation System (GMOS) Standard Operation Procedures (SOPs) established within the global network. Preliminary results concerning the characterization of TGM values and variability in high Himalayas were presented by IIA-CNR (see Fig. 3).

5) Research activities were carried out concerning indoor pollution, to monitor the air quality in lodges of the Khumbu Valley, coupled with investigations on the assessment of

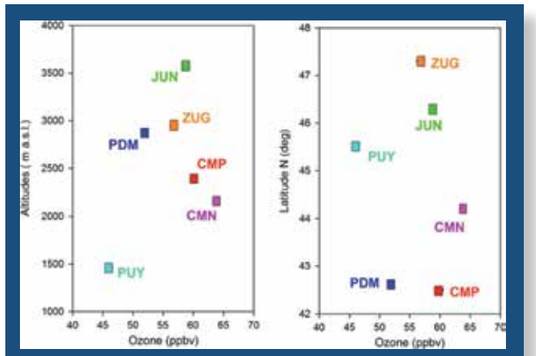

Fig. 1 - Summertime mean ozone values at Campo Imperatore, Monte Portella (CMP) during the experimental campaign in comparison with the climatological values (period 2001–2008) for five European mountain stations: Jungfraujoch (JFJ), Zugspitze (ZUG), Pic du Midi (PDM), Monte Cimone (CMN), Puy de Dome (PUY). On the left (right): the y-axis reports the altitudes (latitudes) of the measurement sites (from Cristofanelli et al., Pure Appl. Geophys, 2013). The ozone mean level at CMP during the campaign was not very different from the climatological values observed at CMN, ZUG and JUN, suggesting that ozone levels observed at CMP in August 2009 can be regarded as representative of those at high altitude sites in the Mediterranean basin.

respiratory health and ventilation inside houses in collaboration with WP1.5 (November 2013).

6) Assessment of the long-term (1991 – 2011) ozone variability at Mt. Cimone and comparison with other baseline measurement sites in the Alps and Mediterranean basin.

7) Study and analysis of long term observations (2005 – 2012) concerning aerosol physical properties at Mt. Cimone were performed.

8) Study and analysis were carried out on long-term observations (2009 – 2011) of the aerosol chemical properties at Mt. Cimone and the influence of air-mass transport from the Planetary Boundary Layer (see Fig. 4).

9) Analysis of atmospheric composition and meteorological variability at Mt. Cimone for summer 2013 was performed.

10) Continuous measurements were achieved of ozone, aerosol size distribution and meteorological parameters at Campo Imperatore - Mt. Portella (2388 m a.s.l.), in the Central Italian Apennines.

Fig. 2 – AWS QC and AWS Namche installed at 3570 m a.s.l. (Nepal). The comparison activity was carried out from 11 May to 21 June 2013.

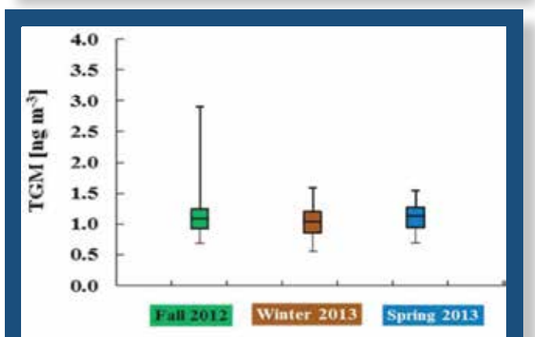

Fig. 3 - Total gaseous mercury (TGM) at the Nepal Climate Observatory – Pyramid (NCO-P), 5079 m asl in Himalaya, during 2013: descriptive statistics by Box and Whisker Plots including mean (midlines), 25th and 75th percentiles (box edges), and 5th and 95th (whiskers). The TGM mean concentration observed is less than the background concentration for the northern hemisphere, and within the range of values expected for background levels in the southern hemisphere (1.1-1.3 ng m-3).

Objectives foreseen in 2014

1) Continuation of the observation activities at the measurement stations belonging to the SHARE network and data entry into reference databases (GAW-WMO, UNEP-ABC, SHARE Geonetwork, AERONET, ACTRIS).

2) Upgrade of the monitoring programmes at Campo Imperatore-Mt. Portella and analysis of the typical variability observed for ozone, aerosol size distribution and meteorological parameters.

3) Establishment of new measurements of Hg in precipitation at NCO-P, in order to contribute to a full global scale network of atmospheric Hg observations and to investigate Hg variability in the free troposphere and the transport of atmospheric Hg on the global scale.

4) Long-term analysis of Saharan dust transport at the Mt. Cimone WMO/GAW Global Station.

5) Long term analysis of meteorological parameters observed along the Khumbu valley by the SHARE network.

6) Routine use of the calibration facility at the Pyramid Laboratory for in-situ calibration of air-temperature and atmospheric pressure sensors.

7) Implementation of snow measurements at Pyramid in agreement with SPICE (Solid Precipitation Intercomparison Experiment) – WMO, since AWS Pyramid site was selected as a SPICE site.

8) Analysis of indoor pollution in lodges of the Khumbu valley.

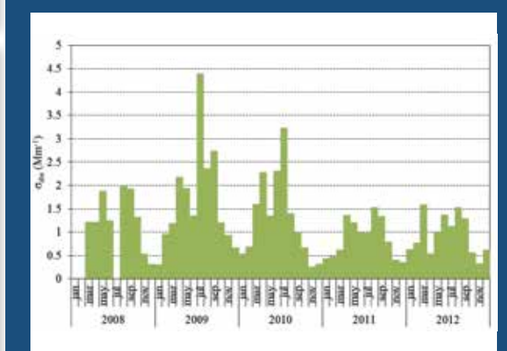

Fig. 4 - Long-term aerosol scattering absorption at Mt. Cimone (Italian Apennines, 2165 m a.s.l.). By Bourcier et al., in preparation. Aerosol scattering is a key-parameter for investigating the direct climate effect of atmospheric aerosol.
The aerosol scattering at Mt. Cimone is usually characterised by higher values during warm months compared to cold seasons, due to the more efficient vertical transport of polluted air masses.

SHARE abc
Stations at High Altitude for Research on the Environment

Pilot Project

Project Coordinators: **Paolo Cristofanelli, Paolo Bonasoni**
Institute of Atmospheric Sciences and Climate - Italian National Research Council (ISAC-CNR), Italy

Objectives foreseen in 2013

1) Continuation of the ongoing measurement activities at the GAW-WMO Nepal Climate Observatory – Pyramid (NCO-P) global station.

2) Performance of spring and fall campaigns concerning instrument calibration and maintenance activities operating at NCO-P station.

3) Installation of a station to measure the atmospheric composition in Kathmandu (Nepal), to combine with the intensive SusKAT campaign.

4) In collaboration with the University of Stockholm, feasibility study to start the measurement of the carbon isotope at NCO-P.

5) Validation and analysis of meteorological and atmospheric data collected in Multan (Pakistan).

6) Installation of a permanent observatory to study the atmospheric composition variability in North Pakistan (Northern Areas).

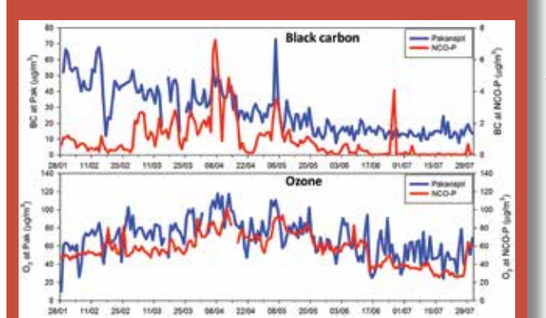

Fig. 1 - Comparison of daily black carbon (upper plate) and ozone (bottom plate) behaviours at NCO-P (red lines) and Kathmandu - Pakanajol (blue line). Note the different scale for y-axis for BC, highlighting the lower average concentrations observed at the NCO-P (5079 m a.s.l.). Daily averages are reported. Different seasonality affected the two measurement sites: while NCO-P is characterised by a maximum of BC concentration during the pre-monsoon (when vertical air-mass transport are more efficient), at Kathmandu the seasonal maximum is observed during the dry winter season (when a more stable atmosphere characterised South Asia, and pollutant emissions are more frequently trapped within the lowest part of the atmosphere). This reflects the importance of the vertical transport in determining the level of primary pollutants in the High Himalayas. More similar seasonal behaviour and concentrations characterised surface ozone at the two measurements site. Similarities and differences between atmospheric composition variability at these measurement sites will be better investigated during the next year of SHARE activity.

Results obtained in 2013

1) Publication of the following results:
a. *"High black carbon and ozone concentrations during pollution transport in the Himalayas: Five years of continuous observations at NCO-P global GAW station"* in Journal of Environmental Sciences (Marinoni et al., see List of Publications).
b. *"Influence of open vegetation fires on black carbon and ozone variability in the southern Himalayas (NCO-P, 5079 m a.s.l.)"* in the Environmental Pollution Journal (Putero et al., see List of Publications).
c. *"Estimated range of black carbon dry deposition and the related snow albedo reduction over Himalayan glaciers during dry pre-monsoon"* in Atmospheric Environment Journal (Yasunari et al., see List of Publications).

2) Long-term observations of atmospheric compounds (gas and aerosol), meteorological parameters and solar radiation fluxes are continuing at the global stations WMO-GAW NCO-P . The related scientific research activities are also on-going.

3) In May 2013, a campaign for instrument calibration and maintenance was performed at the NCO-P station. For the purpose of evaluating the feasibility of carbon isotope measurements, specific aerosol samplings were carried out.

4) In January 2013, a new permanent monitoring station was installed at the EV-K2-CNR Representative Office in Paknajol, Kathmandu. The station is equipped with a state-of-the-art measurement system for the continuous determination of SLCF/SLCP (short-lived climate forcers/pollutants), surface ozone, aerosol number size distribution (for particles with diameters from 0.28 to 10 µm), total particle number concentration, PM_{10}, $PM_{2.5}$, meteorological parameters and global solar radiation. The station contributed to the SusKAT (Sustainable Atmosphere for the Kathmandu Valley) international campaign, coordinated by IASS Potsdam (Germany) and ICIMOD (Nepal) and promoted by ABC-UNEP, to conduct a comprehensive assessment of various aspects of air pollution in the Kathmandu valley.

5) A first characterization of SLCFs/SLCPs variability in Kathmandu was achieved. This allowed to identify the presence of extremely high levels of ozone, black carbon and $PM_{10}/PM_{2.5}$, especially during the winter season (see Fig.1).

6) Surface ozone, aerosol mass (PM_{10} and $PM_{2.5}$) and meteorological measurements from the ABC Station in Multan (Pakistan, 30°11′ N 71°28′ E) were validated and a preliminary analysis carried out. Two maintenance campaigns

were undertaken to guarantee the functioning of the station in the harsh environmental conditions of Multan (see Fig.2).

7) For the aim of providing the first long-term observations of atmospheric composition in the Karakorum region, a Remote Climate Station, powered by solar energy, has been installed in the Pakistani Deosai National Park at 4200 m a.s.l. in collaboration with WAPDA and PMD and in synergy with SHARE-PAPRIKA.
After a complex installation activity, begun in July 2013, the first continuous measurements of pollutant/climate-altering compounds (ozone, equivalent black carbon, aerosol size distribution from 0.28 nm to 10 µm) and meteorological parameters were activated from September to October 2013.
After a stop due to technical problems, the observations restarted on December 2013.
The station is the first ABC-UNEP measurement site in the Karakorum region (see Fig. 3).

Objectives foreseen in 2014

1) Continuation and upgrade of the ongoing measurement activities at the GAW-WMO NCO-P global station.

2) Performance of spring and fall campaigns concerning instrument calibration and maintenance activities at NCO-P station (upgrade of the SMPS system in compliance with the guidelines provided by the ACTRS UE-Project).

3) Execution of an experimental campaign on post-monsoon 2014 at NCO-P to investigate the chemical composition of size-segregated (nucleation) particles (in collaboration with PSI, Helsinki University).

4) Long-term investigation (2006 – 2012) of surface ozone variability at NCO-P.

5) Analysis of SLCF/SLCP variability in Kathmandu and comparison with the atmospheric composition observed at the NCO-P.

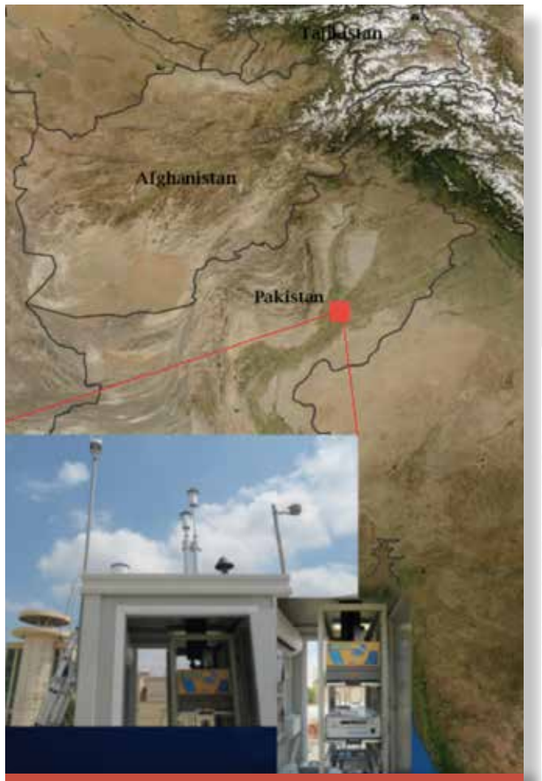

Fig. 2 - Location of the City of Multan and external view of the air-quality station.

Fig. 3 - RCS installed in Deosai - Pakistan (4000 m a.s.l.)

SHARE Modeling Center
Stations at High Altitude for Research on the Environment

Pilot Project

Project Coordinator: **Bhupesh Adhikary**
Ev-K2-CNR c/o Ev-K2-CNR Representative Office, Kathmandu, Nepal

Objectives foreseen in 2013

1) Drafting of scientific papers/presentations on the modelling studies of meteorology and air quality over the Himalayas for presentation both locally and internationally.

2) Growth and implementation of the modeling laboratory in terms of activities and personnel.

3) Assessment of Weather Research Forecasting/Sulfur Transport Deposition Model (WRF/STEM) skills and supply of real-time forecasts to the general public, in cooperation with local meteorological organizations.

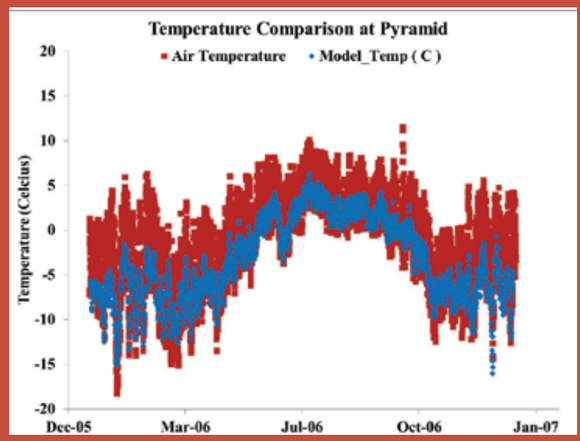

Fig.1 - Comparison of observed Temperature with WRF model temperature at Pyramid.

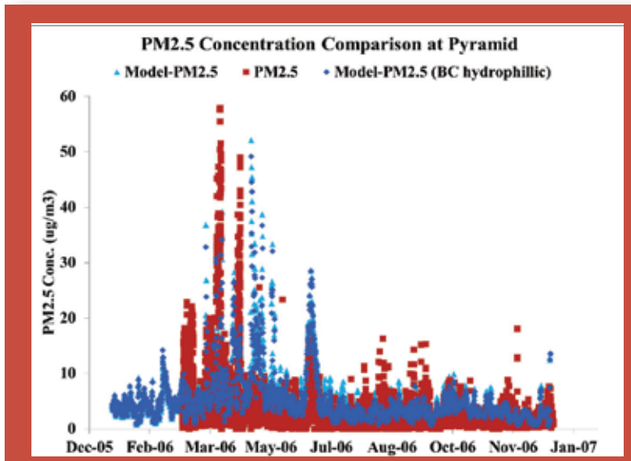

Fig. 2 - Comparison of modeled $PM_{2.5}$ aerosols with observed $PM_{2.5}$ aerosols at NCO-P.

Results obtained in 2013

1) Modeling results were presented at various workshops and conferences. Some example results are also shown in Figures 1-2-3 below. Figure 1 shows a comparison of model performance with regard to temperature at NCO-P, illustrating meteorological model evaluation. The second figure shows a comparison of PM2.5 at NCO-P, illustrating chemical model performance evaluation. The third figure, based on the modeling study, shows the source area from which these pollutants reached the measurement site, NCO-P. Such studies are useful to policymakers for understanding the phenomena and devising suitable mitigation strategies. Similar results have been presented at both scientific and policy-making meetings.

2) On September 8, 2013, in agreement with Nepal Academy of Science and Technology (NAST) the modelling center was re-named Numerical Modeling and Earth Observation Laboratory.
Dr. Hemu Kafle was appointed by NAST as a new researcher involved in the project. Training activities on air pollution studies and air pollution/meteorological modeling work are being organized by Dr. Adhikary to increase her modeling capacity and skills (Fig. 4).

3) The Laboratory is also supporting the SusKAT project (see SHARE ABC sheet) in terms of results interpretation. In particular, Ev-K2-CNR contributed to the first WRF modelling results of the first joint modeling exercise organized by the Institute for Advanced Sustainability Studies (IASS).

4) Daily meteorological data forecasting activities are still ongoing. In terms of modeling deliverables, a website has been created where the data have been continuously uploaded and is ready for delivery to the public as soon as permission is obtained from local authorities.
The modeling framework was able to provide forecasts throughout 2013, with the exception of one day, due to internet problems. Some of the data generated by 2012/13 modeling activity, including chemistry data, have been uploaded to the UNEP ABC project's modeling data center in Japan.

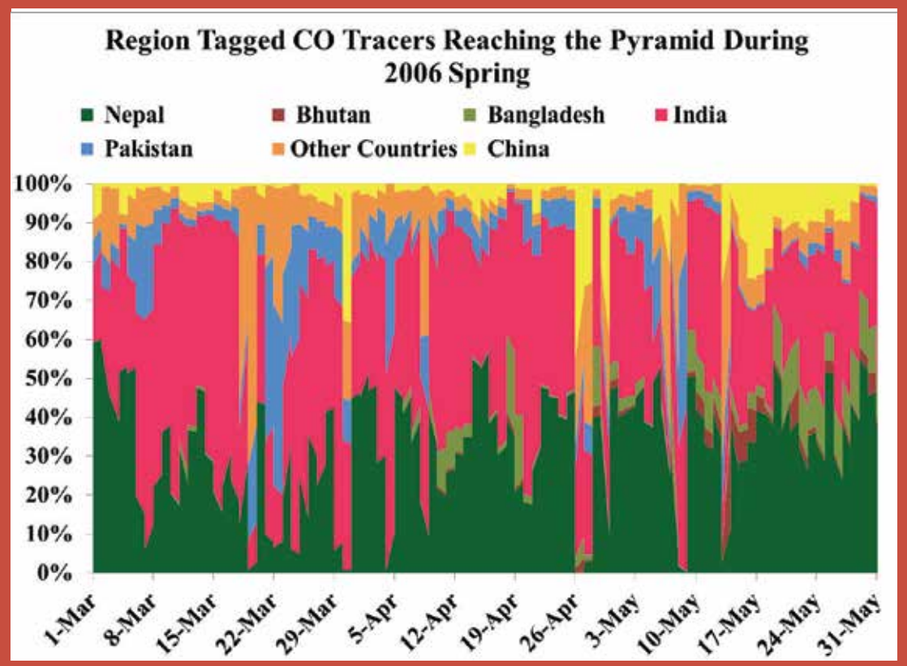

Fig. 3 - Modeling results illustrating the source regions and contribution to pollutants reaching the NCO-P during spring, 2006.

Objectives foreseen in 2014

1) Providing modeling results and analysis in aid to the SusKAT project/ SHARE project in Khumbu.
Maintenance and operation of the SusKAT air quality laboratory in Paknajol.

2) Improvement of emissions inventory currently used in the chemistry transport model to better constrain model results.
For example, the Hemispheric Transport of Air Pollutant (HTAP) project has developed a new emissions inventory for the year 2010 at a 10km grid resolution for the globe.
One goal will be to use this emission in the modeling framework for Nepal, for further analysis.
In addition, the modeling work will still pursue the goal of disseminating meteorological and pollution forecasts to citizens, in collaboration with the Department of Hydrology and Meteorology (DHM – Nepal Government).

3) Drafting of scientific papers/presentations and their presentation both locally and internationally.

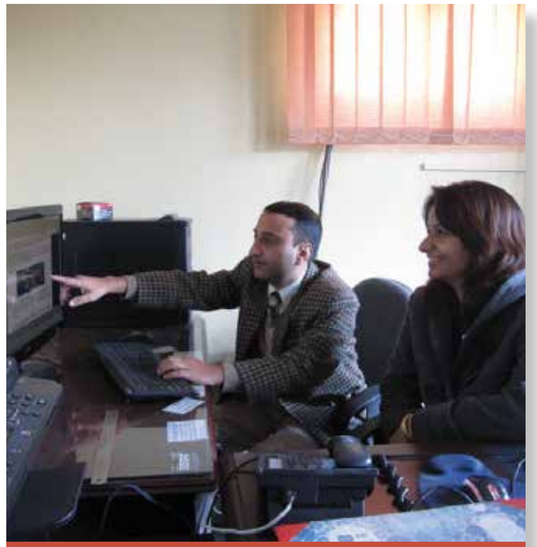

Fig. 4 – Training activities: Dr Adhikary and Dr. Kafley working together at Ev-K2-CNR Representative Office.

WP 1.2: Earth Sciences

Reference Persons: **Claudio Smiraglia, Guglielmina Diolaiuti**
Department of Earth Sciences "A. Desio"- University of Milano, Italy

WP 1.2.1: Glaciology

Reference Person: **Guglielmina Diolaiuti**
Department of Earth Sciences "A. Desio"- University of Milano, Italy

Objectives foreseen in 2013

1) Maintenance of the SHARE Alpine AWS network, also including the "satellite stations" (measuring rock temperatures and melt-water discharge) and the permafrost borehole at the Stelvio Pass. (the latter, under the scientific coordination of Prof. M. Guglielmin, UNINSUBRIA).

2) Distributing the energy budget and melting at the Forni Glacier surface by analysing the AWS1 Forni data (in the framework of the SHARE STELVIO project and in cooperation with Prof. M Maugeri, UNIMI Fisica).

3) Completing the model for evaluating the meltwater discharge in the Dosdè Glacier basin (in cooperation with the POLIMI DIIAR staff, PhD D. Bocchiola).

4) Performing a pilot experiment to evaluate fine debris and dust distribution and features at glacier melting surfaces and their influence on ice albedo and melt rates.

5) Participation in the SPICE experiment (Solid Precipitation Intercomparison Experiment (2012-2014)) developed and promoted by the WMO, since the AWS1 Forni site was selected as a SPICE site.

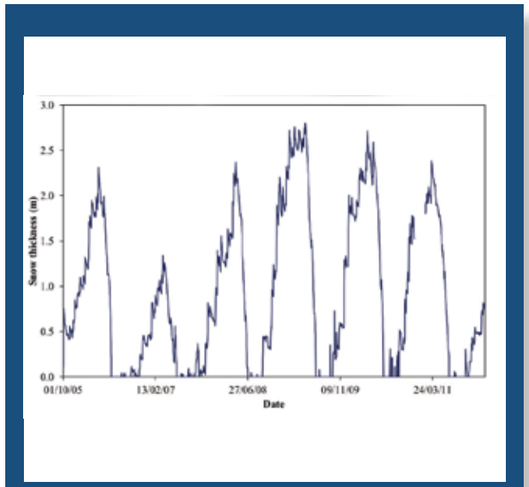

Fig. 1 - Measured snow thickness at the AWS1 Forni site from 2005 to 2011.

Results obtained in 2013

1) Data from the SHARE Alpine AWS network were checked and analysed to calculate the glacier point energy budget and melt amount.

2) Glacier accumulation amount was assessed at each site by analysing AWS snow depth data and through snow pits performed at the end of the accumulation season according to the AINEVA protocol, permitting the calculation of the glacier mass balance. The long sequence of snow data (see Fig. 1) also permitted the insertion of AWS1 Forni into the SPICE Experiment, developed and promoted by the World Meteorological Organization.

3) Forni AWS data were analyzed and used in order to:
- validate a model for calculating distributed incoming solar radiation data at the glacier surface, starting from data acquired outside the glacier area (see Fig. 2);
- validate a model for calculating distributed incoming long-wave radiation data at the glacier surface, starting from data acquired outside the glacier area (see Fig. 3);
- validate a model for calculating distributed vapor pressure data at the glacier surface, starting from data acquired outside the glacier area (see Fig. 4);
- evaluate the most suitable daily air temperature threshold to be applied for evaluating the degree-day amount from degree-day models (also named T-Index approaches);
- develop a further enhanced T-Index model, which also considers radiative energy fluxes and not only air temperature data, to compute the melt amount;

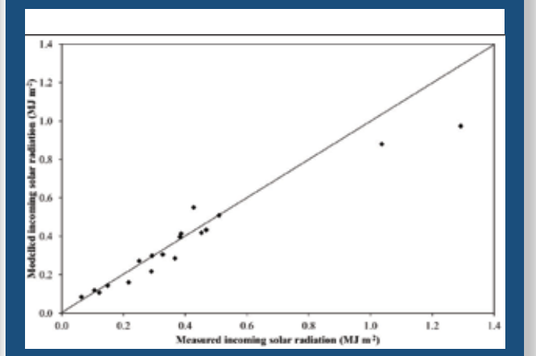

Fig. 2 - Modelled and measured daily incoming long-wave radiation at the Forni Glacier during May-September from 2005 to 2012.

- crosscheck energy data acquired at several sites spread aound the glacier melting surface by a net portable radiometer.
Such measurements were carried out in the framework of the pilot experiment aimed at developing a protocol for describing and quantifying fine debris and dust at the ice surface and assessing their influence on glacier albedo and melt rates (within the context of the SHARE STELVIO project).
The protocol was developed and has been submitted for publication.

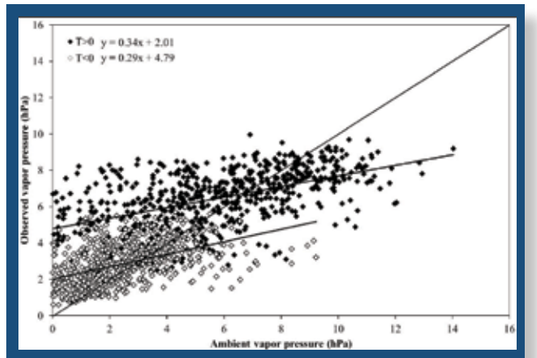

Fig. 3 - Scatter plot showing ambient (x axis) and observed (y axis) vapor pressure at the AWS1 Forni site from 2006 to 2009.

Objectives foreseen in 2014

1) Maintenance of the SHARE Alpine AWS network, also including the "satellite stations" (for measuring rock temperatures and melt-water discharge) and the permafrost borehole at the Stelvio Pass (the latter under the scientific coordination of Prof. M. Guglielmin, UNINSUBRIA)

2) Planning of tests to evaluate snow depth at the Forni site, employing different instruments and techniques (replying to SPICE'S requests).
The results will also be compared to snow data from pits to be dug at the end of the accumulation season, according to the AINEVA protocol.

3) Distributing the turbulent heat fluxes at the glacier surface for the calculation of the distribution glacier energy budget (data from AWS1 Forni will permit model validation).

4) Computing glacier melt and accumulation at sites where SHARE AWSs are running (Forni, Dosdè and Gigante glaciers).

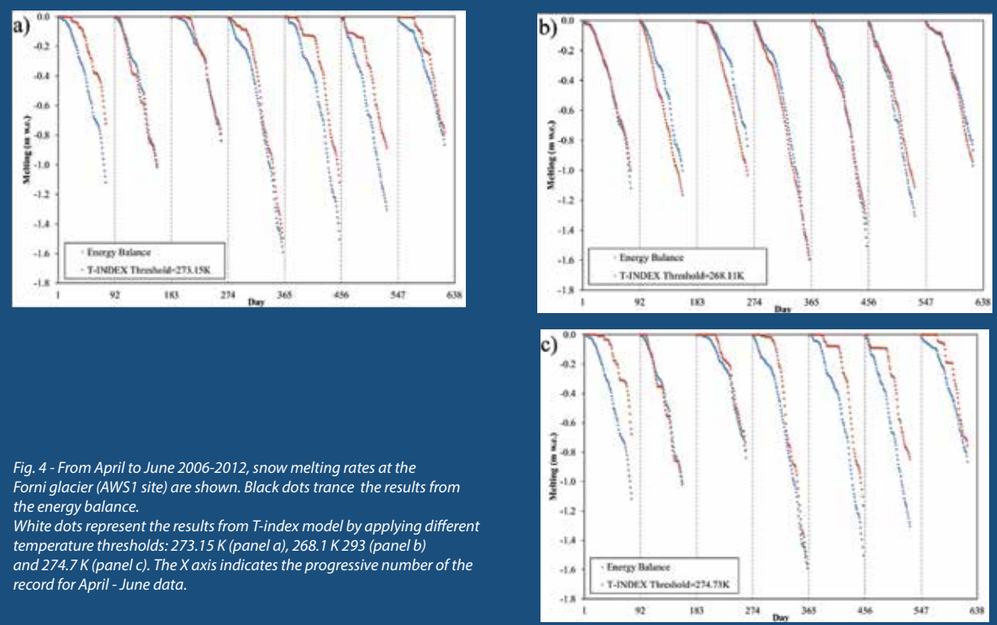

Fig. 4 - From April to June 2006-2012, snow melting rates at the Forni glacier (AWS1 site) are shown. Black dots trance the results from the energy balance.
White dots represent the results from T-index model by applying different temperature thresholds: 273.15 K (panel a), 268.1 K 293 (panel b) and 274.7 K (panel c). The X axis indicates the progressive number of the record for April - June data.

SHARE stelvio
Stations at High Altitude for Research on the Environment

Pilot Project

Project Coordinator: **Guglielmina Diolaiuti**
Department of Earth Sciences "A. Desio", University of Milan, Italy

Objectives foreseen in 2013

1) Maintenance of the survey site AWS1 Forni at the surface of the Forni, the largest Italian valley glacier.

2) Maintenance of the survey site Stelvio-Permafrost borehole, drilled into the rock at the Stelvio Pass (ca. 3000 m a.s.l.) .

3) Analysis of lakes located in Stelvio National Park in terms of surface and geometry and response to climate change.

4) Analysis of water samples (surveyed in the previous year at selected lakes).

5) Evaluation and modelling of water discharge due to ice and snow melting, in the Forni Glacier area, through field surveys to check and validate data modeling. Description of melt-water runoff and forecasting of future water availability under different climate change scenarios.

6) Modeling the dynamics of the Forni Glacier tongue.

7) Analysing meteorological and atmospheric data acquired in 2011 and 2012 at a high elevation site in the Stelvio Park area.

8) Analysing the relations between climate change and high altitude natural systems.

9) Disseminating the results from the SHARE Stelvio project, through the publication of a trilogy of papers to disseminate the results from WP1, WP2 and WP3.

Results obtained in 2013

1) The AWS1 Forni and Stelvio permafrost borehole were maintained and periodically checked. They acquired data quite continuously (AWS 1 Forni collects meteorological and energy data continuously, while at the borehole a thermistor chain measures rock temperatures from surface down to the bottom level where permafrost was found).
Such activity permitted the enlargement of the cryo-database describing glacier micro meteorology and permafrost occurrence and features (see Fig. 1 and Fig. 2).
The acquired data were also used to validate several models, from the simplest ones aimed at calculating the amount of degree days driving ice and snow melt to the most complex approaches for reconstructing distributed energy fluxes at the glacier surface starting from input data collected outside the glacier area. The developed models are described in detail in papers currently submitted for publication in international peer-review journals.

2) The Stelvio Park Lake Inventory (Lombardy Sectors) was completed. The Lake data were analyzed in the 1954-2007 time frame (with comparisons in the following sub time-windows: 1954-1981-1992-1999-2003-2007) and with respect to climate data covering the past 50 years. The analysis was performed thanks to the cooperation of the ITT (Infrastructure for the Territory Information) Unit of the Lombardy Regional authorities.

3) Processing and analysis of data collected in summer 2012 by the surveying system located at the Casati –Guasti Hut (ca. 3200 m a.s.l.) to measure the main climate and environmental parameters . The analysis was carried out by scientists and technicians from CNR-ISAC Bologna, CNRS-LGGE Grenoble and Ev-K2-CNR Committee Bergamo. Additionally, energy fluxes at the glacier surface and ice albedo variability were measured and described by UNIMI. This activity was performed to permit the analysis of albedo variability with respect to dust and black carbon occurrence.

4) Researchers and technicians from IRSA-CNR and ISE-CNR analyzed water samples collected at selected lakes in the Stelvio National Park to describe lake chemical, physical and biological features.

5) Albedo measurements were performed by UNIMI scientists at the melting surface of the Forni Glacier, to describe albedo variability in relation to glacier surface conditions (debris free area vs debris covered ice, in the latter case

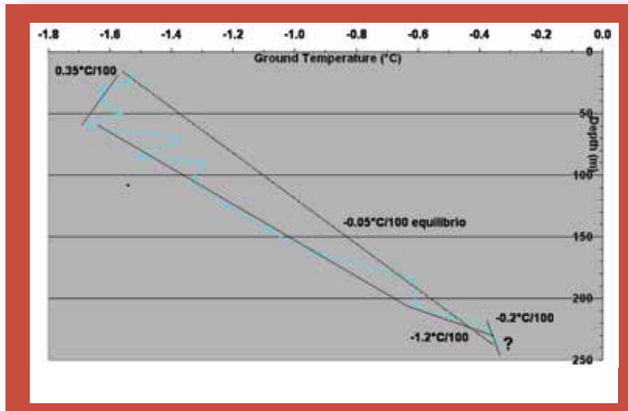

Fig. 1 – Temperature profile at the Stelvio Permafrost Borehole. The bottom was found to be continuously frozen (-1.2°C), thus proving permafrost occurrence (data processing and analysis by M Guglielmin, UNINSUBRIA).

with rock debris: abundant, sparse or rare). Ice ablation and snow accumulation data were also measured in the field to check and calibrate the glacier mass balance model (see Fig. 4).

6) The model describing the Forni Glacier tongue dynamics was made operational. It was developed by researchers from UNIMI and POLIMI in cooperation with personnel from UNICATT and FLA. The model reproduces the glacier tongue dynamics and describes glacier geometry (length and volume) variability (see Fig. 5). The methods introduced by Wallinga et al. 1998 were followed.

7) Analyses to evaluate rates and magnitude of climate change impacts on natural systems were performed on some selected areas of the Stelvio National Park by researchers from FLA (POLIMI, UNICATT, UNINSUBRIA), who obtained further details on the relation among permafrost presence and pattern of marmots.

8) To disseminate the results from the SHARE Stelvio project, a workshop was organized. It was held by the University of Milan on 11 December, 2013.
The purpose of the workshop was to describe to press agents, journalists and policy makers the main results obtained, analysing climate change impacts on waters and cryosphere of a large natural protected area. The first book of the trilogy "Un Mondo D'Acqua d'Alta Quota" was officially presented (see Fig. 6).

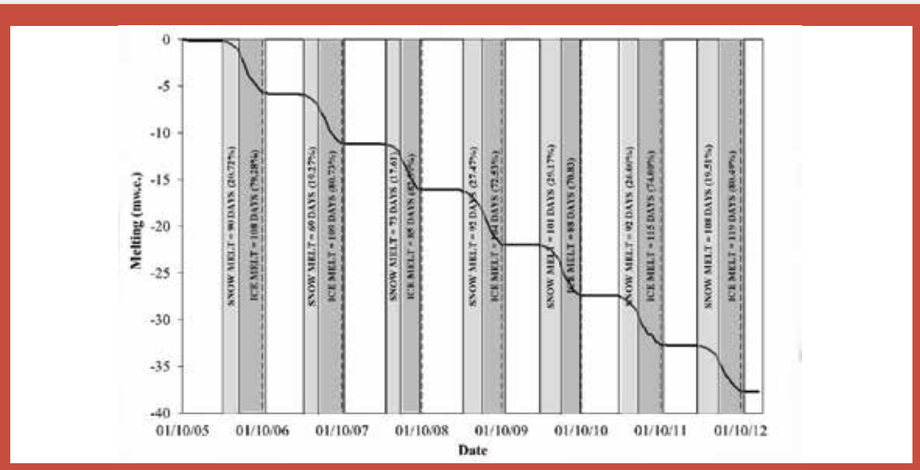

Fig. 2 - Cumulative melting amount at the Forni Glacier site, obtained by computing the point energy budget over a 7-year period (from October 2005 to December 2012). Data input comprised the values acquired by the SHARE AWS Forni. The dotted lines mark the beginning of the hydrological year (1° October). In some cases, ablation continues also in a few days of October. In light grey, the time frames with snow melting and, in dark grey, the ice melting periods are also shown.

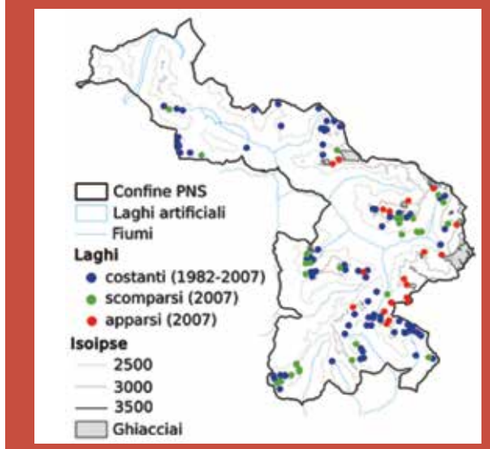

Fig. 3 – Map of lakes located in the Stelvio National Park.

Fig. 4 - Series of pictures illustrating: (a) sampling supra-glacial debris, (b) measuring albedo and (c) acquiring high resolution digital images of the glacier surface.

Fig. 6 – Cover of the book "Un Mondo D'Acqua d'Alta Quota"

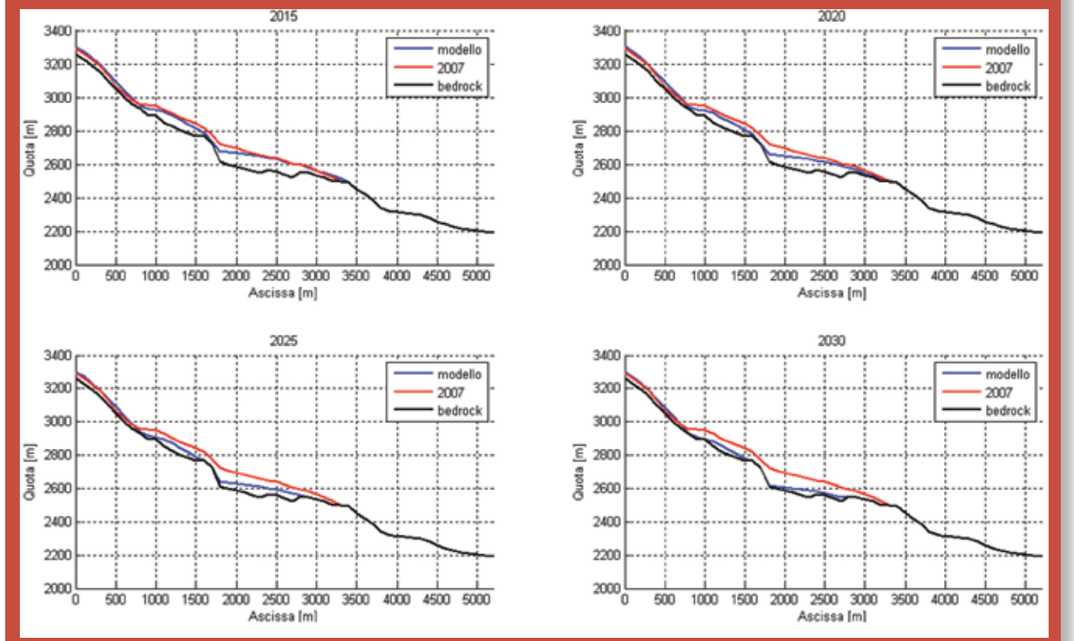

Fig. 5 - Outputs from the flow model to forecast Forni Glacier tongue evolution (blue lines indicate the expected glacier surface in 2015, 2020, 2025 and 2030, according to the applied climate scenarios; black lines indicate the glacier bedrock profile obtained from GPR investigations performed in summer 2012; red lines show the glacier surface obtained from 2007 DEM derived from a stereo pair surveyed in summer 2007).

SHARE paprika
Stations at High Altitude for Research on the Environment

Pilot Project

Project Coordinators: **Antonello Provenzale, Elisa Palazzi**
Institute of Atmospheric Sciences and Climate - Italian National Research Council (ISAC-CNR), Italy

Objectives foreseen in 2013

1) Creation of a database containing information on the Karakoram glaciers.

2) Assessment of ice thickness and volume of the Karakoram glaciers.

3) Description of recent (2001-2010) glacier changes in the Karakoram area and investigation of the factors explaining the "Karakoram anomaly"; analysis of the factors affecting glacier evolution (snow coverage, supra-glacial debris, etc.).

4) Development and calibration of a distributed hydrological model accounting for ice/snow melt and ice flux.

5) Maintenance of the Shigar hydrological station and restoration of the Paiju station.

6) Update of the control section topographic survey and subsequent new calibration of the stage-discharge curves.

7) Characterization of water quality in a number of sites on the Shigar watershed.

8) Assessment of the spatial and temporal variability of water chemistry on the Shigar watershed.

9) Analysis of the atmospheric composition data collected during the 2011/2012 summer campaigns on the Baltoro glacier.

10) Installation of a permanent station in northern Pakistan for the analysis of air composition.

11) Analysis of snow depth in the Karakoram-Himalaya region using global reanalyses and global climate models (GCMs).

12) Study of the synoptic origin of winter precipitation in the Karakoram.

13) Provision of regional climate scenarios produced by the RegCM4 regional climate model.

14) Definition of the modelling chain connecting the GCMs to the hydrological model.

15) Development of hydrological scenarios of water availability.

16) Characterization of the micro-meteorology and surface energy fluxes in the accumulation area of the Changri Nup Glacier, Nepal.

17) Description of the Changri Nup glacier albedo variability.

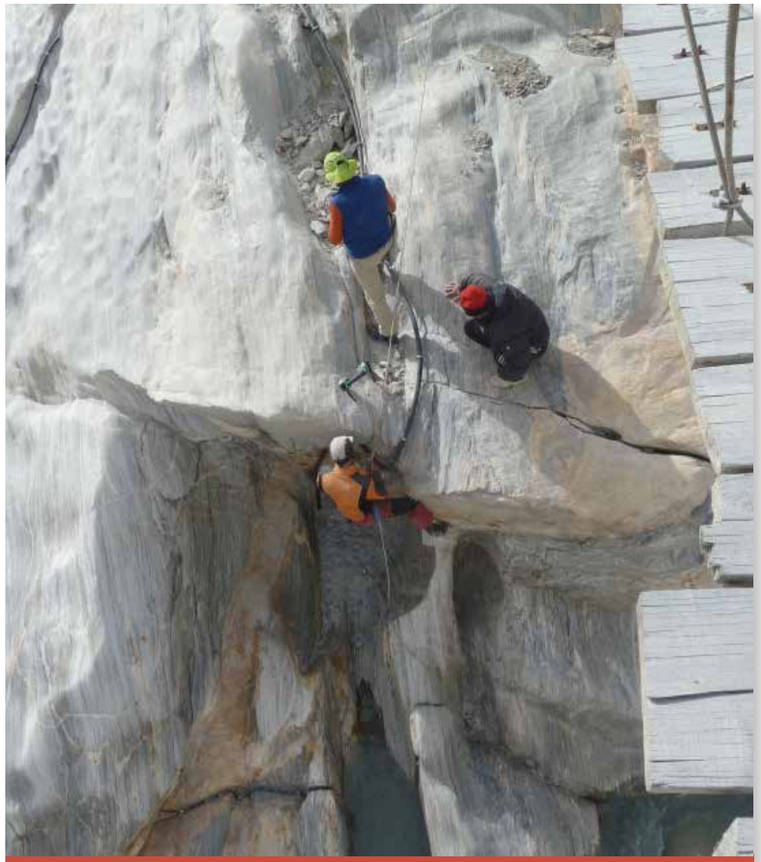

Fig. 1 - Picture taken at Paiju bridge.

Results obtained in 2013

1) A database was created with information on 700 glaciers located in the Central Karakoram National Park (CKNP). Data on glaciers were obtained from the analysis of 2001 and 2010 satellite Landsat images, providing a description of current glacier coverage and changes during the last decade.

2) The mean and maximum ice thicknesss were assessed by applying indirect theoretical methods, and the volume of all glaciers included in the CKNP Glacier database was estimated.

3) The snow coverage changes in the period 2001-2011 were derived from the analysis of the MODIS snow satellite products, to evaluate the role of snow variability in driving the Karakoram glacier evolution. Supra-glacial debris coverage distribution over the whole CKNP area was analyzed by applying a supervised classification of Landsat images, as rock debris has been recognized as a fundamental factor driving rates and magnitude of buried ice melt.

4) A distributed ice melt model was developed, describing the Karakoram glacier behaviour and forecasting melt-water discharge; it was calibrated/validated using glaciological data collected during three field campaigns.

5) The Shigar station was maintained by substitution of the solar panel; two new piezometric sensors were installed at the Paiju control section in a safer position (see Fig. 1).

6) A high precision topographic survey was carried out for both Shigar and Paiju control sections; the two-stage discharge curves were updated using newly collected data.

7) The quality of water in the Shigar watershed was characterized by analyzing the major ions, nutrients and trace metals in a number of sampling points along an altitudinal gradient.

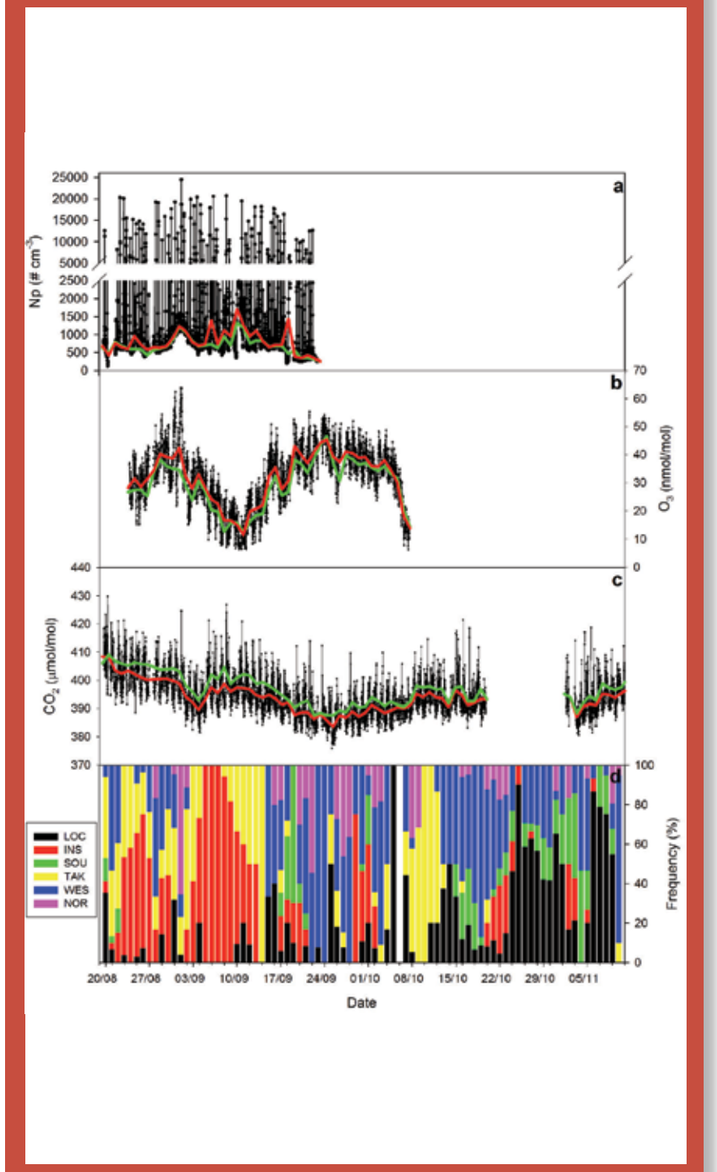

Fig. 2 - Time series of CPC particle number concentration (Np, panel a), surface ozone (O3, panel b), carbon dioxide (CO2, panel c) and daily air-mass circulation occurrences (panel d, WES-Westerly; TAK-Taklamakan; LOC-Local; SOU-Southern Pakistan; INS-Indian Subcontinent; NOR-Northerly). Red lines denote daily averages (computed excluding the "local contamination events"), while green lines represent night-time (between 21:00 and 4:00) averages. [Putero et al., Submitted to Atmospheric Environment]

The chemical survey performed over a three-year period showed good water quality: trace metals and other inorganic contaminants were almost absent and episodes of water contamination by local sources were found only in a very few cases.

8) The chemistry of water in the Shigar Valley turned out to be mainly controlled by land cover (bedrock lithology) and hydrological factors. A contribution of atmospheric deposition to the nitrogen content of water samples (mainly as NO3) cannot be excluded.

9) Using the data collected during the summer 2011/2012 campaigns, the average level and variability of PM10, ozone, carbon dioxide and particle concentrations were depicted for the Baltoro region (see Fig. 2). The contribution of long-range transport processes, thermal wind circulation and domestic emissions was investigated.

10) A permanent station, powered by solar energy, was installed on July 2013 in the Pakistani Deosai National Park, at 4200 m a.s.l., in collaboration with WAPDA, PMD and in synergy with SHARE-ABC. The station has been operating since September 2013 (with only one break in November,2013), measuring pollutant/climate-altering compounds and standard meteorological parameters.

11) The snow depth representation for the Karakoram-Himalaya regions was analyzed in a set of GCM simulations participating in the CMIP5 effort. The spatial pattern of the winter snowpack, the seasonal snow cycle and future snow depth projections were evaluated. Significant snow depth reduction in the Karakoram and an even stronger decrease in Himalaya (almost 50% over a century) were projected by the GCMs.

12) The synoptic control of winter precipitation in the Karakoram, associated with the arrival of western weather patterns originating in the Mediterranean/Atlantic regions, was investigated, focusing special attention on the role played by the NAO teleconnection pattern.

13) The RegCM4 regional model was run by ICTP at 50 km resolution to evaluate the regional climatic impact of aerosol in the Karakoram-Himalaya regions. Three simulations were undertaken, in which the external boundary conditions for a present-day (2000-2009) simulation were provided by the ERA-Interim reanalysis and by the CMIP5 EC-Earth 2.3 model. A future scenario simulation was performed for the decade 2040-2050 with RegCM4 nested into EC-Earth.

14) All elements of the modelling chain connecting GCMs to the hydrological model were provided: the EC-Earth and RegCM4 outputs, the RainFARM stochastic rainfall downscaling procedure, and the hydrological model.

15) Future scenarios of water availability were generated by using the hydrological model driven by the climatic input provided by EC-Earth under the RCP 4.5 and RCP 8.5 scenarios (see example in Fig. 3).

16) The micro-meteorology and energy fluxes at the surface of the accumulation area of the Changri Nup Glacier, Nepal, were characterized using the data collected by a SHARE station operating since February 2010.
The glacier surface energy budget and glacier melt were calculated over two ablation seasons and the results cross-checked against ablation data collected in 2011 and 2012.

17) The Changri Nup Glacier albedo variability and melting rates were analyzed as a function of dust and black carbon (BC) deposition.

18) Preliminary simulations with the hydrological model were performed on the Changri Nup basin, using discharge data collected by the station installed in 2012.

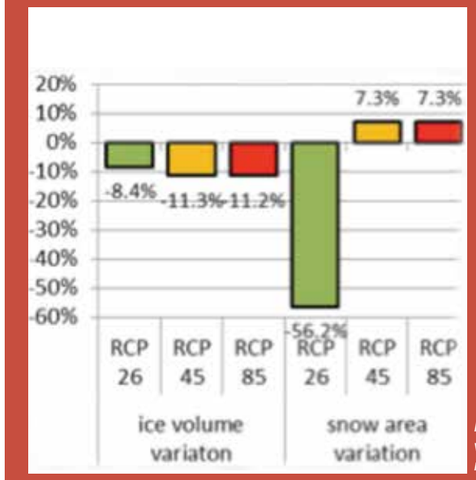

Fig. 3 - Ice volume and snow covered area variations in 2040-2049 as compared relative to present-day values.

WP 1.2.2: Geology/Risk Assesment

Reference Persons: **Giorgio Poretti[1], Franco Rolfo[2]**
1 Department of Mathematics and Geosciences, University of Trieste, Italy 2 Department of Earth Sciences, University of Turin, Italy

Research Activity on Installation of a Permanent GPS Station at the Pyramid International Laboratory-Observatory, Nepal

Reference Persons:
Giorgio Poretti, Chiara Calligaris
Department of Mathematics and Geosciences, University of Trieste, Italy

Objectives foreseen in 2013

1) Activation, collection and retrieval of the data recorded by the permanent GNSS station located at the Pyramid Laboratory (part of a network of 4 GNSS permanent stations).

2) Creation of an internet link able to send these data to the server located at the Department of Mathematics and Geosciences (DMG) of the University of Trieste.

Fig. 1 - Pyramid Lab and old GPS location (1992).

Results obtained in 2013

1) At the end of 2012 the GPS station at the Pyramid Laboratory was moved to a new location for a better tracking of the visible satellites and closer to the other meteorological instruments on the hill above the Pyramid Lab. Since then, the station has been recording GPS data at 15 sec. intervals.

2) Almost one year of GNSS data was uploaded on the server of the DMG of the University of Trieste and was made available to researchers.
Data are presented in Rinex format on a daily bases and can be easily downloaded *(www.dmg.units.it/GPS/)*. This server also makes available more information from the permanent GNSS station located in Islamabad is.
The third GNSS station of the network present at the Karakorum International University (KIU) of Gilgit, is still operating on a local bases and needs a "public IP" in order to transfer its data to the server in Italy.

3) In the course of the year a software was purchased for the publication of the RTK corrections from the GNSS station at the Pyramid Lab and also at the other stations of the network.

Objectives foreseen in 2014

1) In Spring 2014, the installation at Skardu of a permanent GNSS station, which will be linked to the Himalayan GNSS network and enabled to send the RTK corrections to the researchers operating in the area of the CKNP, along the Baltoro glacier and the Khumbu Valley.

2) Submission of a proposal to the Survey Department of Nepal to include the GNSS station now located in Nagarkot, to the Himalayan GNSS network of the Ev-K2-CNR Committee and to enable the transmission of the RTK corrections also along the Kathmandu valley. For this purpose Satline senders should be provided for the GNSS stations.

Fig. 2 - New GPS location (2013).

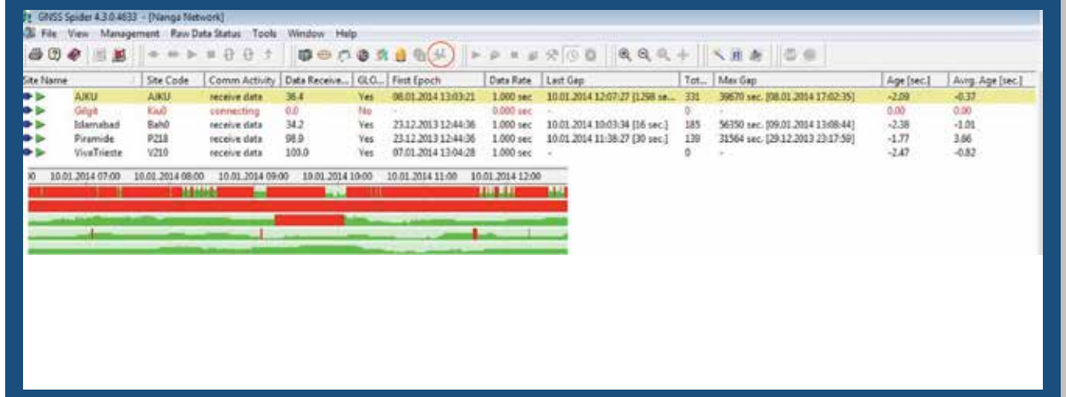

Fig. 3 - Computer output of the management of the Himalayan GNSS Network

Research Activity on Metamorphic CO2 degassing from the active Himalayan orogen and its influence on the long-term global climate changes

Reference Person:
Franco Rolfo
Department of Earth Sciences, University of Turin, Italy

Objectives foreseen in 2013

1) Carrying out of fieldwork activity (including rock and water sampling) in both pre- and post-monsoon seasons, in order to refine the estimate of the volumetric proportions of CO_2-source rocks in eastern Nepal.

2) Laboratory study of rock and water samples collected in November 2012 in Nepal, including: petrography, preliminary fluid inclusion study, meso-structural data processing, geochemical analysis of water samples, and preliminary drafting of geological maps.

3) Collection of water samples from selected hot springs in Nepal (in collaboration with Nepalese partners), for the direct measurement of CO_2 degassing.

4) Presentation of preliminary results to national and international meetings.

Results obtained in 2013

1) In the pre-monsoon season, fieldwork activity was performed along the Singalila Ridge on the border between Eastern Nepal and West Bengala (India) (see Fig. 1).
A detailed geological cross section was surveyed from Maneybanjang to the south, to Phalut to the north. In the post-monsoon season, fieldwork activity was performed in eastern Nepal along an east-west transect from Tumlingtar to Lukla across the Salpa La pass. Both areas crosscut good exposures of the Lesser Himalaya Sequence, the Main Central Thrust Zone and the Greater Himalayan Sequence. Along these geological transects, metamorphic units occur, consisting of ortho- and paragneiss, locally mylonitic and anatectic.
Of special interest to this project are unusual calc-silicate granofels occurring as intercalations within gneissic rocks and representing the CO_2-source rocks. During the post-monsoon activity, additionally water samples were collected from selected springs at different structural levels.

2) Laboratory study of rock samples collected in the previous geologic expeditions in eastern Nepal were performed, including: (i) petrographic characterization of all samples; (ii) minerochemical analyses; (iii) petrologic study of selected samples; (iv) processing of meso-structural field data collected; (v) production of preliminary geological maps. Geochemical analyses of water samples collected in November 2012 in Nepal were also performed.

3) Collection of water samples from selected hot springs in Nepal was postponed to February 2014, to match the Nepalese partner's schedule.

4) Preliminary results were presented at one national and two international meetings. Three scientific papers were published in peer-reviewed journals .

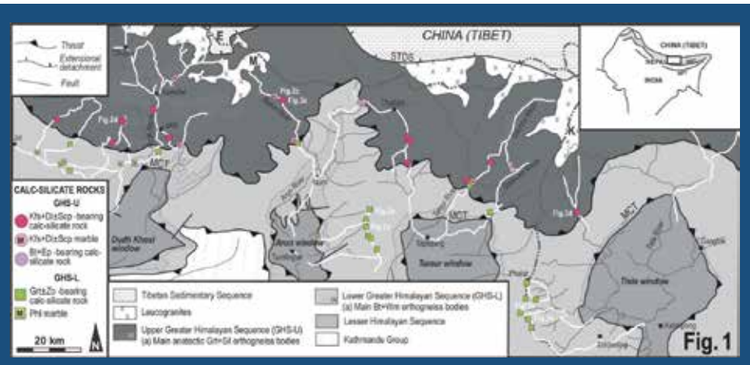

Fig. 1 - Geological sketch map reporting the distribution of different types of metacarbonate rocks in the Eastern Himalayas.

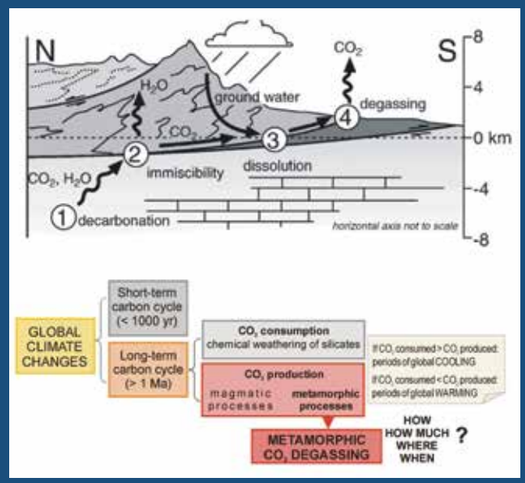

Fig. 2 - Schematic model of CO_2 metamorphic degassing in the Himalayas: CO_2 produced through metamorphic decarbonation (1) exsolves from metamorphic fluids due to decompression and temperature decrease (2); metamorphic CO_2 dissolves in meteoric groundwater (3) and is finally degassed near the Earth's surface (4). Flow-chart illustrating the motivations and rationale behind the project.

Objectives foreseen in 2014

1) Planning of the next field missions. In spring 2014, fieldwork is planned either in SW Sikkim or Ladakh (India), according to the availability of local partners. Additional fieldwork is planned in autumn 2014, and will include rock and water sampling at different structural levels between the Arun Valley (Tumlingtar) and the Singalila Ridge on the border between E Nepal and NE India (West Bengala). Rock samples and meso-structural data will be collected, with particular attention paid to the potential CO_2-source rocks. This will actually complete the database our team collected in a number of years of fieldwork in eastern Nepal and will eventually allow us to estimate the approximate volumetric proportions of CO_2 source rocks from Rolwaling Himal to Sikkim.

2) Laboratory study of rock and water samples collected in November 2013 in Nepal (Tumlingtar – Lukhla geological transect), including: petrography, preliminary fluid inclusion study, meso-structural data processing, geochemical analysis of water samples, preliminary drafting of geological maps.
Implementation of petrological modelling already started in 2013, through other promising CO_2-source rocks. Geochronological study of the samples petrologically investigated in 2013 will also start.

3) In early 2014, continuation of collaboration with our Nepalese partner of the Nepal Geological Society, in direct measurements of CO_2 degassing from selected hot springs located along important structural discontinuities, by collecting water samples in Rasuwa (Langtang Himal), Tatopani/Kodari and Kaligandaki valleys.

4) Presentation of preliminary results at national (FIST-SIMP) and international (HKT-IAEG) meetings in Autumn-Winter 2014.

WP 1.3: Water Resources

Reference Persons: **Riccardo De Beranrdi[1], Andrea Lami[2], Franco Salerno[3]**
1 Ev-K2-CNR Committee, Bergamo, Italy
2 Institute of Ecosystem study - Italian National Research Council (ISE- CNR) 3 Water Research Institute Italian National Research Council (IRSA – CNR)

Objectives foreseen in 2013

1) Assessment of climate change (temperature, precipitation) within the study region through data analysis and climatic model on a regional scale.

2) Evaluation of the possible impact of climate change on water resources within the region.

3) Evaluation of water quality by the analysis of both natural and anthropogenic compounds (nutrients, trace metals, organics).

4) Assessment of long-term change of chemical characteristics of lake water in relation to atmospheric deposition or climate drivers.

5) Analysis of macroinvertebrate and diatom community composition at the lakes under study.

6) Chemical and isotopic characterization of wet deposition and atmospheric flux quantification of the main chemical compounds.

Results obtained in 2013

Main hydrologic dynamics

The results achieved are summarized below:

1) A continuous measurement of potential evaporation was carried out at the Pyramid laboratory: 170 mm in 77 days (equal to precipitation), an amount surprisingly high and tied to the high solar radiation of this environment (R2 = 0.90 p <0.0001). It was observed that the commonly used formula for estimating potential evaporation (e.g. Penman's formula) does not work at such high altitudes (see Fig. 1). This finding opens the need for very accurate long-term studies, considering its importance for understanding the energy/hydrologic balance at these high altitudes.

2) An initial water budget of Lake Superior of the Pyramid was calculated: the lake renewal time is very fast (only 4 days). Therefore, the chemistry of the lake is due only to the processes occurring in the basin, and lakes become sentinels of climate change.

3) Concerning the topsoil, a significant inverse correlation between carbon stock and altitude (r =-0.51, p<0.02) was identified, although the concentration of organic carbon and nitrogen are inversely correlated with altitude (r=-0.76, p<0.0001, r=-0.68, p<0.001).

4) Concerning the isotopic characterization of precipitation, a highly significant correlation between the δ18O ‰ and altitude in all months was identified: in fact, rain is progressively impoverished in the transition from lower (2500 m) to higher altitudes (5600 m).

Long-term change in lake water chemistry

1) The analysis of long-term chemical data at the studied lakes leads to the following results:
The comparison of newly collected data with those available since 1990 confirmed the tendency towards an increase in the water solute content. This shift in the chemistry of the lakes is occurring on a regional scale and should be ascribed to climatic factors.

2) According to hydrological studies, the Pyramid Lakes have a very short water renewal time, which would not allow significant change in water chemistry due to in-lake processes. The observed trends must be ascribed to a change in the runoff chemical composition, in turn affected by catchment processes (e.g. glacial retreat).

3) Conductivity (and ionic content) of the Pyramid lakes was significantly correlated with air temperature (see Fig. 2). Peaks in solute concentrations were observed after warmer than average winters (e.g. 2005-06, 2008-09 and 2009-10). Warm winters lead to earlier snow and glacier melt in the catchment area and earlier ice cover break up, with higher runoff amounts and a greater surface exposed to weathering processes.

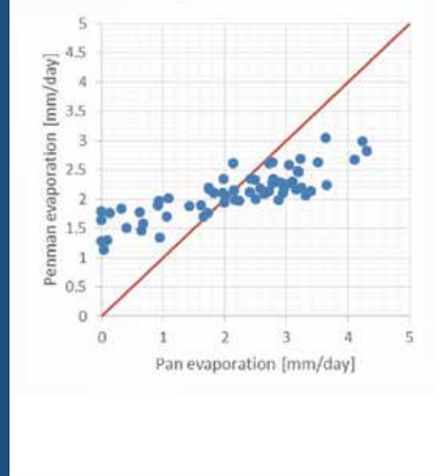

Fig. 1 - Relationship between the pan evaporation and the potential evaporation estimated with the Penman's formula.

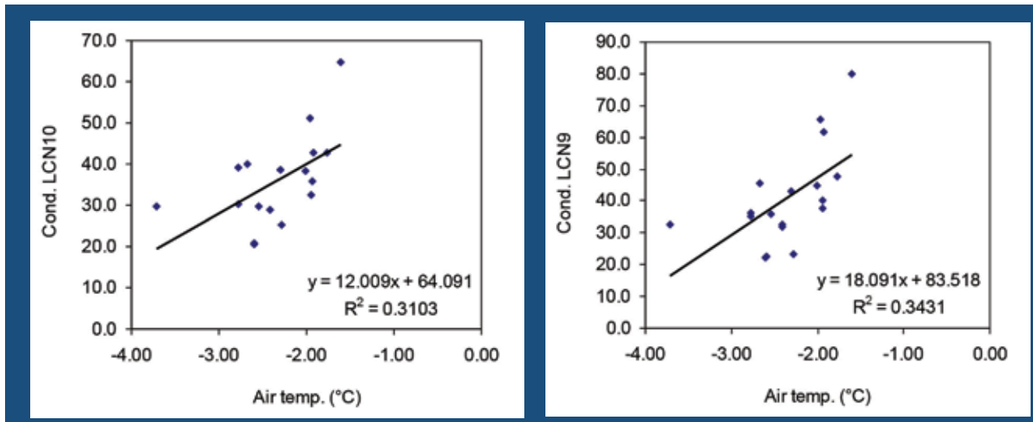

Fig. 2 – Linear regression? between annual values of temperature and precipitation recorded at the Pyramid Station and conductivity of lake water for the Pyramid lakes (data from 1992-2012).

Water quality and biodiversity

The main results obtained from the analysis of biological samples were:

1) A preliminary estimate of the geographic distribution of the main macroinvertebrates (19 sites) and benthic diatom (13 lakes) groups. The lower abundance and diversity of the fauna at higher altitudes (> 4500 m a.s.l.) is due to the effect of temperature. Epilithic Diatom assemblages were more related to chemical parameters than altitude.

2) Water quality proved to be high at all sites, with very low concentrations of nutrients (phosphorus and nitrogen compounds), organic carbon and heavy metals. Biological investigations confirmed the very good ecological status of surface water (see Fig. 3);

3) Richness in Epilithic Diatoms is low, as commonly found in remote environments.
The indexes H' and E indicate a rather good ecological status, with a rather homogeneous species distribution, except for three lakes where the diatom community is dominated by an endemic species (LCN10, LCN21 by Cyclotella antiqua var *minor*; LCN 14 by *Planothidium septentrionalis)*.

Chemical and isotopic characterization of wet depositions (GAW programme)

The chemistry and the isotopic composition (stable isotopes of oxygen and deuterium) of wet deposition were investigated at the Pyramid International Laboratory, during the 2012 monsoon season within the GAW programme. In addition, all snow events occurring in winter and spring 2013 were sampled.
The data were processed also integrating the results obtained by the monitoring performed during 2007- 2008.

The results achieved are summarized below:

1) In precipitation, the major cations were NH_4^+ and Ca_2^+, while HCO_3^- accounted for approximately 70% of the anions, followed by $NO_3^- > SO_4^{2-} > Cl^-$; data treatment suggests that Na^+, Cl^- and K^+ derive from long-range transport of marine aerosols; Ca^{2+}, Mg^{2+} and HCO_3^- are related to the contribution of rock and soil dust; NO_3^- and SO_4^{2-} derive from anthropogenic sources; NH_4^+ derives from the scavenging of gaseous NH_3.

2) The time variations of NO_3^- and SO_4^{2-} exhibited maximum concentrations at the beginning and end monsoon phases (see Fig. 4). The NH_4^+ enrichment in July was probably due to the local transport from low-lying valleys dominated by farmland and vegetated soil.

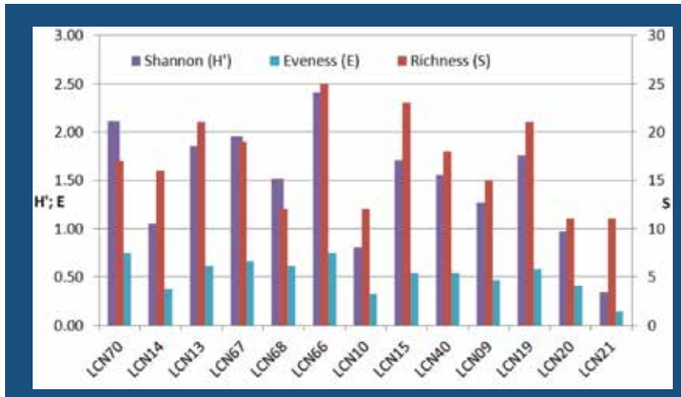

Fig. 3 - Richness, Shannon diversity index and Eveness are shown for the studied lakes (ranked according altitude)

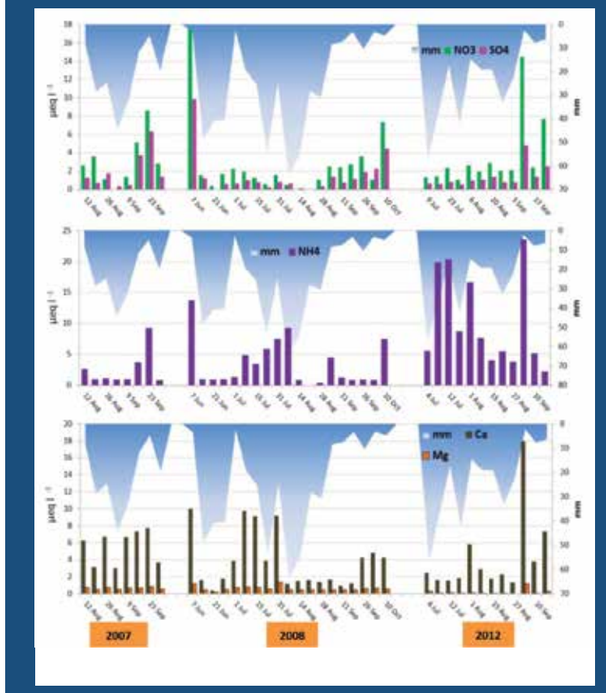

Fig. 4 – Temporal trends of the main ionic species in weekly precipitation samples collected during 2007, 2008 and 2012.

3) Also the isotopic composition was found to be strongly influenced by the amount of precipitation, with depleted values characterizing the central monsoon period.

4) Observations on the wet deposition chemistry indicate that, during summer, the presence of anthropogenic species, especially NO_3^- and SO_4^{2-}, tracers of fossil fuel combustion, was very scarce and a background atmosphere condition occurred.

5) The low nitrogen concentrations associated with very modest amounts of precipitation produced nitrogen loads considerably lower (0.30-0.49 kg ha^{-1} yr^{-1}) than those measured in high-altitude environments in Europe and North America.
Higher N loads were reported for other different ecosystems in the most remote regions of the world, such as the Northern Africa dry savannah and the Central Amazonia tropical rain forest.

6) The analysis of snow samples revealed concentrations of some chemical species (NO3-, NH4+, S042-) considerably higher than those measured in rain; these findings support the hypothesis that during non-monsoon periods the area is affected by the presence of relatively contaminated air masses, while also indicating that the dry deposition deposited on the snowpack during winter could contribute to the total deposition fluxes of nitrogen species and other compounds.

Objectives foreseen in 2014

1) Completion of the analysis of lake chemical data, focusing on the relationships between water chemistry and meteorological variables, with the aim of submitting a manuscript to an ISI journal in the first half of 2014.

2) Commencement of a multivariate analysis (es. CCA) on biological data, using water chemistry and lake geographical and morphological features as driving variables.

3) Completion of the analysis on the impact of climate change on surface hydrology, with the aim of submitting a manuscript to an ISI journal in the first half of 2014.

4) Investigation of the knowledge of the nitrogen biogeochemical cycle, analyzing the relationships between atmospheric deposition fluxes, surface waters, soils and the physical features of the Khumbu catchment.

5) Continuation of the ongoing measurement activities on chemical precipitation at the GAW-WMO NCO-P station.

WP 1.4: Biodiversity

Reference Persons: **Sandro Lovari[1],Graziano Rossi[2]**
1 Department of Life Sciences, University of Siena, Italy; 2 Department of Land end Environmental Sciences, University of Pavia, Italy

WP 1.4.1: Animal Biodiversity

Reference Person: **Sandro Lovari**
Department of Life Sciences, University of Siena, Italy

SHARE Snow Leopard
Stations at High Altitude for Research on the Environment

Pilot Project

Project Coordinator: **Sandro Lovari**
Department of Life Sciences, University of Siena, Italy

Objectives foreseen in 2013

1) Continuation of data analyses and publication of the results of work carried out in Sagarmatha National Park (SNP) on relationships between snow leopards, common leopards and their main prey.

2) Surveys in Hemis High Altitude National Park (HHANP), Leh, Ladakh, and Dachigam National Park (DNP), Srinagar, Kashmir (India), to evaluate (i) the feasibility of a research effort on ecological relationships among the snow leopard, Tibetan wolf and main prey; (ii) genetic identification of Kashmir red deer, with implications for its conservation; (iii) planning of a census of Kashmir red deer, scheduled for autumn 2014.

Results obtained in 2013

1) A review of food habits of snow leopards and common leopards in Asia showed that the spectrum of prey of the latter was 2.5 times greater than that of the former. Diet overlap between the cats was extensive, from 0.83 (weight categories) to 1.0 (main food categories). A great potential for competition should be expected in areas where these cats live in sympatry. Implications for the conservation of the snow leopard were formulated also in relation to current climate changes (see Fig. 1).

2) Analysis of data collected in SNP (2006-2010) showed that snow leopards and common leopards separate their ecological niches on the basis of habitat partitioning: the former used grassland and shrubland, the latter selected forest.
Snow leopards and common leopards preyed upon similar wild (Himalayan tahr, musk deer) and domestic prey species (Bos spp., dogs). Dietary overlap between the snow leopard and common leopard was 69% (yearly), 76% (colder months) and 60% (warmer months) (see Fig. 2).
Thus, habitat separation should be the result of other factors, most likely avoidance of interspecific aggression, rather than exploitation of different food resources. In turn, habitat partitioning could allow the coexistence of these potentially competing predators, although habitat changes, i.e. forest up-lift

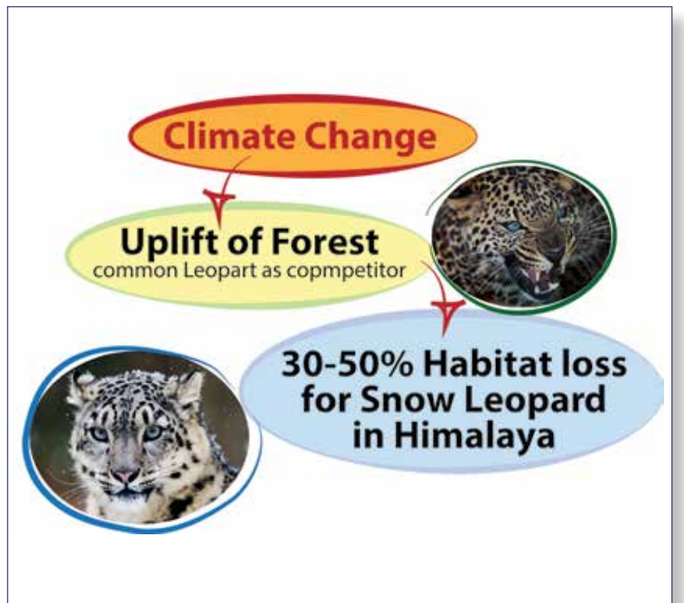

Fig. 1 - If climate change continues, a strong decrease in habitat (ca. 10,000 km2) may be expected for the snow leopard along the Himalayan range, because of increasing competition with the common leopard and other large forest carnivores.

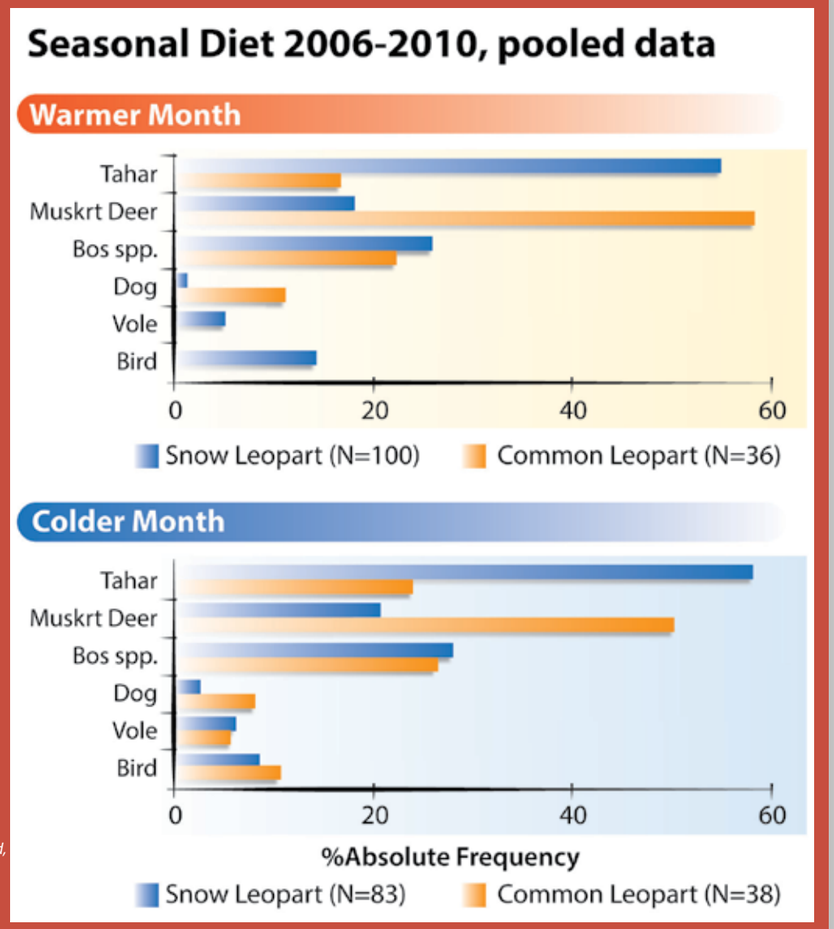

Fig 2 - Seasonal diets of the snow leopard and the common leopard, in terms of absolute frequency of occurrence, in the Sagarmatha National Park, Nepal.

due to climate change may reduce suitable habitat for the snow leopard.

3) The survey conducted in October 2013 in DNP allowed the identification of 23-30 suitable geo-referenced locations at which to count deer, covering an area of ca. 13 Km^2.

Objectives foreseen in 2014

1) Start of research in HHANP to investigate ecological relationships (habitat/diet partitioning; minimum population sizes; ranging movements; minimum home range sizes) between snow leopards and wolves, to (i) assess ecological factors allowing the coexistence of these large predators; (ii) predict their population evolution.

2) Data collection in HHANP on habitat use, food habits, minimum numbers, sex ratio, ranging movements and minimum range size of wolves and snow leopards.

3) Publication of genetic assessment of Kashmir red deer *Cervus elaphus hanglu*, with proposal of a new species *Cervus tarim* inclusive of red deer from North China, Tadzikistan and Kashmir.

4) Census of red deer in DNP through the roar count method. During the activities a short formative preliminary course will be organized by Italian experts to increase the knowledge of local operators.

WP 1.4.2: Plant Biodiversity

Reference Person: **Graziano Rossi**
Department of Earth and Environmental Sciences, University of Pavia, Italy

Objectives foreseen in 2013

1) Set up of a germination experiment in Khumbu valley (Nepal) to evaluate the effects of global warming on seed germination of alpine and nival Himalayan plant species.

Results obtained in 2013

1) A field experiment in the Khumbu Valley (Pyramid and Pheriche areas) was set up and the monitoring system to evaluate the growth of seeds commenced in collaboration with Pyramid staff (see Fig. 1, Fig. 2 and Fig. 3).
The aim was to understand whether the alpine species currently growing in subalpine areas (Pheriche) are currently able to germinate and establish at higher altitude (Pyramid area). We are studying seed germination of alpine and subalpine species under both natural and moderate warming conditions.
Seeds of four subalpine and four alpine species growing spontaneously at ca. 4000 m and 5000 m altitude, respectively, were sown at ca. 5000 m (in alpine habitat), both inside and outside open top chambers (OTC), small greenhouses used for field manipulation of climate. In each plot, seedling emergence and survival (seedling recruitment) is monitored by Italian researchers, who regularly (every 15 days) receive high resolution pictures showing the seed behavior from the Pyramid staff. Monitoring activities will continue for at least one year after sowing.
Temperature and water potential are recorded at hourly intervals inside and outside the OTC, using a data logger. In the meantime, germination test on seed lots used in the experiment were carried out at room temperature at HSB laboratories in NAST. The seeds showed a high percentage of germination (close to 100%), confirming the good vitality of the seeds used.

Fig. 1 – Testing plots at Pyramid.

Fig. 2 – Seeding into the plots.

Objectives foreseen in 2014

1) Conclusion of the experiment on seed germination in the Khumbu Valley.

2) Preliminary survey in the Rwenzori area (to be defined).

3) Publication of papers on research activities carried out in Nepal and Italy in 2010/2013 (e.g. on seed dispersal and climate change in the Khumbu Valley, based on data collected during the first field mission in 2010).

Fig. 3 – Species studied during the experiment at Pyramid: Meconopsis horridula (left) and Tanacetum gossypinum (right)

SHARE Seed Bank
Stations at High Altitude for Research on the Environment

Pilot Project

Project Coordinator: **Graziano Rossi**
Department of Earth and Environmental Sciences, University of Pavia, Italy

Objectives foreseen in 2013

1) Cleaning, processing and storage of the seed collected in the Khumbu Valley in the 2012 field expedition.

2) Collection of new samples in the Khumbu Valley in 2013.

3) Starting of a database containing all the information on seeds collected in 2012-13.

4) Installation of a fully independent management and electrical supply system of the HSB.

5) Plant identification (taxonomy), herbarium specimen preparation and duplication in three different Herbaria (HSB, Godavari-DPR (KATH) and Tribhuvan University (TU).

6) Improvement of knowledge on HSB, as a study case of seed bank in developing countries, in terms of experiences and suggestions.

Objectives foreseen in 2014

1) Collection of the curation (cleaning and storage) of seed and herbarium specimen collected in 2013. The majority of the work is in progress (help from Italian staff is required).

2) Inclusion of all data on seed collection, curation and germination in a database (the database has to be implemented with the assistance of Pavia staff).

3) Performance of seed germination research in Italy if permission for seed exportation by Nepalese researchers is obtained.

4) New instrumentation to be provided, in order to improve HSB activities (to be defined).

5) HSB staff training for germination tests (to be defined).

Results obtained in 2013

1) Collection and storage was accomplished of more than 150 seed lots sampled in 2 years (see Fig. 1). Some difficulties were experienced in plant identification, seed cleaning and storage, involving long time expenditure.

2) A database containing collection, cleaning and germination information of the seed lot was started.

3) Germination tests were performed at HSB by Deepa Dhital, NAST's researcher, under the supervisions of Pavia University staff, obtaining high levels of germination (90-100%).

4) Submission of a paper entitled "Ex situ plant conservation initiative in developing country: Nepal as a case study" in a special issue of Plant Biosystems, an international botany journal. The paper is in publication (accepted) in a special issue entitled "Plant ecology and conservation in international cooperation: approaches and methodologies". The topic focuses on the difficulties and solutions in setting up a seed bank in developing countries.

Fig 2 – Rhododendron hodgsonii J.D. Hooker, one of the rarest Rhododendron species of the Khumbu valley stored in HSB.

Fig. 3 – Part of the seeds collected in 2012 and stored in glass jars in HSB.

Fig 1- Seed collection in Sagarmatha National Park, Nepal, in October 2013.

WP 1.5: Environmental Medicine and Human Health

Reference Persons: **Annalisa Cogo**
Clinica Pneumologica e Centro Studi Biomedici applicati allo Sport, University of Ferrara, Italy

SHARE Gard Khumbu
Stations at High Altitude for Research on the Environment

Pilot Project

Project Coordinator: **Annalisa Cogo**
Clinica Pneumologica e Centro Studi Biomedici applicati allo Sport, University of Ferrara, Italy

Objectives foreseen in 2013

1) Assessment of respiratory function (spirometry) in subjects exposed to different levels of indoor pollution due to the use of biomass fuel in Chaurikharka village m a.s.l (Solukhumbu district, Buffer Zone Sagarmatha National Park, Nepal), at 2660 m a.s.l.

2) In the same subjects, detection of markers of early atherosclerosis with ultrasound.

3) Taking of blood samples from the subjects, to measure lipid profile, electrolytes, glycemia in order to discriminate between the role of indoor pollution and the role of well-known cardiovascular risk factors (i.e. diet, metabolic impairment). New markers of pollution exposure will be also measured.

Results obtained in 2013

1) 41 houses in Chaurikharka village were visited (see Fig. 1), in which the inside ventilation and environmental Carbon Monoxide (CO) were measured. The environmental mean CO is 51ppm with the brazier on and 2.32ppm with the brazier off, as regards inside ventilation. Currently, conclusive results are still to be achieved.

2) *Respiratory function:* acceptable and interpretable spirometries were performed on 74 non-smoker subjects, aged 16-85 years, of which 55 females (F) and 19 males (M).
Spirometry test: 6 subjects (2 M and 4 F) show a non reversible bronchial obstruction, index of the presence of Chronic Obstructive Pulmonary Disease (COPD). In particular, five of them are over 50 years of age (2 M, and 3 F). This means that the prevalence of COPD among these subjects (with age > 50 years) is 26.92%, greater than expected in a population of non-smoker subjects.
"Early obstruction" (i.e. FEF25-75 >65%) is present in 21 non-smoker subjects (27.63%). Among them, 11 are more than 50 years old (8 F and 3 M). The prevalence of "early obstruction" is therefore 55% in subjects > 50 years and 18.6% in younger subjects. Again, the prevalence is higher than expected in non-smokers.

3) *Cardiovascular study:* was performed on 71 subjects (48 F and 23 M) with a mean age of 41.5 ± 6 years. The preliminary analyses show that the average values of blood pressure were 128/79 mmHg and average heart rate 65 bpm. In particular, each subject underwent the following analyses:
i- Cardiac study through echocardiography: all subjects

Fig. 1 - Indoor pollution due to wood biomass combustion.

had normal left ventricular function (EF mean 64 ± 9%) and preserved left ventricular diastolic function. The mean pulmonary artery systolic pressure was 27 ± 8 mmHg.

ii- Vascular study through:

a) digital plethysmography: was performed on 51 individuals (34 F and 17 M). 23 of the 51 subjects studied had impaired microvascular endothelial function and there were no significant differences between the sexes (women 0:54 ± 0.27 , men 0.56 ± 0.25 , P = 0.64)

b) study of endothelial function in the brachial artery: was successfully performed on 71 individuals. The population had a brachial artery diameter 4.02 ± 0.96 mm. The maximum percentage increase in diameter after reactive hyperemia was 4:07 ± 2:34 % (range 0.73-12.33 %). As expected, women had a lower brachial artery diameter and endothelium-dependent vasodilation greater than in men. In contrast, the difference in endothelium- independent vasodilation was not statistically significant.

c) arterial stiffness: was performed in 71 subjects, 10 of whom showed an increase in arterial stiffness. The population had a mean value of carotid-femoral PWV of 8.2 ± 2.0 m / s.

iii - Heart Rate Variability (short term): the examination was successfully performed on 63 subjects (44F and 19 M). The relationship between spectral component at low frequency and high frequency (LF / HF ratio) was 1.48 ± 1.24 (range 0:13 to 5:53). Whereas a cut-off of normality of 2 was found for for the LF / HF ratio, 17 individuals had an altered sympathovagal balance.

Objectives foreseen in 2014

1) Processing of data collected in 2013.

2) Continuation of the educational project to improve knowledge on spirometry and awareness of COPD among the public and health providers in Nepal.

3) Planning of a post-mission study in order to check and calibrate at altitude a new instrument for the assessment of peripheral airways and the instrument to measure the exhaled CO.

The campaign carried out in 2013 was the first part of a longitudinal study; the first follow-up study will be undertaken in 2015.

Fig. 2 – Local woman involved in the research study.

WP 2: Scientific and Technological Research

Reference Person: **Gian Pietro Verza**
Ev-K2-CNR, Bergamo, Italy

In the SHARE project the main technological component used in 2013 was represented by the RCS - Remote Climate Station. This innovative and technological tool represents an evolution of the NANO-SHARE prototype.

Objectives foreseen in 2013

1) Test campaign of RCS – Remote Climate Station for annual measurement in Karakorum, in the framework of the UNEP-ABC programme.

2) Test of a portable analyzer to monitor indoor pollution emissions.

Results obtained in 2013

1) The RCS is a modular system, equipped with real-time data transmission, able to perform measurements in extreme environmental conditions, where the installation of a fully-equipped permanent laboratory or standard monitoring station may be too difficult.
It uses renewable energy sources, in order to ensure a low environmental impact. It can be equipped with different modules in order to guarantee the monitoring of atmospheric composition and other environmental indicators in remote regions.
In 2013 the RCS was installed in Deosai, Pakistan, to measure the following parameters: concentration of surface ozone, black carbon, particulate matter, meteorological parameters (i.e. temperature, pressure, relative humidity, wind speed and direction) and solar radiation.

2) A mobile system was tested in Nepal in order to measure indoor pollution emissions in the local houses, and, in particular, Black Carbon emissions from the cooking stoves used.

Objectives foreseen in 2014

In 2014 the WP 2 will be re-named as Scientific and Technological research and Technological systems, and all activities will be promoted under the SHARE project.

1) Implementation of new RCSs, equipped with further sensors, able to monitor other atmospheric parameters (e.g. NOx).

2) Installation of RCSs in different sites of interest, in order to perform new environmental monitoring activities in remote area and start feasibility study.

Fig. 1 – Monitoring of Black Carbon and particulate concentration in several buildings of Chaurikharka village.

WP 3: Information System

Reference Person: **Maria Teresa Melis**
Department of Chemical and Geological Sciences, TeleGIS Laboratory, University of Cagliari, Italy

SHARE Geonetwork
Stations at High Altitude for Research on the Environment

Pilot Project

Project Coordinator: **Maria Teresa Melis**
Department of Chemical and Geological Sciences, TeleGIS Laboratory, University of Cagliari, Italy

Objectives foreseen in 2013

1) Installing the WDB in the final server.

2) Uploading of all data currently in our possession (raw and validated).

3) Completion of the page with PHP and access management styles.

4) Development of the PHP page with products obtained from the DB data : graphs with the means, standard deviations, etc..

5) Downloading of the data provided by the query in netCDF format.

6) Contribution of SHARE- GN system to Next Data portal.

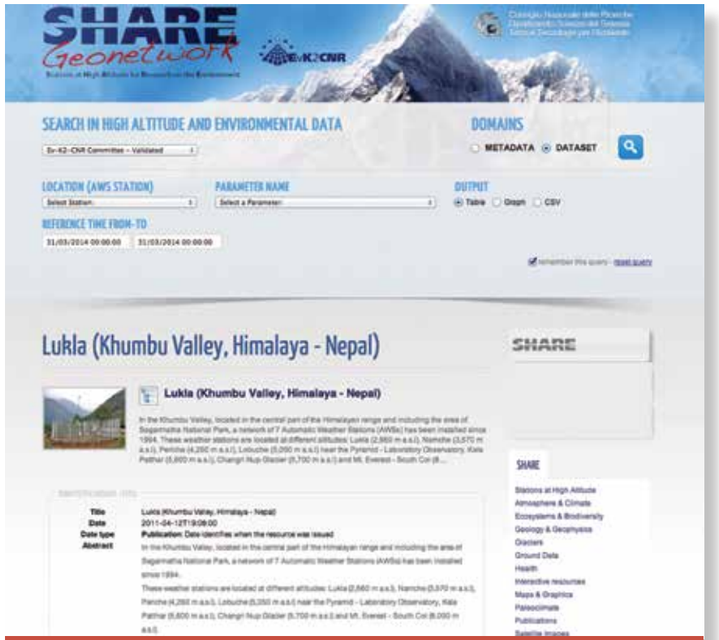

Fig. 1 - Page for data querying and downloading.

Results obtained in 2013

1) The database WDB was installed in the new server and is now online. This project is developing a web platform to access meteo-climatic and atmospheric composition data, past climate information from ice and sediment cores, and has adopted SHARE GN as its web service.

2) All available data were uploaded into the database and are now available.

3) The page for the querying and downloading of the data was completed and the service is currently active (see Fig.1).

4) The web service permits users to obtain data in table or graph formats (see Fig. 2).

5) It is possible to download data in csv format. This format was chosen for its standard use.
The next step will be the implementation of the downloading in netcdf format.

6) The DOI (Digital Object Identification) service was added to the web system. Ev-K2-CNR has joined the project DataCite and has become an autonomous "Data Center".

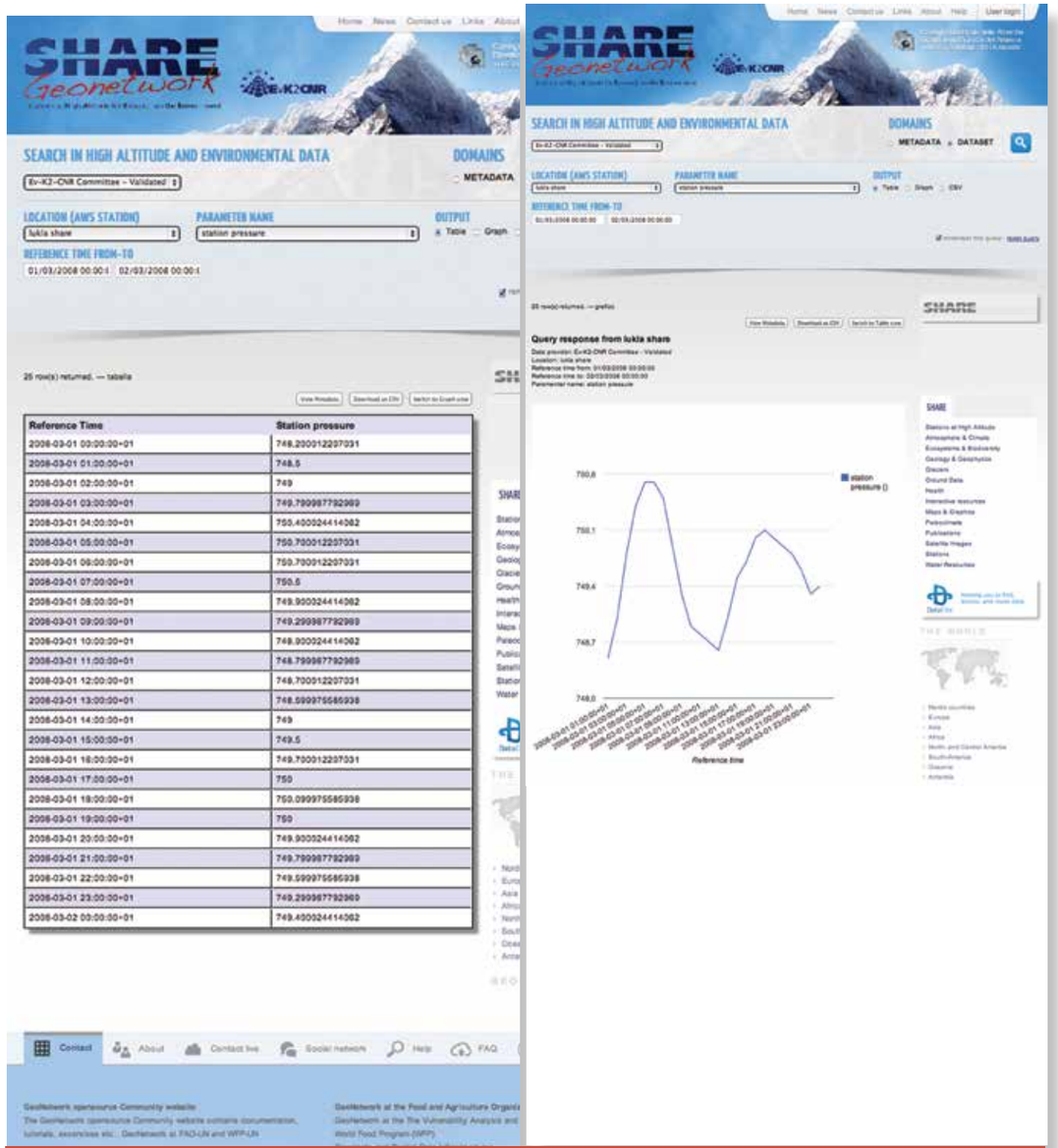

Fig. 2 – Available data in table (csv) and in graph format.

Objectives foreseen in 2014

1) Development of the PHP page with products obtained from IDB and SDB.

2) Upgrading of the system of querying and data results.

3) Upgrading of Geoserver services.

4) Collection and uploading of metadata and data related to new projects: Permafrost and DataGRALP.

WP 4: Capacity Building

Reference Person: **Stefania Proietti**
Department of Industrial Engineering, University of Perugia - Italy

Objectives foreseen in 2013

1) Continuation of training courses for technicians and researchers involved in the Project.

2) Organization of World Chronic Obstructive Pulmonary Disease Day in Kathmandu, with the direct involvement of Nepalese doctors.

3) Continuation of collaboration with the SPCC and Eco Himal Society for Cooperation Alps Himalaya, for the management and maintenance of the existing waste disposal system, and the improvement of waste management in the Khumbu region.

4) Start of activities related to energy and environmental planning in mountain territories and experimental development of innovative sustainable solutions.

Results obtained in 2013

1) Local researchers and technicians were involved in training activities organized by Italian researchers, both during field missions and in the laboratory. During the year, lectures and seminars were also organized.

2) In the framework of the World Environmental Day Celebration, an awareness campaign continued in the Khumbu Valley. In particular, a local technician Laxman Adhikary distributed the book "What is Global Warming?" among Nepalese schools, showing the fundamental role of mountain regions and the important effects of climate change. In this framework, five Nepalese students had the possibility to spend a few days at Pyramid and be directly involved in the activities undertaken there.

3) On occasion of the World COPD Day, a conference was organized at the Tribhuvan University Teaching Hospital in Kathmandu on 12/1/2013, with the support of the Chiesi Foundation. During the event, the GOLD Guidelines for the diagnosis and treatment of COPD were illustrated by Prof. Annalisa Cogo, University of Ferrara and coordinator of WP 1.5. In addition, a member of the local medicine research group presented the Nepalese scenario, in terms of educational approach, access to diagnosis and therapeutic treatments, focusing on people who live in remote areas (see Fig. 1).

4) In order to create a waste collection center in Namche Bazar, the Nepalese authorities required the installation of an additional disposal device. Rirstly, pyrolysis and gasification technologies were assessed, but were found to be expensive, inconvenient in terms of transport, and at a pilot/non-commercial stage. Initial steps were undertaken to develop and optimize a system based on incineration technology, starting from SPCC data on waste collected from expedition groups, trekking trails and some villages (see Fig. 2).

5) SERA - Smart Ecosustainable Residential Area project aims to promote useful strategies for sustainable development in the Khumbu Valley, through energy and environmental planning. For this purpose, a thorough analysis was conducted to identify the specific features of the reference context from several points of view; at the same time, a survey on efficiency solutions started, concerning the building sector, renewable energies and distributed generation. To support the experimental development stage and the creation of a repeatable pilot project, an on-site investigation was organized in a village of the Khumbu Valley (see Fig. 3 and Fig. 4).

Fig. 1 – On the left, Prof. Annalisa Cogo introduces the GOLD Guidelines during COPD Day 2013; on the right, Contribution of a local medicine research group at COPD Day, Kathmandu.

Fig. 2 – Basket for separate rubbish collection, supervised by SPCC.

Fig. 3 – Traditional house, built in wood and stone, covered with mortar or mud.

Fig. 4 – Stove in stone and mud, equipped with a hood, but without a chimney for blowing out the smoke.

Objectives foreseen in 2014

1) Continuation of training courses for technicians and researchers involved in the project.

2) Involvement of additional Nepalese researchers for capacity building activities, with the support of NAST, and organization of lectures/workshops during on-site missions.

3) Optimization of an existing incinerator, selected on the basis of waste collection data from SPCC.
Tests, measurements and monitoring activities will be necessary to make the device: simple to build, move, assemble and install; optimized/automated; easy to operate.
The research could include a detailed assessment of the selected incinerator;
the design of possible modifications (e.g. heavy-duty steel casing, refractory cement lining, combustion chamber, exhaust gas recirculation) through standard methods, as well as monitoring campaigns; thermo fluid-dynamic modeling.

4) Selection of the best proposals to be considered during the experimental development stage of SERA, on the basis technical-economic feasibility studies, with particular attention to the environmental impact during the entire life cycle of products or processes (Life Cycle Assessment).

5) Identification of solutions to submit to experimentation, evaluated in terms of environmental benefits, potential advantages for well-being of the local population, comparability with local territory, repeatability, visibility. Specific Research & Development activity could be necessary to define possible measures for optimizing costs and benefits.

6) Experimental development of some sustainable measures in a limited area, to create a repeatable pilot project on technological innovation for energy efficiency and renewable sources. This phase should involve the educational community to increase awareness on the problem of energy saving and the use of renewables.

Highlights 2013

Atmosphere and climate

SusKAT (Sustainable Atmosphere for the Kathmandu Valley)

As reported by the United Nation Environmental Programme, air pollution is a major environmental concern in South Asia, which is one of the most polluted as well as most populated regions of the world. This is particularly true of Nepal and the Kathmandu urban area, the latter being considered one of the most polluted cities in Asia. As shown by the atmospheric measurements carried out at the Nepal Climate Observatory – Pyramid (5079 m a.s.l., high Khumbu valley), large amounts of these pollutants, including short-lived climate-forcing pollutants (SLCP), such as ozone and black carbon, when transported from the foothills and the Indo-Gangetic Plains, can even affect the high Himalayas with significant impacts on regional climate, cryosphere and ecosystems. It is therefore necessary to implement swift actions to reduce SLCP emissions , which, as well as reducing anthropogenic forcing on climate, will also avoid the loss of a large number of deaths due to air pollution.

Fig. 1 - Landscape of Kathmandu valley from the SusKat Observatory at the Ev-K2-CNR Representative Office in Pakanajol.

To implement effective mitigation measures in Nepal, a correct understanding of the physical processes (emissions, meteorology, air-mass transport) is required. Therefore, the project **Sustainable Atmosphere for the Kathmandu Valley (SusKat)**, coordinated by IASS (Germany) and ICIMOD (Nepal), has been implemented to conduct a comprehensive assessment of various aspects of air pollution in the Kathmandu valley, as part of the ABC-UNEP Project. In the Suskat project, an extensive internationl field campaign was carried out from December 2012 to March 2013, with the scientific involvement of research groups from Europe, Asia and north America. In this context, a new permament monitoring station has been installed at Kathmandu by EV-K2-CNR in collaboration with ISAC-CNR.

The new Observatory was implemented at the EV-K2-CNR Representative Office (see Fig.1) at Pakanajol, in Kathmandu city center. The station is equipped with state-of-the-art instruments for the continuous determination of atmospheric composition variability: an integrated weather station (WXT520, Vaisala), a pyranometer (CMP21, Kipp&Zonen), an optical particle counter (FAI Instruments), a ß - absorption system for the near-real-time determination of PM_1 and PM_{10} (FAI Instruments), a Multi Angle Absorption Photometer MAAP 5012 (Thermo Electron), a UV-aborption ozone analyzer (Thermo Electron).

The station is provided with suitable systems for air sampling and UPS, so as to avoid any loss of data or instrument failures due to power loss or electrical discharges.

The monitoring activity running at the Pakanajol Station obtains information on the seasonal and diurnal variability of key atmospheric compounds: equivalent black carbon concentration (BC), surface ozone mixing ratio, size distribu-

Fig. 2- Internal view of the SusKat station at Paknajol: condensation particle counter, OPC, MAAP and ozone analyser.

tion of aerosol particles (fine and coarse mode), PM_{10}, $PM_{2.5}$ and PM_1. The preliminary analysis of the first set of measurements indicated very high values of BC during the dry winter season, with hourly average values exceeding 60 µg/m3 (average value from February to July 2013: 10.6 ± 9.1 µg/m³). Extremely high aerosol mass values have also been observed, with PM1 and PM10 showing average concentrations equal to 41.2 ± 145.4 µg/m³and 152.8 ± 203.4 µg/m³ (see Fig. 4). On a seasonal basis, ozone hourly values peaked during pre-monsoon (up to 100 ppb), with an average value of 32.6 ± 22.9 ppb during the period from winter to monsoon.

These observations highlight the need to implement appropriate mitigation measures to reduce the amount of SLCP in Kathmandu (and Nepal).

Since these SLCP also are dangerous atmospheric pollutants, the adoption of reduction measures will also produce benefits in term of impacts on regional climate, air-quality, ecosystems and human health.

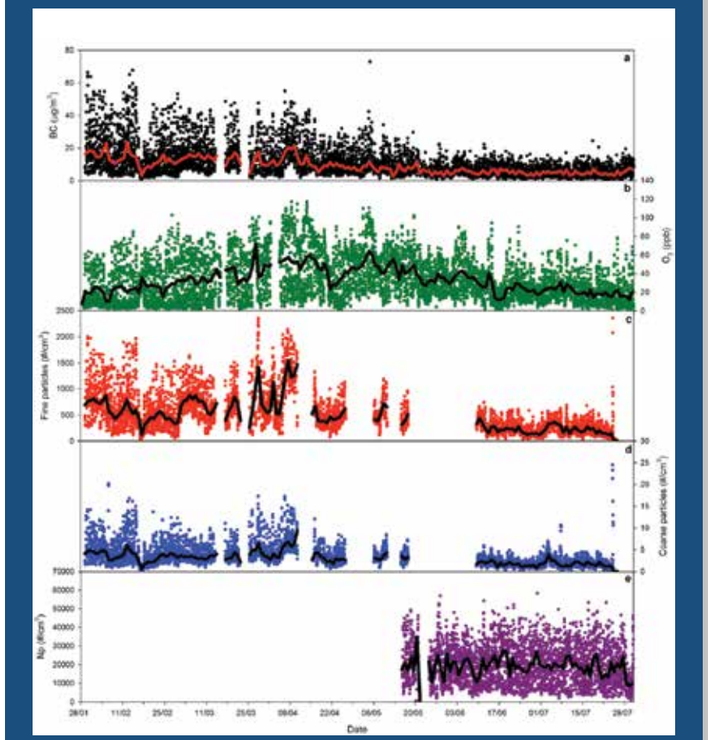

Fig. 3 - Hourly average values of BC (black), surface ozone (green), fine (red), coarse (blue) and total (purple) particle number at Pakanajol – Kathmandu from February to July 2013.

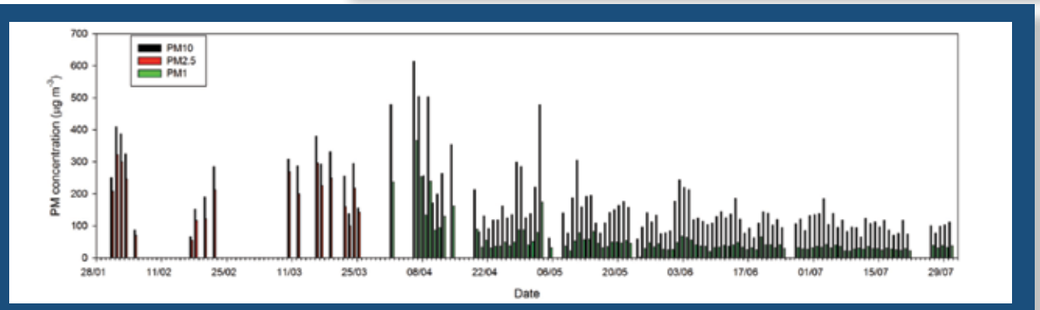

Fig. 4 - Daily mean values of PM2.5 (red, until March), PM1 (green, starting from April) and PM10 (black) at Pakanajol – Kathmandu from February to July 2013.

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Glaciology

Glacier shrinkage driven by climate change half century (1954-2007) in the Stelvio National Park (Lombardy, Italian Alps)

In the recent past glaciers have been melting at rates that cannot be explained by natural climate variability alone (Dyurgerov and Meier, 2000).

Glacier shrinkage is particularly severe on the Alps, and is likely to be driven by the important changes occurring in mid-tropospheric conditions, such as the widely acknowledged rapid temperature increase over the last few decades (IPCC 2001; 2007).

In the Alps, atmospheric warming has been estimated to be more than double the planetary average over the past 50 years (Böhm et al. 2001), with a significant summer warming, particularly severe since 1970 (Casty et al. 2005). Between 1850 and 1980, glaciers in the European Alps lost approximately one third of their area and one half of their mass, and since 1980 another 20 to 30% of the ice has melted (European Environmental Agency, 2004).

Glacier geometry changes are key variables for determining strategies for the early detection of enhanced greenhouse effects on climate (Kuhn, 1980, Hoelzle et al., 2003). Glacier inventories should be carried out at intervals compatible with the characteristic dynamic response times of mountain glaciers (a few decades or less in the case of small glaciers), and the currently observed glacier down-wasting calls for frequent updates of inventories (Paul et al., 2007). In the Alps, Maisch (2000) evaluated an overall decrease of 27% from the mid-nineteenth century to the mid-1970s, with even greater losses in some areas.

Still more striking was the recession in the Berne-Valais area during 1973-98 (Kääb et al., 2002). Diolaiuti et al. (2012a, b) analyzed geometry changes of several glaciers in the Italian Alps (Lombardy and Val d'Aosta regions) during 1991-2003 and 1975-2005, respectively.

They found that Aosta Valley glaciers lost 44.3 km2 during 1975–2005, i.e. ca. 27% of the initial area, and Lombardy glaciers experienced a 21% reduction in the period 1991– 2003.

These observations emphasize the need for more studies and research, to better understand the magnitude and rates of glacier shrinkage in the Alps and assess the links between climate and glacier evolution.

As make a contribution to this topic, in the framework of the SHARE STELVIO project, we studied the Stelvio National Park area (Ortles Cevedale Group, Lombardy sector) in the 1954-2007 time frame. By processing and analyzing aerial photos and orthophotos, the surface area changes of all the glaciers located in this extensive protected area were evaluated.

Study site

Ortles Cevedale is one of the most important glacierized sectors of Italy. The highest peaks are Ortles (3905 m asl) and Cevedale (3769 m asl). The First Italian Glacier Inventory (CNR and CGI, 1961) classified 113 glaciers in the Ortles Cevedale Group. These glaciers were located in Lombardy (39% of the area coverage), in Alto Adige (43% of the area surface) and in Trentino (18% of the area coverage). In the SHARE Stelvio Project, we analyzed the Lombardy glacierized sector of the Ortles Cevedale, which includes Forni, the largest Italian valley glacier (ca. 11.36 km² of area), and several important other glaciers with different size, aspect and geometry, thus being representative of the whole Italian glaciation. In the Lombardy sector the main peaks are Cevedale, San Matteo (3692 m asl), Gran Zebrù (3857 m asl), Corno dei Tre Signori (3360 m asl) and Punta Thurwieser (3641 m asl). The Ortles Cevedale glacierized region is located inside the Stelvio National Park (ca. 600 km² of area in Lombardy), among the most important and representative protected areas of Italy. In the park area, according to the 92/43/EEC directive, several Sites of Community Importance (SCIs) are recognized. Forni Glacier, with its scenic, scientific and naturalistic value, is also among the Lombardy Region List of Geosites (Regione Lombardia, 2009). ardy Region List of Geosites (Regione Lombardia, 2009).

Results

1. The 2007 Stelvio Park (Lombardy sector) Glacier Inventory

We first studied the description of the most recent regional glacier database, i.e. the 2007 glacier record.

The obtained data were passed to the ITT (Infrastructure for the Territory Information) Unit of the Lombardy Region, and will be soon available to the scientific community through the GEOPORTALE (i.e.: the official web-GIS of the Lombardy Region, see *http://www.cartografia.regione.lombardia.it/geoportale*).

The estimated Ortles-Cevedale glacierized area was of 29.29 km² ± 0.10 % in 2007 (67 glaciers). We considered glaciers wider than 0.1 km², thus neglecting glacierets and ice bodies with unclear signs of ice flow and glacier dynamics. Glaciers with a surface below 0.5 km² are prevalent in the Ortles-Cevedale Group (*i.e.* more than 50% of the whole sample), highlighting how the glacier resource is spread into several small ice masses.

About 13% of the sample is accounted for by ice bodies larger than 1 km². The most typical maximum length ranges between 0.51 and 0.75 km (*i.e.* for more than 30% of the sample) and less than 5% of the glaciers were longer than 3 km. The minimum glacier elevation, indicative of glacier terminus altitude, is between 2801 and 2900 m a.s.l. (more than 35% of the overall sample).

Ortles-Cevedale glaciers show a preferred North aspect. The slope frequency distribution indicates that on average glaciers in this area have a gentle slope, with a mean value of 16.9°. A negative correlation was found between terminus elevation (i.e.: glacier minimum elevation) and glacier area (ρ = - 0.6), i.e. larger glaciers tend to reach lower elevations, while smaller glaciers have higher termini. These patterns were observed in other glacier areas, namely the Alaska Bro-

oks Range (Manley, 2008), the Swiss glaciers (Kääb *et al.*, 2002), the Cordillera Blanca (Racoviteanu *et al.*, 2008), and in the Piazzi-Dosdè group in the Italian Alps (Diolaiuti et al., 2011).

2. Glacier changes during 1954-2007

The Ortles-Cevedale glacierized area was 50.03 km^2 ± 0.33% in 1954 (54 glaciers), 42.84 km^2± 0.38% in 1981 (56 glaciers), 38.60 km^2± 0.28% in 1990 (57 glaciers), 32.12 km^2 ± 0.08% in 2003 (63 glaciers), and 29.29 km^2 ± 0.10% in 2007 (67 glaciers, ca. 60% of ice cover in 1954) (see Fig. 1). The number of glaciers surveyed is different in the five data sets, due either to unreliable detection of some glaciers in the aerial photos (e.g. arising from the effects of cloud and/or snow cover), or to the disappearance of some glaciers. Although the Ortles-Cevedale glaciers generally underwent losses in area (losing the largest part of their tongues), their number increased. This is caused by fragmentation of previous larger glaciers, which generates smaller ones, and is typical of the ongoing deglaciation phase. A similar behavior was reported, for example, by Knoll and Kerschner (2009) for the South Tyrolean glaciers (Eastern Alps), where more than 50 smaller glaciers were derived from the disintegration of previously larger ones, and by Diolaiuti et al. (2011) for glaciers in the Dosdè-Piazzi group (Lombardy, Italy). In order to evaluate the area changes of Ortles-Cevedale glaciers, only the surface coverage of glaciers present in all the data sets were compared. The records for 1954, 1981, 1990, 2003 and 2007 were considered, which allowed evaluation of the evolution of 43 glaciers. The 43 glaciers thus analyzed covered an area of 48.70 km^2 ± 0.40% in 1954, 42.16 km^2 ± 0.39% in 1981, 38.23 km^2 ± 0.28% in 1990, 32.05 km^2 ± 0.08% in 2003 and 29.27 km2 ± 0.10% in 2007. The area change between 2007 and 1954 was -19.43 km^2 ± 1.2% (-40% of the area coverage in 1954), with the fastest rate of change in the later time period. In fact, the mean estimated rate is -0.69 km^2/year during 2003–2007, against -0.48 km^2/year during 1990-2003, -0.44 km^2/year during 1981-1990, and -0.24 km^2/year during 1954-1981.
These results are in agreement with findings of other authors for different Alpine glacierized sectors (Paul et al., 2004; Diolaiuti et al., 2011; 2012a,b) and suggest a general acceleration of alpine glacier shrinkage.

See also:
D'Agata C., C. D'Agata, D. Bocchiola, D. Maragno, C. Smiraglia, G. A. Diolaiuti (on line first) Glacier shrinkage driven by climate change in The Ortles-Cevedale group (Stelvio National Park, Lombardy, Italian Alps) during half a century (1954-2007). Theoretical Applied Climatology *http://link.springer.com/article/10.1007/s00704-013-0938-5*

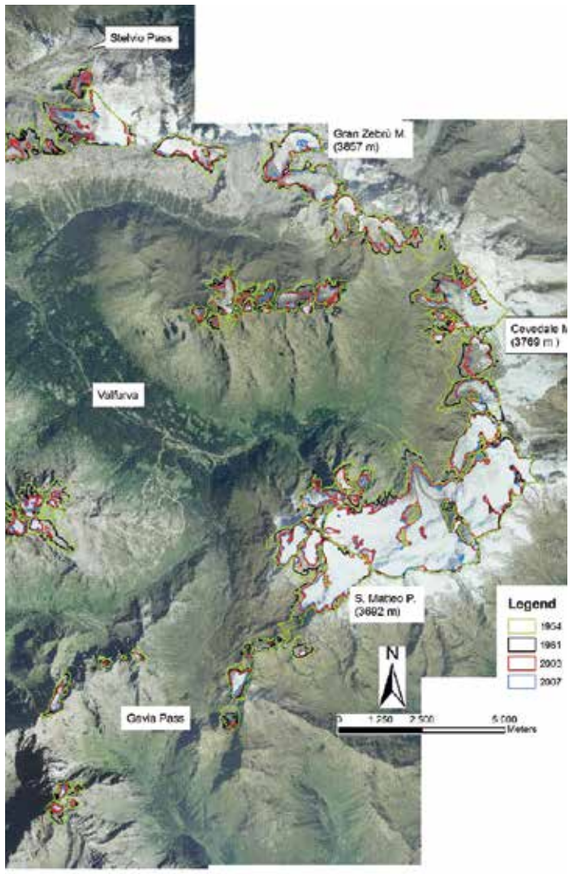

Fig. 1 - The Ortles-Cevedale glaciers. Light green indicates the 1954 glacier boundaries. Dark blue marks the 1981 limits, while red and light blue show the 2003 and the 2007 glacier limits, respectively. The base layer is the 2007 orthophoto (Flight Terraitaly IT2000 surveyed in 2007 by Blom CGR).

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Water resources
Climate change impact on water resources of Mt Everest

The SHARE Project aims to assure a continuous environmental monitoring in mountain sites through long-term, high quality data series and to contribute to the study of climate change impacts. Within this framework, we refer the main findings of research focusing on climate drivers of change and observed impacts on rivers and lakes.
The current uncertainties on Himalayan deglaciation are mainly attributed to the lack of meteorological measurements. The Pyramid meteorological observatory (5050 m a.s.l.) is located at the highest altitude at which weather data have ever been gathered in the region. The collected time series represent a valuable dataset for investigating climate change in southern-central Himalaya. We developed a monthly temperature and precipitation reconstruction for the last twenty years (1994-2013) using all the available in-situ measurements and applying quantile mapping and expectation maximization techniques. We observed an increase of +0.53±0.12°C (significance 90%), comparable to that of the Northern Hemisphere. In addition, the increasing trend occurred mainly in winter months (see Fig. 1, top). As regards precipitation, we observed a substantial decrease (about -16.2 ±1.1 mm y^{-1} of precipitation, $p<0.001$) in both winter and summer months. The main implications of these findings are as follows:

- the melting of glaciers is usually ascribable to the temperature increase during summer, while we observed a stationary trend during the warmer months;
- consequently, the role of precipitation becomes central in the climate change impact studies of the region.

Our results agree with the findings of other research groups, showing a weakening of the monsoon since the '70s. Furthermore, since 2005, the monsoon underwent a sort of intensification and shortening (see Fig. 1, centre).
Concerning the impact on river discharges, we found for the 1964-2011 period, no significant variation in Dudh Koshi River flow (3000 km2) during summer, while a decreasing trend in winter was observed.
The decrease in winter may be due to the observed reduced precipitation, while the summer stationarity is not congruent with the precipitation decrease observed also in this season.
To offset this lower input must match a rise in the summer glacial melt, although we observed that the temperature in this season is stationary.
The described scenario points out the central role of solar radiation on the entire hydrological cycle at these high elevations. It was also observed that the flow rate shows, from the '60s to today, and especially starting from the '90s, the appearance of a second peak in discharge during the monsoon period (see Fig. 1, bottom). This evidence is confirmed by the analysis of other discharge series located in the region. In the coming months, we will analyze how the observed impacts on the hydrological system can affect the socio-ecosystem and, in particular, local agriculture production.
As regards climate change impact on the water quality of Himalayan lakes, many limnological surveys of lakes located between ca. 4500 and 5500 m a.s.l. have been performed since 1992 in the Khumbu Valley. The comparison of the newly collected lake water chemical data with those collected since

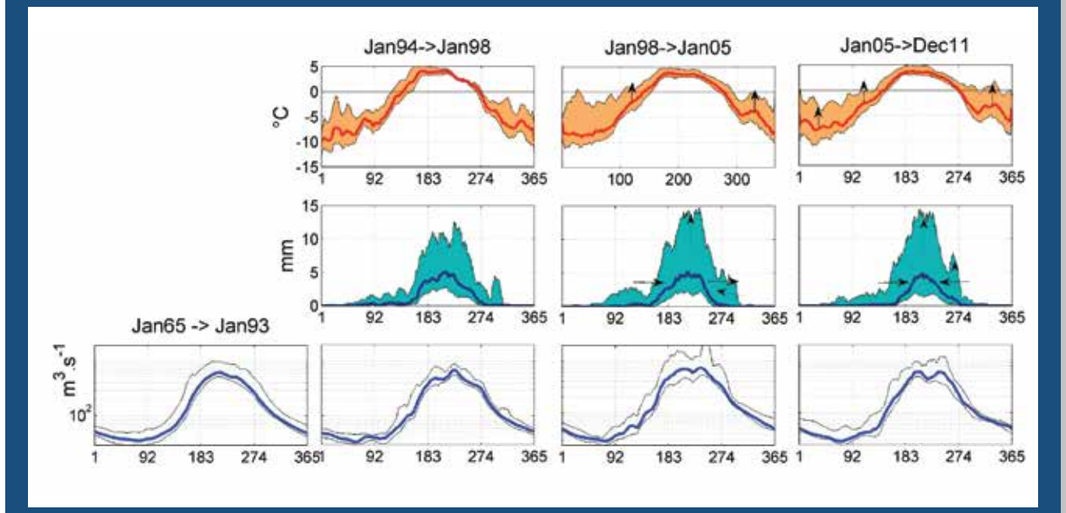
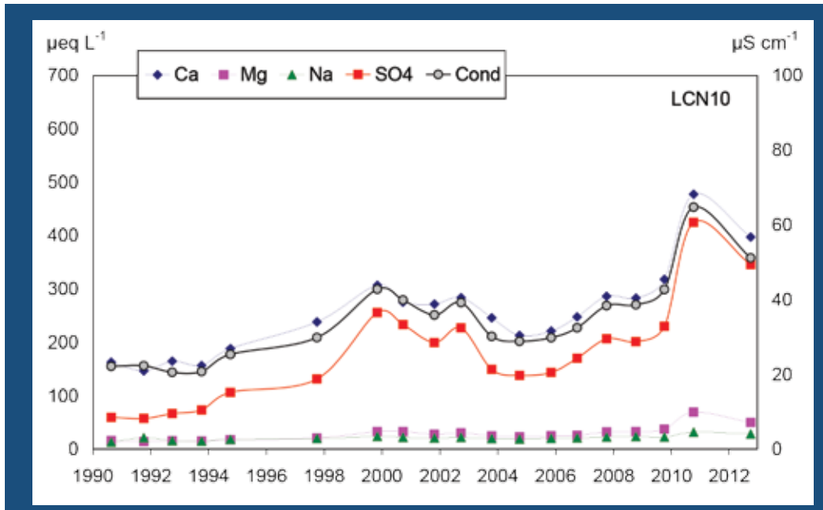


Fig. 1 - Daily values of (top) Temperature, (centre) precipitation and (bottom) discharge, averaged on each of four selected time windows. The solid line is the mean value, the extremes of associated areas the minimum and maximum, respectively. The X-axis represents the Julian days.

the '90s, has confirmed the tendency towards an increase in the water solute content in these lakes, as shown by the trend in Fig. 2. This shift in the chemistry of the lakes is occurring at a regional scale and should be ascribed to climatic factors. Conductivity (and ionic content) of the Pyramid lakes proved to be significantly correlated with air temperature (see Fig. 2).

According to hydrological studies, the Pyramid Lakes have a very short water renewal time, which would not allow significant change of water chemistry due to in-lake processes. The observed trends must be ascribed to a change in the runoff chemical composition, in turn affected by catchment processes (e.g. glacial retreat).



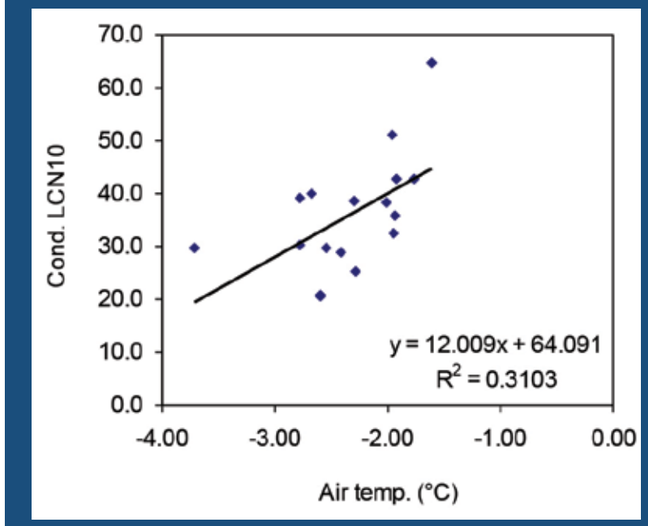


Fig. 2 – Lower Pyramid lake: trend of the major ion concentrations (up), and linear egression between annual values of air temperature recorded at the Pyramid Station and conductivity of lake water (down).

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Biodiversity

Ex situ plant conservation initiative in developing countries: Nepal as a case study

The loss of biodiversity is one of the most pressing environmental problems of the twenty-first century. To halt biodiversity loss, conservation actions both in situ (e.g. natural reserves and protected areas) and ex situ (e.g. seed banks and botanical gardens) are necessary and urgent. Global Strategy for Plant Conservation (GSPC) within the framework of the UN Convention on Biological Diversity (CBD) declares under article 9 that contracting parties shall adopt measures for ex situ conservation of components of biological diversity, preferably in the country of origin. In the world, there are different infrastructures devoted to ex situ conservation, both large (e.g. the Millennium Seed Bank, Royal Botanic Gardens, Kew, UK, that hosts accessions from all over the world) or small regional infrastructures (e.g. Lombardy Seed Bank, Italy, which hosts local flora).

Despite its small land surface (147,181 km2), Nepal is very rich in terms of biodiversity. The altitudinal gradient ranging from tropical forest (<100 m a.s.l.) to the highest peak of the Earth (Mt. Everest 8848 m a.s.l.) allows the differentiation of a very rich flora, estimated in more than 6,500 taxa of native vascular plants. Unfortunately, as in many other developing countries, wild plant diversity, as well as agro-biodiversity, are under threat from several factors. Wild plants are most threatened by land use change, deforestation, unsustainable harvesting, over-exploitation, alien invasion, and climate change. To contribute to halt the loss of plant diversity and in line with Nepal Biodiversity Strategy we initiated in 2010 the Himalayan Seed Bank (HSB) Project, as part of the scientific activities undertaken by the SHARE project, the HSB is hosted at the Nepal Academy of Science and Technology, in Lalitpur, close to Kathmandu.

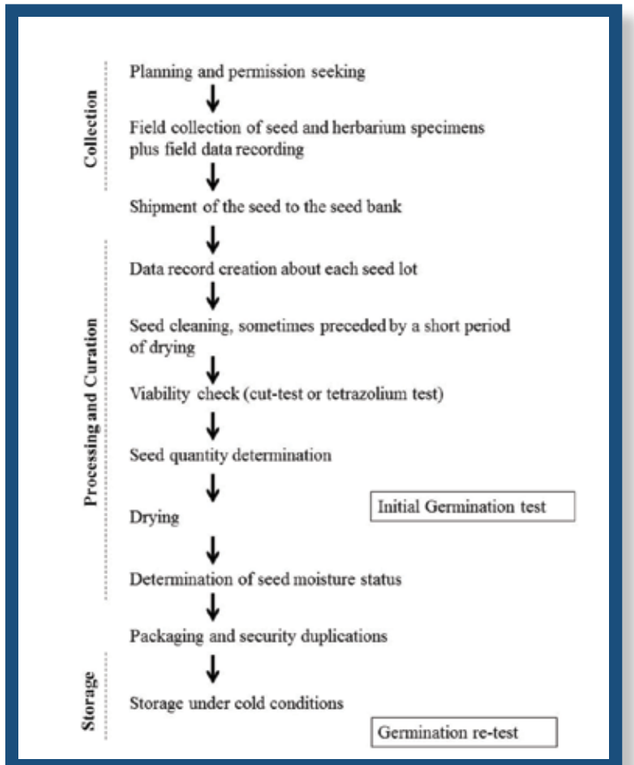

Fig. 1 - Steps to be follow to storage seed in a seed bank.

Although the ex situ conservation of biodiversity in the country of origin is ethically correct, it presents many difficulties (lack of electricity; high maintenance costs). We decided to discuss, in a sort of guidelines, the technical details useful to set up a cost-efficient, high-standard seed bank for ex situ conservation in a developing country, focusing on energy independent and fully functional small facilities.

The HSB has been provided with the basic equipment necessary in order to clean, dry and deep- freezer storage (-20°C) of seeds. However, the main difficulty faced was the lack of a continuous electricity supply system. Therefore, to guarantee an Uninterrupted Power Supply (UPS), a combination system was designed and implemented using solar systems, batteries and a diesel generator, to cope with short-term or long-term electrical interruptions. The system can provide power up to 6 Kw AC using a double inverter conversion unit. The electrical system provided by SHARE in 2013 was fully operative and no electricity interruptions occurred.

Currently, the Himalayan Seed Bank hosts at least 150 seeds lots collected in Sagarmatha National Park (Solukhumbu District, Eastern Nepal) in two field expeditions by a joint Nepalese-Italian team in 2012 and 2013. In the future, an extension is expected of the collection areas to include other mountains in the Nepalese Himalayas.

Highlight extracted from the paper: Rossi G., Orsenigo S., Dhital D., Shrestha S., Shrestha B.B., Maharjan S.R., Bhuju D.R., Panthi S., Pokharel Y.R., Verza G.P., Mondoni A. 2014. Ex situ plant conservation initiative in developing country: Nepal as a case study. Plant Biosystems (Special Issue entitled Plant ecology and conservation in international cooperation: approaches and methodologies), in press.

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Information system

SHARE GN2: first upgrade for a new system of environmental data sharing

The new version of SHARE GeoNetwork, SHARE GN2 was published during 2013. SHARE GN2 is a web platform for free access to resources regarding environmental data. It provides three basic types of services: i) a structured metadata archive (a complete description of the stations and how the data are acquired and validated), ii) free access to data and results from high-altitude environments research and projects; iil) a dedicated webGIS for geographic visualization of data collected during research.

The new interface is friendly and provide abundant information (see Fig. 1). Two simple requests are possible: metadata and data querying.

Geographic navigation is implemented and it is possible to upload maps and geographic objects and view the information about them clicking on the link (see Fig.2).

All the data described by their metadata, are accessible from the DATASET interface.

The aim is to supply a knowledge support to researchers interested in climate modelling and climate change. All data are free and explained by their metadata.

Moreover, the system is linked to the international DOI (Digital Object Identification) Foundation through the DataCite project.

Ev-K2 CNR has joined the project DataCite and has become an autonomous "Data Center" under the CRUI member (Conferenza dei Rettori delle Università Italiane) for the assignment of an unlimited number of DOI, through the DataCite platform.

The main objective of the service is to assign DOI to the data acquired by the high-altitude stations and distributed with the SHARE GN2 service. In this context, it was decided to assign a DOI to metadata relating to the data and then direct the DOI to the corresponding tab in SHARE GN2.

The DOI permits the identification of the resource of interest on the web and to access its metadata and finally the data.

Such activities demonstrate the keen interest in the importance of data sharing in terms of complete data knowledge for correct use in research programmes.

Fig. 1 - SHARE GN2 (http://geonetwork.evk2cnr.org).

Fig. 2- Geographic link to information.

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Capacity building

SERA - Smart Ecosustainable Residential Area takes the first steps towards the experimental development

The project is geographically set within Sagarmatha National Park and Buffer Zone and aims at *promoting useful strategies for sustainable development of the Khumbu Valley, through energy and environmental planning.*

After the survey on possible efficiency solutions and the selection of the best actions to be implemented, the project considered their technical/technological experimentation in a limited area. To support the experimental development stage and the creation of a repeatable pilot project, an *on-site investigation was organized at Chaurikharka* (Sagarmatha zone, Solukhumbu district, 27° 41'48" N, 86° 43' 17" E, 2660 m a.s.l.) from November 17 to December 3, 2013. The mission involved Prof. Annalisa Cogo, Dr. Eva Bernardi, Dr. Lorenza Pratali, Dr. Rosa Maria Bruno and Dr. Paolo Sdringola from Italy; Dr. Nenad Dikic from Serbia; Dr. Sanjiv Bhandari, Dr. Bikash Basyal from Nepal, and the Pyramid Laboratory technician Lakpa.

The village and its inhabitants were the focus of a cross assessment, concerning the following areas of interest:

1. Verification and check of the preliminary information about Chaurikharka village.
2. Cardiovascular and spirometry tests, including the collection of blood samples, survey on the typology of ventilation inside the buildings and the environmental air pollution (CO measurements).
3. Monitoring of Black Carbon and particulate concentration.
4. Energy and structural audit of the inspected households and of the school, in order to establish the main housing features of the village (directly performed by Perugia University).

Fig. 1 – Chaurikharka village.

Fig. 2 – Mission participants.

During the mission, overall *no. 45 households were investigated*, obtaining information about: the household and management of incomes from working activities (sufficiency or not; priority order of the yearly expenditures; willingness to make changes of their housing conditions); building (structure and plants); energy (fuel typologies and their use). Through the *direct dialogue with villagers*, additional information was collected concerning: waste management approach from SPCC; traditional crops grown by the people at local level; rough estimation of yearly income and possible access to credit; location of hydropower resources and perspectives of mains connection.

During the field mission, some *thermographic sessions* (see Fig. 3) were undertaken . Thermography, in brief, is a procedure of imaging based on a tool, the thermocamera, which measures infrared rays and converts the signals into a thermal image, representing the temperature distribution of the focused surfaces. This technique is useful, for example, to visualize energy losses, observe insulation deficiencies and imperfections, and identify air infiltrations or thermal bridges. The experimentation phase should involve also the educational community; so the last day of the field mission was used for the *survey on the school* of Chaurikharka Village Development Committee.

The housing situation in Chaurikharka was found to be slightly different, and better in some respects, compared to other villages in the northern part of the Khumbu Valley. Dwellings, lodges and also the school are built on 1 to 3 levels. Many

buildings have the traditional subdivision of inner space, i.e. stores/stables at ground level and a single room on the first floor, with the stove located in a "central" position. The structure is built mainly in wood and stone. With a few rare exceptions, the roof is constructed in corrugated galvanized iron sheets and a wood frame. The external walls are on average 50 cm thick, sometimes covered with mortar or mud, and plywood on the inside. Stoves are mainly in stone and mud, covered in metal and equipped with a hood, but without a chimney for blowing out the smoke. They are almost exclusively used for cooking. In a few cases, the stoves are in metal and have both hood and chimney. They are fed exclusively by firewood, gathered from surrounding areas in part by the inhabitants themselves and partly on commission. Some lodges have evacuated tube collectors for hot water production. Solar flat-plate panels were observed at the school hostel, but they had not worked for two years. As for electricity, most of the buildings are connected to the hydropower plant, around 5 kW, installed in the Dud Koshi river; inner lightning is usually guaranteed by Compact Fluorescent Lamps, 20 W/each. The total annual income of households was judged sufficient on its own, although in a few cases householders needed to request loans (5-10 %), mainly from other villagers, as the banks charge very high interest rates. Household expenditures are focused primarily on: children's education, food, fuel, clothing and religious practices. With the exception of a few cases, people were found to be willing to make possible changes to their housing situation, but currently they are impeded by financial constraints. On the basis of all the data collected on-site, the local context is definitely described in terms of: housing and construction standards distinctive of the village; consumption and conditions of energy supply; management of incomes from working activities; approach of the people to possible changes of their housing conditions. Such information will be extremely useful in assessing the compatibility of efficiency solutions, concerning the building sector, renewable energy development, distributed generation, etc., as alternatives to current practices. In the perspective of a possible pilot project on Carbon Credits and Housing, particular attention will be paid to the study of heating, lighting and cooking solutions, based on renewable and clean energy technologies. The purpose is to guarantee a sustainable development of the territory, combat climate change, and reduce health problems due to indoor pollution.

Fig. 3 – Thermographic assessment.

Fig. 4 – Example of traditional house.

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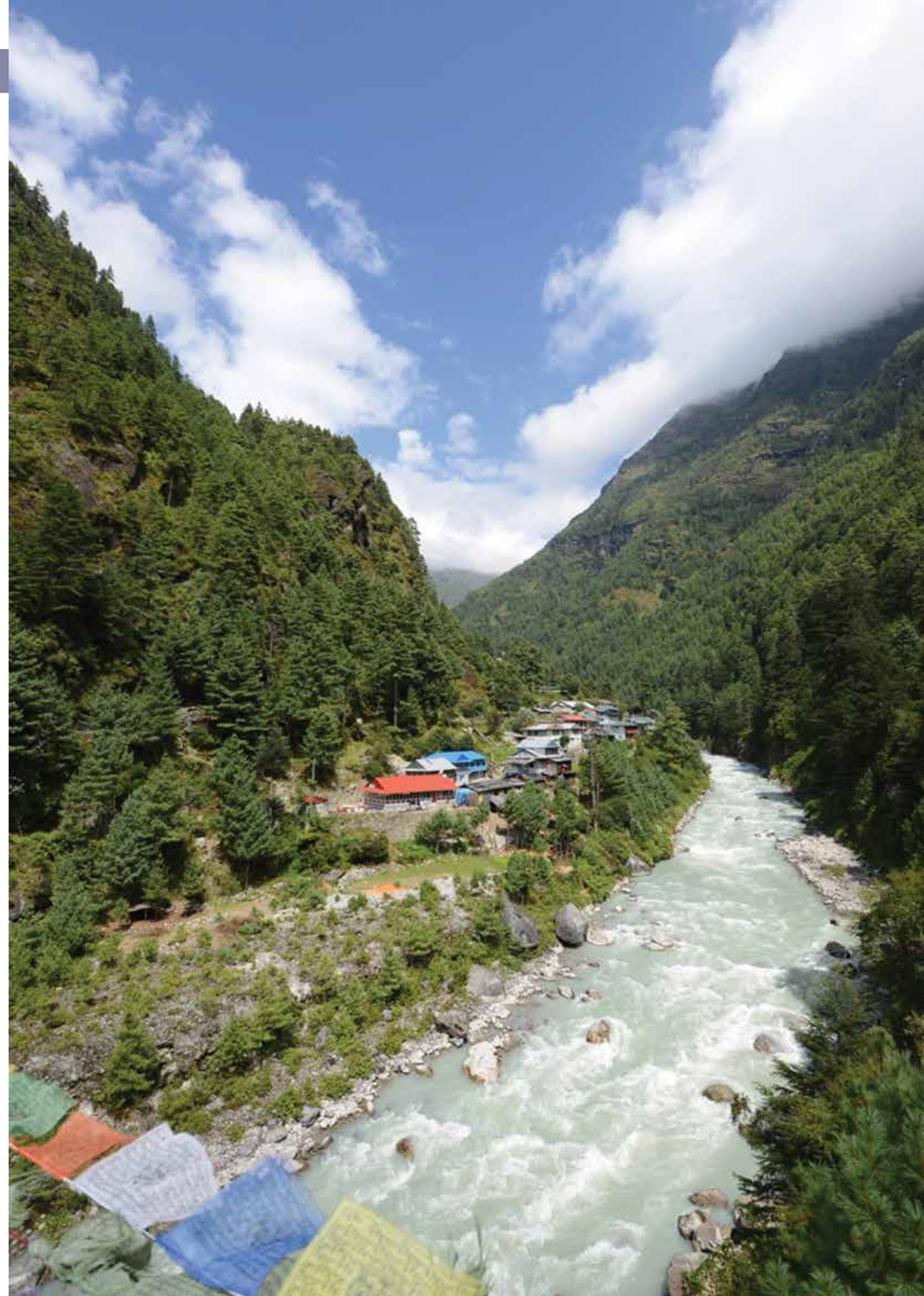

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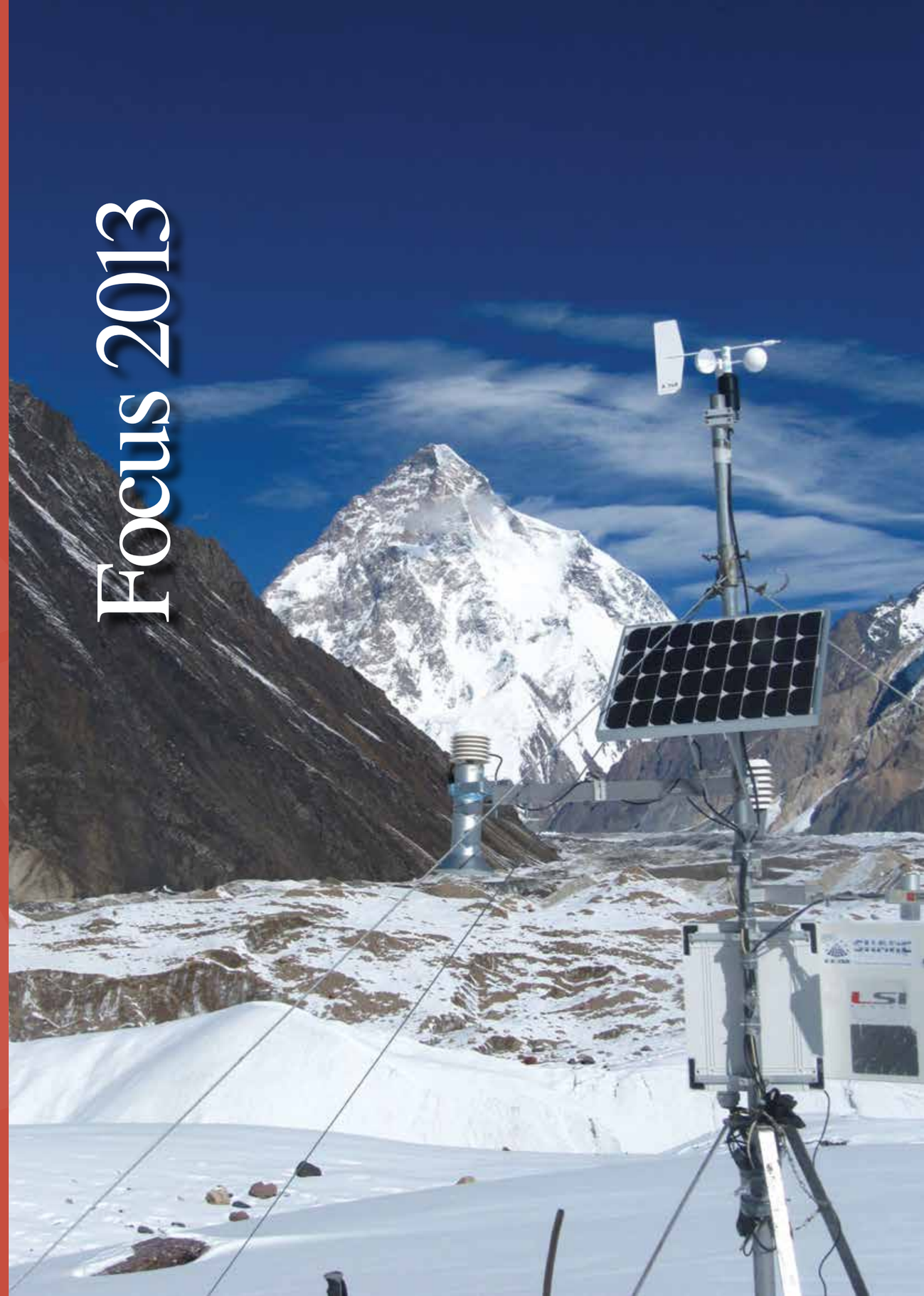

Summary Results of SHARE STELVIO PROJECT

The SHARE STELVIO project was concluded in 2013. This project, developed as part of the SHARE program, was funded by the Lombardy Region and managed by the Ev-K2-CNR Committee and FLA (Fondazione Lombardia per l'Ambiente). The Stelvio project aimed to detect and describe climate change impacts on the cryosphere and water resources of the Stelvio National Park (ca. 600 km2), the largest natural protected area of Lombardy.

During the three-year project many scientists from the CNR (ISAC, ISE and IRSA institutes) and Lombardy universities (Università degli Studi di Milano, Università Cattolica, Politecnico di Milano, Università dell'Insubria) worked together to collect, process and analyze environmental data in the glacierized sectors of the Stelvio National Park, home to large glaciers (e.g. Forni, the largest Italian valley glacier) and permafrost (i.e. permanent frozen soil and/or rock) zones. These cool resources play a fundamental role in feeding rivers, streams, ponds and lakes, and also constitute not negligible resources (freshwater and hydropower production). Moreover, tourism is also influenced by ice and snow presence, which impact on the appeal and features of mountain areas (the Stelvio National Park includes several sites listed as "Geosites").

The main results obtained are reported below:

1) Glacier shrinkage driven by climate change over half a century (1954-2007) in the Ortles-Cevedale group (Stelvio national park, Lombardy, Italian alps)

The recent evolution of a representative subset of Alpine glaciers (i.e. 43 glaciers located in the Stelvio National Park, Ortles Cevedale Group, Italy) was described by analyzing surface area changes (Fig. 1). The data base covers half a century of Alpine glacier history (from 1954 to 2007), allowing the description of glacier changes on a relatively long time window. Furthermore, the subset of Alpine glaciers chosen for the analysis are among the best-known and studied in Italy, also comprising the widest Italian valley glacier. The analysis provided area surface changes as: -19.43 km^2 ± 1.2%, ca. -40%, from 1954 to 2007. Small glaciers contributed strongly to total area loss. The area change rate has accelerated recently, with a surface reduction of ca. 8.7 % between 2003 and 2007, i.e. a mean area loss of ca. 0.7 km^2/year. The mean yearly loss over the previous periods (1954-1981, 1981-1990, and 1990-2003) were 0.2 km^2/year, 0.4 km^2/year, and 0.5 km^2/year, respectively. From a geodynamical point of view, the Ortles Cevedale group is now experiencing a transition from a glacial to a para-glacial system. Areas where until recently the main shaping and driving factors were glaciers, are now subject to the action of melting water, slope evolution, and periglacial processes. We also investigated seasonal values of key climatic variables (1951-2007), namely temperature, precipitation and snow cover in the area, to evaluate their potential effects on glacier dynamics. We found increased temperature, and decreased precipitation and snow cover, likely to have driven accelerated the glacier's shrinkage in the last three decades. More precisely, air temperatures were found to have increased mainly in spring (+2.97 °C mean increase in the time window 1981 -2007) and snow coverage turned out to have diminished (-20 cm /per year, -29 cm in spring, time window of analysis: 1971 - 2007).

Fig. 1 - A net radiometer installed at the surface of the Cevedale Glacier to sample energy fluxes in order to calculate surface albedo. Albedo data have been analyzed with respect to BC concentration values.

2) Retrieval of a 4000-year-old buried log in the Forni Glacier Valley: new data to describe the Subboreal transition on the southern side of the European Alps.

A buried log was found at 2385 m a.s.l. on the North-East-facing slope of the upper Forni Valley (Italian Alps). Using a multidisciplinary approach involving scientists from the University of Milan supported by technicians from the Stelvio National Park (Lombardy Sector), a complete characterization was performed of the log's condition and dendrochronological featuresthe stratigraphic and sedimentological aspects, and the geomorphological settings.

The log belongs to the stone pine species (Pinus cembra L.) (Fig. 2), has nearly 300 tree rings and was probably uninterruptedly buried in the deposit since the Subboreal, at least since 4201-4031 cal. yr BP (date of the outermost tree ring)

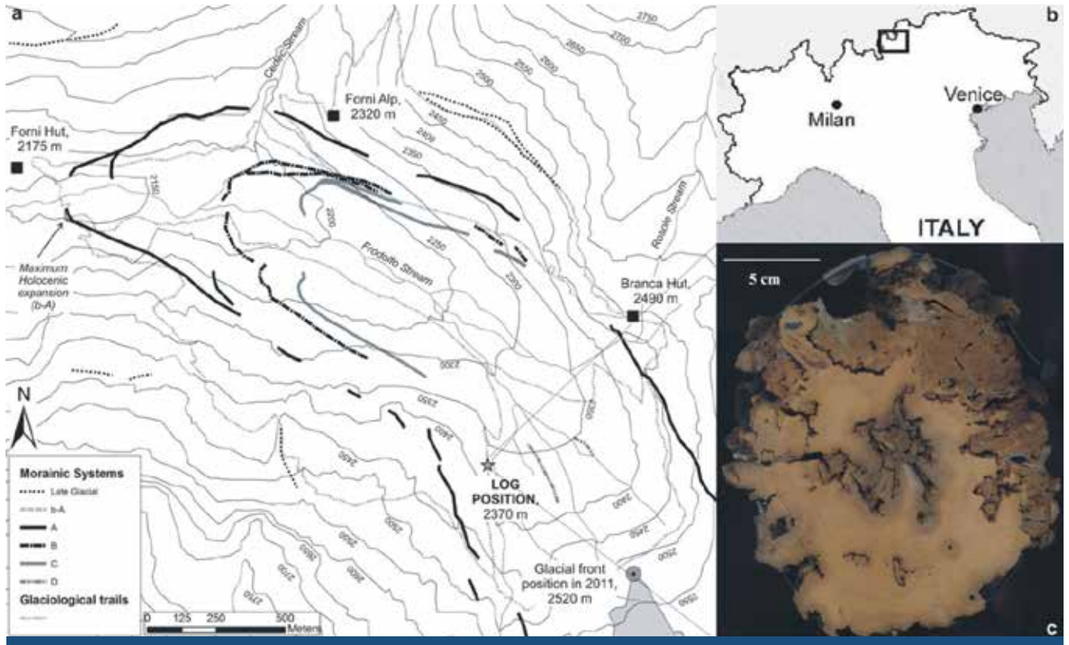

Fig. 2 - Location were was retrieved the buried log which resulted 4000 years old. The site is in the Forni Valley.

and, more recently, also under the Forni Glacier body up to the early 1960s. The analyzed pedosedimentary sequence is composed of two units, consisting of poorly weathered soil horizons. The sedimentological characteristics are compatible either with slope sediments or till deposited laterally on the lower portion of the valley slope, so it is difficult make a distinction between the two kinds of processes. However, the log reveals that during the Subboreal in the Forni Valley much older specimens of stone pine were present on the slopes, in contrast to present-day conditions, characterized only by young trees. The log's tree-ring growth rates are similar to those of stone pine trees of comparable age (growing nowadays at the treeline close to the study site) during the Little Ice Age peak. This may suggest palaeoenvironmental conditions compatible with those occurring in the mid-late Holocene, before the so-called '4000 BP Event'. Currently, there is no other information on the size of the Forni Glacier in the Subboreal, but the retrieval of the buried log and the several results obtained suggest that about 4000 years ago the glacier terminus was situated at an altitude higher than at least 2300 m a.s.l. (it is now at about 2550 m, while at the end of the Little Ice Age (ca. 1860) the tongue reached an elevation of 2100 m).

3) The deepest borehole of the Alps to investigate mountain permafrost features and conditions: -235 m into the rock at the Stelvio Pass (3000 m a.s.l.)

In the framework of the Stelvio Project, a very deep borehole at the Stelvio pass (3000 m a.s.l.) was also drilled to investigate alpine permafrost. The borehole was drilled by personnel from the Università dell'Insubria, who also managed the installation of the thermal chain to measure continuously rock temperatures from the surface down to 235 m. depth. Moreover, the scientists of the Università dell'Insubria are also processing and analyzing the acquired data. The borehole reached a record depth for the Alps and the mountain permafrost areas as well: - 235 m. To our knowledge this value is the deepest in the world for mountain permafrost studies. The temperature data acquired so far reveal frozen conditions at the borehole bottom and suggest that, by processing these thermal data, it will be possible to reconstruct the history of the Alpine climate over the past 200-300 years. Additionally, the discovery of such deep-frozen ground also impacts on the development of hydrogeological models able to describe the current water presence and circulation in the Alps. In fact, before this new borehole, the maximum permafrost thickness was supposed to be 100 m, less than 1/3rd the value found by us at the Stelvio Pass!

4) High Alpine ponds shift upwards as average temperature increases: the case of Stelvio National Park (Ortles-Cevedale mountain group, Italy) in the 1954-2007 time window

Alpine ecosystems are especially vulnerable to climate change and lake and ponds act as sentinels. We employed remote sensing technique to analyze more than 100 ponds located in the Stelvio National Park (Ortles Cevedale Group) in the time frame 1954-2007. In this Alpine sector, it was found that at lower elevations (<2500 m a.s.l.) some ponds have disappeared or have undergone surface area reduction since the Eighties. We link this impact to the increased evaporation/precipitation ratio associated with climate warming. By constrast, at higher altitudes (>2900 m a.s.l.) we observed that since the Fifties lakes have increased in size and new lakes have appeared as consequence of glacier shrinkage and retreat. However, the new lakes are of an ephemeral character. Moreover, we also analyzed the climate trends over the last century. From 1924 to 2007 the temperature increase was found to be 0.012 °C y^{-1}. In the 1981-2007 period, the temperature rose considerably with an acceleration up to three times more intense than in the previous period (1954-1981). Conversely, total precipitation over the whole period (1926-2007) does not seem to have undergone substantial changes.

Fig. 3 - A box containing instruments for the atmospheric monitoring at the Guasti Hut site (Cevedale Glacier)

Lake variations have turned out here to be a highly visible and easily measurable signal of climate change impact on the Alpine environment, as already demonstrated in other remote areas of the world. On the one hand, there is a clear need to extend this analysis to other glacierized sites of the Alps in order to obtain a regional knowledge of the phenomenon. The findings of this study make it possible to interpret the variations induced by climate change on such environments. In addition, monitoring the chemical features of the Stelvio Park freshwaters and the most sensitive groups (macroinvertebrates and diatoms) not only yields information on the quality and ecological value of these water resources, but also highlights the peculiarity of such environments, which show a high chemical variability over small areas and biotic composition changes driven by external factors, like climate change or human impacts (pollution from far and farer sites). Since high altitude lakes strongly influence the Alpine landscape, an element appealing to tourists and visitors, it is really important to continue their monitoring to detect early on changes and impacts, if any, on the biodiversity due to human presence and activities.

5) Are Black Carbon and Saharan dust present on the Lombardy Alps? New climate observations at the high altitude site of Guasti Hut (3285m a.s.l.) in the Stelvio National Park to detect BC and Saharan dust occurrence and describe their impact

The atmospheric composition at high altitutdes in the Stelvio National Park and the influence of anthropogenic and natural processes on atmospheric background concentrations were investigated by direct observations of atmospheric black carbon concentration, particle size distribution, aerosol chemical composition and ozone concentration, performed during two field campaigns (summer 2010 and 2012). More specifically, a temporary observatory (Fig. 3) was established at the "Alessandro Guasti" Hut (3285 m a.s.l.), a building located near the Cevedale Glacier, property of the Italian Alpine Club (Milan unit), where power supply and remote sensor control , including data download, were made available.

Moreover, in summer 2011, measurements of ozone and aerosol number concentration were performed at the Forni Glacier surface by means of an automatic and self-maintained monitoring system.

The atmospheric background concentrations monitored by us gave a PM_{10} mean concentration up to 2 μgm^{-3}, which can be considered a low value given the range generally covered by measurements at high altitude sites. Significant increases in PM_{10} concentrations occurred over 30% of the analyzed time (average value of increases: 10 μgm^{-3}). These events were largely (85% of the cases) driven by Saharan dust from North Africa, with a maximum peak of 29 $\mu g\ m^{-3}$ (mean value on 30 min basis) on the morning of 29 July, 2012. However, the increases in PM_{10} concentrations (15% of cases) seem also related to wind transport (valley winds) of pollutants originating from local-regional sites. During such events both BC and ozone concentrations were significantly higher than those measured in the investigated period. These elements are considered *Short Lived Climate Forcers* which are able to influence the atmospheric warming on a regional scale. The presence of meaningful concentrations of adsorbing particles (BC and dust) in the atmosphere is potentially relevant since their deposition on snow and ice reduces surface albedo, thus increasing melt magnitude and rates.

In 2012 we also performed continuous albedo measurements (by AWS) at the surface of the Cevedale Glacier, to describe albedo variability and relationships with atmospheric soot concentrations.

These activities and the results obtained underline the importance of making continuous observations at high altitude sites, especially in the Southern Alps, an area exposed to the Po Valley pollution export and very poorly known from this point of view. Guasti Hut represents a suitable location for collecting data to describe processes driven by climate change and impacting on the cryosphere, freshwater and mountain biodiversity.

6) Future changes of Lombardy glaciers? Some modeling approaches to forecast their evolution

The scientists of the SHARE STELVIO team evaluated the

hydrological budget in the glacierized areas of the Stelvio National Park and produced output scenarios of temperatures and precipitation, with a particular focus on the Forni Glacier zone.
To achieve these objectives, they evaluated the reliability of liquid and solid precipitation obtained for the Stelvio Park area from EC-Earth and ECHAM6 (IPCC, AR5) models, and calculated the downscaling parameters. They also developed a mono-dimensional model to describe the Forni Glacier flow and to forecast the glacier evolution up to 2099 and thusthe expected melt-water discharges.
The flow model was calibrated and validated using the large available dataset of field and measured data (i.e.: terminus fluctuations over the last century, surface velocity data and Equilibrium Line Altitude values over the last decade, ice thickness changes of the glacier tongue over the last half a century). As regards the melt-water discharge, data from some automatic hydrometers installed in 2011, and then continuously running, were also available, thus permitting the assessment of the reliability of the hydrological outputs from our model.
Our projections suggest that Forni Glacier will greatly decrease in thickness by 2030. This reduction will impact the glacier up to 3000 m a.s.l., thus reducing the ice volume, which is expected to be only the 25-30% of the present value. Moreover, by the end of this century (2099), the glacier could experience a further reduction, declining to a volume equal to 5-10% of the present value. These projections, obtained considering the available climate scenarios, suggest that climate changes of moderate magnitude could impact tremendously on the Alpine cryosphere and freshwater, thus changing forever the landscape of our mountains.

7) The first book of the trilogy devoted to disseminating the SHARE STELVIO outputs and results: Un mondo d'acqua in alta quota - Le acque del Parco Nazionale dello Stelvio
To complete our work, a popular book was produced. It addresses students, teachers, tourists and people visiting Alpine mountain sites and it describes the park's freshwaters. The book (*Un mondo d'acqua in alta quota - Le acque del Parco Nazionale dello Stelvio: un laboratorio a cielo aperto per lo studio dei cambiamenti climatici*) is available on the web page of EvK2-CNR (*http://www.evk2cnr.org/cms/files/evk2cnr.org/Un%20mondo%20d'acqua%20in%20alta%20quota.pdf*) and the first hard copies were officially given to Lombardy Region authorities and Stelvio Park managers during the past International Mountain Day (11 December, 2013) in the framework of the SHARE STELVIO final workshop held at the University of Milan. The book is the first of a trilogy devoted to disseminating to as wide as possible readership the results of the SHARE STELVIO project, describing the features and characteristics of Air, Water and Ice in the Stelvio National Park.
The next volume will focus on the park's cryosphere (glaciers and permafrost) and will be ready by the end of spring, 2014. The last one will be devoted to describing the Atmospheric studies performed by us and will be available by the end of the year.
Such materials will permit all Lombardy citizens to understand the environmental resources of the Stelvio National Park and their recent changes driven by climate change, thus also improving the management and protection of this large, fragile natural area.

8) Evaluating tourists' perception of environmental changes as a contribution to managing natural resources in glaciarized areas : a case study of the Forni Glacier (Stelvio National Park, Italy)
Climate change effects are clearly noticeable above the timberline, where glacier and permafrost processes and mass movements drive surface evolution. In particular, cryosphere shrinkage is deeply changing the features and characteristics of several glacierized mountain areas of the world, and these modifications can also affect the landscape perception of tourists and mountaineers.
At the same time, glacier retreat is increasing the interest of tourists and visitors in areas witnessing clear climate change impacts. In addition, cryosphere shrinkage can impact the touristic appeal of mountain territories which, diminishing their ice and snow coverage, are also losing part of their aesthetic value.
To promote glacierized areas in a changing climate and to prepare exhaustive and up-to-date proposals for sustainable tourism, it is important to deepen our knowledge about landscape perception of tourists and mountaineers and their awareness of ongoing environmental modifications. Here, we present the results of a pilot study performed in summer 2009 on a representative glacierized area of the Alps, the Forni Valley (Stelvio National Park, Lombardy, Italy), a valley shaped by the Forni, the largest Italian valley glacier. During summer 2009 in the framework of the SHARE STELVIO project, tourists visiting the Forni Valley were given a questionnaire. This study aimed both describe the characteristics of tourists and mountaineers visiting this Alpine zone in summer, and evaluate their landscape perception and ability to recognize climate change impacts and signs.
Our results suggest that the dissemination strategies in a natural protected area have to take into account not only the main landscape features, but also the sites where the information will be given. In particular, the specificities of the huts located in the area (e.g. different accessibility and whether of not they part of mountaineering network, like the one of the Italian Alpine Club (CAI)) must all be taken into account. Such factors can select the visiting people, thus requiring different dissemination strategies. Differences in the viewpoints from where visitors can observe and understand landscape have also to be considered.
Additionally, in a protected area where climate change effects are evident, the dissemination strategies should be developed in close cooperation with scientists who are analyzing the area and with the support of periodic interviews, which could be very useful in assessing the effectiveness of the dissemination methods adopted.
Last but not least, the questionnaire should be standardized and distributed in several protected areas, thus permitting useful comparisons and the identification of common solutions for sharing in a friendly way the scientific knowledge about climate change and its environmental and landscape effects.

Summary Results of SHARE PAPRIKA PROJECT

June 2013 saw the end of the three-year research project SHARE-PAPRIKA, devoted to determining the state of glaciers and water resources in the Hindu-Kush Karakoram Himalaya region (HKKH) and to estimating their conditions in the coming decades in different climate change scenarios.

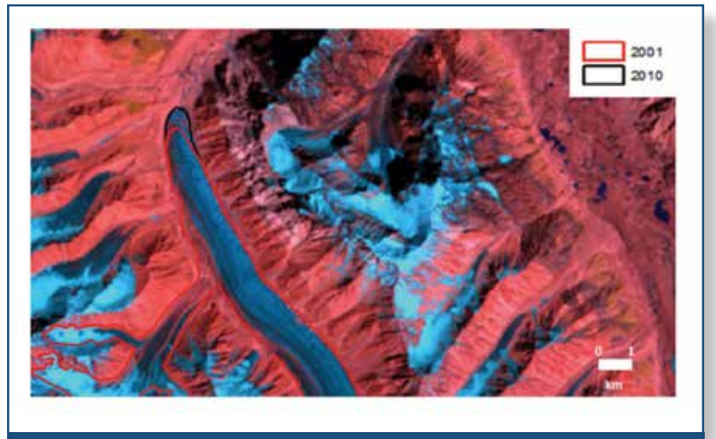

Fig. 1 - Example of an advancing glacier terminus near the Braldu glacier from 2001-2010.

PAPRIKA included the twin national projects PAPRIKA-Italy and PAPRIKA-France, having two different focus areas in the HKKH region in terms of data collection and modeling. The main focus area of PAPRIKA-Italy was the Karakoram region, in particular the Baltoro glacier and the upper Indus basin in northern Pakistan. Another focus of PAPRIKA-Italy was the Changri Nup glacier area, lying on a lateral valley of the Khumbu region in Nepal, the principal area where PAPRIKA-France was active. A fruitful collaboration between PAPRIKA-Italy and PAPRIKA-France took place during these three years of activity, especially in the Khumbu region, to share and discuss the research results in terms of modeling activity and information extracted from the experimental data. A particularly important issue requiring a joint effort was to quantify the differences possibly existing between the behaviour of the retreating glaciers in eastern Himalaya and those of the Karakoram, whose response is still largely unknown.

During three-year project many scientists from National and International Research Centers and Universities (ISAC - CNR, ISE – CNR, Polytechnic of Milan, University of Milan, Bavarian Academy of Sciences and Humanity, TU Delft, International Centre for Theoretical Physics, National Institute of Geophysics and Volcanology, EV-K2-CNR) worked together in order to reach the final objective of the project.

In particular, the main goals of Paprika-Italy, both scientific and targeted to address societal challenges and needs, were:

• Obtain a **quantitative assessment** of the current state of the **atmospheric composition and circulation**; **aerosol** load, deposition and chemical properties; **glacier status**, mass/energy balance and flow estimates; hydrologic characteristics, including **water quantity and quality**, in the two study areas, with an enhanced observational effort in the Baltoro glacier region.

• Provide an ensemble of **integrated modeling tools**, based and validated on field and remotely sensed data, **to obtain quantitative and reliable estimates of water availability and climate change impacts** on agriculture, environment and ecosystems in the coming decades (2010-2050).

• Develop strategies for **capacity building, dissemination and information transfer to policy makers**, in collaboration with the SEED (Social, Economic, Environmental Development of Central Karakorum National Park (CKNP) and Buffer Zone) project.

Following these targets, the PAPRIKA-Italy activities were structured into four main themes - Observations, Modeling, Impacts, and Capacity building and dissemination - in turn organized in several specific work packages. Here we provide an overview of the top results obtained by PAPRIKA-Italy.

1) A glacier inventory for the Central Karakoram National Park (CKNP)
The Central Karakoram Nation Park is a recently (2009) established protected natural area in the Karakoram region. The park area occupies ca. 13 000 km^2, and roughly 40% of it is covered by ice. An analysis of the satellite data performed during PAPRIKA allowed the retrieval of information on the variations, during the years 2001-2010, of the ice-covered areas, supra-glacial debris coverage, and snow cover in the CKNP area, to draw up an up-to-date inventory of glaciers and their characteristics and to better understand the behaviour of the cryosphere system, and its changes in the region. The CKNP glacier inventory highlighted that glaciers in this area have been quite stable in the last decade, confirming the exceptional and anomalous behaviour of the Karakoram glaciers. 700 glaciers in the CKNP area, in fact, were analyzed, for which no significant area change between 2001 and 2010 was detected, owing to the interplay of meteorological conditions (the increase in winter precipitation and decrease in summer temperatures, both contributing to snow and ice preservation) and surface glacier characteristics. The analysis of satellite images showed that, in the thaw season, an increase in the snow-covered area at high elevations (~5500 m a.s.l.) protected glaciers from melting, since fresh snow, with its high albedo, reflects the incoming solar radiation. At lower altitudes, where snow is seldom present and ablation takes place making the glaciers vulnerable to melting, another factor comes into play and contributes to glacier stability: the presence and thickness of supra-glacial debris cover. All these factors together are thought to be responsible for pushing the CKNP glacier mass balance towards positive or neutral values. An example of an advanced glacier terminus in 2010 relative to 2001 is provided in Figure 1.

Fig. 2 - Picture taken during the hydrological campaign at Shigar Bridge.

However, it is worth noting that much of the CKNP and Karakoram glacier behaviour has still to be understood and that, although satellite measurements are a valuable and precious source of information, the availability of in-situ snow depth data at the highest altitude accumulation areas would considerably improve our knowledge of the Karakoram cryosphere.

2) Hydrological observations in the upper Indus basin: water quantity and water quality

During PAPRIKA-Italy, specific activities were performed to monitorg the quantity and quality of water originating from the Karakoram glaciers. In fact, ice and snow melting due to warming temperatures may lead not only to changes in discharge activity but also to an increase in soil microbial activity and mineral weathering rates, causing enhanced nutrient and solute fluxes to mountain lakes and streams. Four dedicated hydrological campaigns were performed to assess the quantity and quality of water, in April and July 2011, May 2012 and April 2013. In particular, two permanent hydrometric stations were installed at two key sites, the Shigar Bridge and Paiju (see Figure 2), providing continuous measurements of water level and, hence, discharge activity, and of water chemistry. The analysis of the three-year discharge data from the two hydrometric stations provided information on the hydrological behaviour of the Shigar basin, also useful for calibrating the hydrological model implemented during the project. In terms of water chemistry, our analyses indicated overall a good quality of surface waters in the study area, with low levels of nutrient and organic substances, very low concentrations (mostly below the detection limit of the measurement device) of toxic metals such as Cu, Cr, Ni, Cd and Pb. Water chemistry proved to be mainly controlled by land cover (bedrock lithology) and hydrological factors (dilution/concentration processes in relation to the amount of water). However, a contribution of atmospheric deposition processes to the nitrogen content of water samples (mainly as NO_3) could not be excluded: nitrate, in fact, is usually absent in surface waters at remote locations, where direct anthropogenic inputs can be excluded.

3) Quantitative assessment of atmospheric composition in the Baltoro glacier area and installation of a permanent climate station in Northern Pakistan

The current state of atmospheric composition variability in the Baltoro glacier region, both in terms of pollutant-gases and aerosol particles and their relationship with atmospheric circulation, was assessed during the project to obtain information on short- and long-lived climate forcing factors in this remote mountain area. To this end, two dedicated experimental campaigns were undertaken at Urdukas (35°43'N, 76°17'E, 3926 m a.s.l.) and Askole (35°40'N, 75°48'E, 3015 m a.s.l.) in summer 2011 and 2012, respectively. Akole is a village (about 300 inhabitants) located in the Braldu valley on the route to the Baltoro Glacier, while Urdukas is more than 40 km from Askole and is located along the Baltoro Glacier; both sites are suitable for investigating the transport processes occurring along the valley and the possible influence of local-regional anthropogenic emissions on the atmospheric composition of this pristine environment.

During summer 2011, aerosol measurements at Urdukas revealed relatively low PM_{10} values on average (7.7 ± 7.1 μg/m³), with episodic enhancements in the aerosol load (an event of 300 μg/m³ was detected) due to transport of mineral dust from the Taklimakan desert.

The experimental campaign carried out at Askole in summer 2012, indicated that domestic combustion could represent a possible systematic source of contamination in the valley. Excluding these local contamination events, we found that a mountain thermal wind regime dominates the diurnal variability of particle number concentration (Np), Ozone (O_3) and Carbon Dioxide (CO_2). Nevertheless, the variability of the observed climate forcing factors appeared to be dominated by day-to-day changes. Part of the day-to-day atmospheric composition variability can be ascribed to synoptic circulation variability. In particular, the observed low O_3 and high CO_2 values were linked to possible air-mass transport from South Asia and the Taklamakan desert area. Long-range transport from South Asia was found to be a major source of fine particles in the Karakoram, while higher O_3 values were mostly tagged with air-masses possibly coming from the free troposphere.

In addition to these field campaigns, a permanent climate station, powered by solar energy, was installed in summer 2013 in the Pakistani Deosai National Park, at 4200 m a.s.l., in collaboration with the Water and Power Development Authority (WAPDA) of Pakistan, the Pakistan Meteorological Department (PMD) and in synergy with SHARE-ABC. The station has been operating since September 2013 (a battery failure in November 2013 caused the suspension of measurements for about a month), measuring pollutant/climate-altering compounds (ozone, black carbon, aerosol size distribution) and standard meteorological parameters.

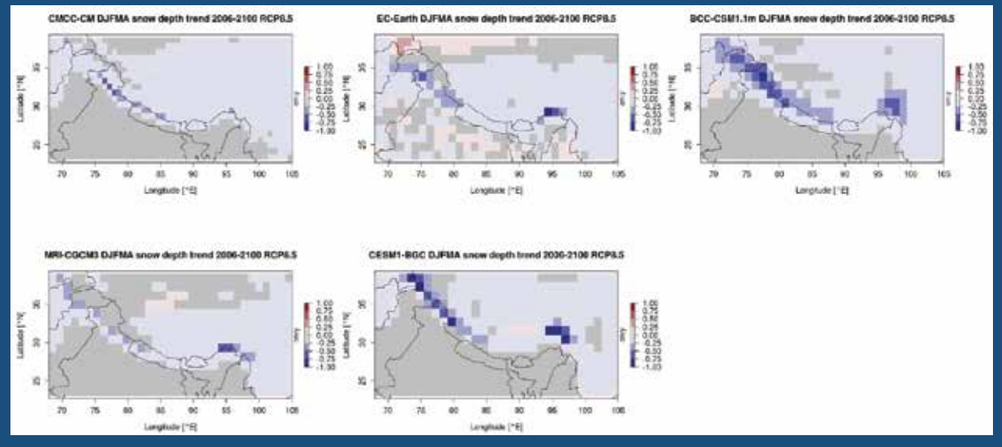

Fig. 3 - Projections of winter snow depth trend over 2006-2100 provided by five state-of-the-art global climate models (from Terzago, S., J. von Hardenberg, E. Palazzi, A. Provenzale, Snow depth changes in the Hindu-Kush Karakoram Himalaya from CMIP5 Global Climate Models, submitted to the Journal of Hydrometeorology)

4) From climate projections in the HKKH region to water availability scenarios

Reliable estimates of water availability in future decades in the HKKH region required the implementation and use of a modeling chain, taking the output of Global Climate Models (GCMs) to provide climate scenarios at a coarse resolution, downscaling the GCM projections to provide a higher-resolution estimate of the climatic conditions, and finally running a hydrological model to simulate the hydrological response at the basin scales. Downscaling of the GCM outputs, performed using different techniques, is a necessary step to obtain climatic information at the high spatial and temporal resolutions required for running hydrological and impact models and, hence, making projections of the climate change effects at the local scale.

During PAPRIKA-Italy we analysed the output of the last generation GCMs, the same used in the fifth IPCC assessment report (AR5 2013), to provide climate projections for the whole HKKH region under different emission scenario hypotheses. We considered climatic variables such as temperature, precipitation and snow depth and, after validating the models against observed data in the historical period, we analyzed the climate picture provided by the models for the twenty-first century.

The GCM projections clearly showed, for example, positive summer precipitation changes in the Karakoram and in the eastern Himalaya in both the near (2021-2050) and far (2071-2100) future, with respect to a historical baseline (1971-2000). This is consistent with a gradually increasing trend in summer precipitation throughout the twenty-first century found in these regions. In general, the GCM projections of winter precipitation changes turned out to be more scattered than summer projections (in some cases, half of the models gave positive precipitation changes and the other half negative changes in winter), with a slight prevalence towards drier future conditions, except in the Karakoram region, where positive winter precipitation changes in the nearest future with respect to the present are projected.

Future projections of snow depth indicated a general decrease throughout the winter season in both Karakoram and Himalaya (see Figure 3), strongest in the most extreme emission scenario. For the Himalaya region, in particular, the models indicated an expected shift in the snow depth maximum from March to February, resulting in an earlier spring snow melt and a consequent shift in the timing of water discharge.

A glacio-hydrological model, driven by high-resolution climate scenarios obtained after downscaling the GCM projection outputs, was run to investigate future ablation flows from the Shigar river, a glacierized watershed in the Karakoram Mountains, and provide a range of possibilities for the expected future changes in different components of the hydrological cycle in this catchment.

Our hydrological projections for the Shigar basin indicated a strong decrease in both ice-covered areas (up to -45% in the most extreme emission scenario) and ice volume (up to -91%) from mid-century onwards.

Consistently, a negative trend in the in-stream flows and discharge was projected for the second half of the century, which is opposite to the trend projected for the first half of the century, where the hydrological model simulations indicated an increasing in-stream flow trend, in a range from +5% to +25% depending on the emission scenario considered.

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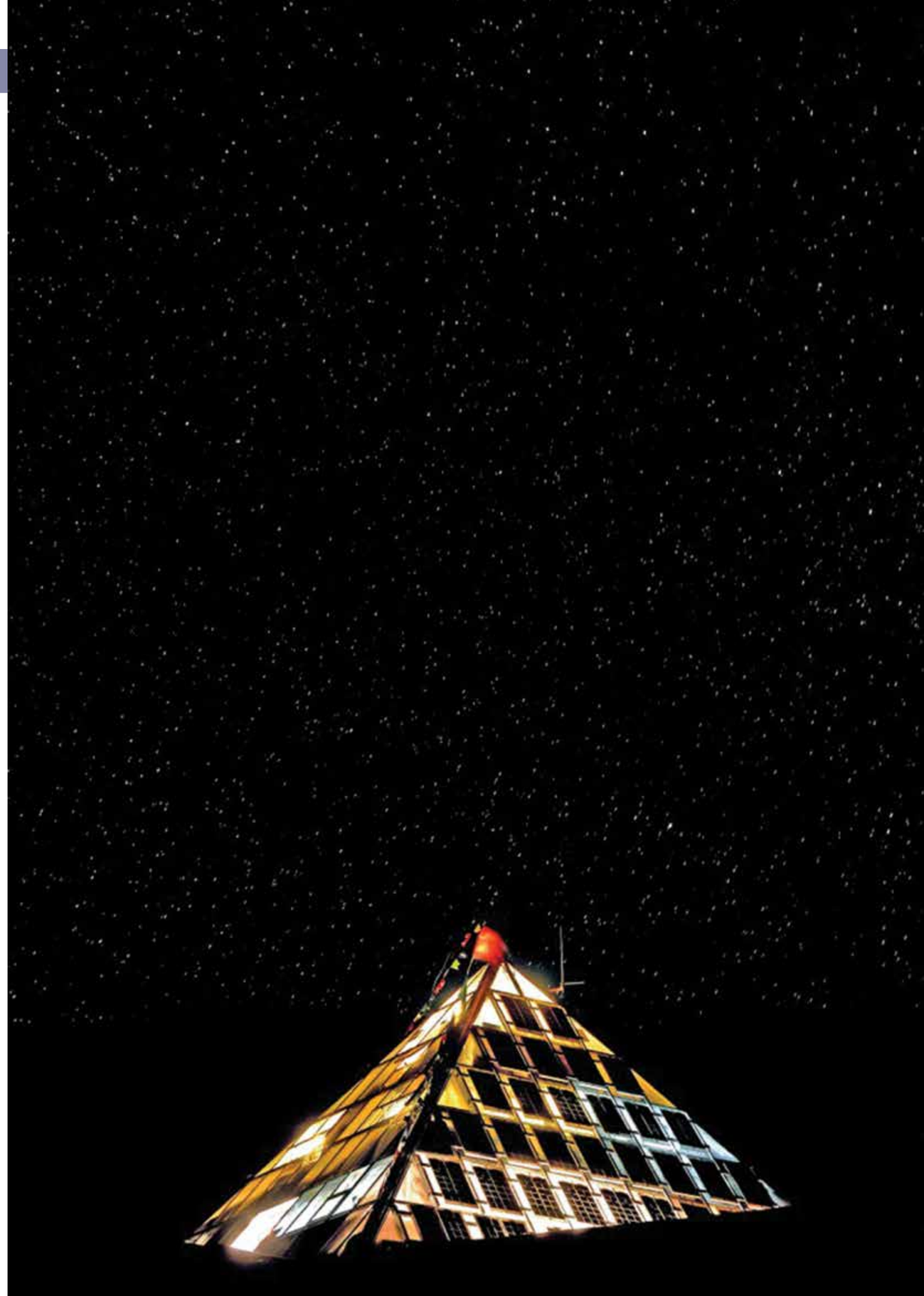

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