Project of Strategic Interest NEXTDATA

Scientific Report for the reference period **01/01/2012-31/12/2012**

WP 1.4 - Environment and climate data from ice cores (Resp. Valter Maggi, Univ. Milano Bicocca)

Partners: UNIMIB, URT Ev-K2-CNR

1. Scheduled activities, expected results and Milestones

Glaciers located in reservoirs where the average annual temperatures are substantially negative become formidable archives of climatic and environmental information. Over the past 150 years there has been a continuous and inexorable retreat of these glaciers with losses from 30% to 70% of the total volume. Anthropogenic influences amplify this effect and lead to the need to protect this information, which, year after year, is destroyed. Given the impossibility of protecting entire glaciers, the objective is to recover and store ice cores from the most important extra-polar glaciers on the planet. In the glaciers that have an easier logistics or where other project activities are already planned (e.g. in the Himalaya and Karakoram) radar measurement of the reservoirs will be started in order to define their thickness, their internal coating and the feasibility of drilling. After collection of the data, if all the necessary information will be available, it will be possible to start drilling operations, both pilot drillings and drilling down to the bedrock.

Milestones:

M2.3.1 (PM6): Definition of field activity procedures.

M2.3.2 (PM12): List of drillable glaciers and planning of field activities.

2. Deliverables expected for the reference period

D1.4.1 (PM12): Report of the field activities and drilling sites selection.

3. Activities which have been actually conducted during the reference period

3.1 Research activities

In addition to the tasks planned for the first year in the Executive Plan, which included the definition of field activities and the selection of the sampling sites, we performed an ice core drilling mission on the Colle del Lys (Valle d'Aosta), including storage of ice cores. This has allowed to test directly in the field the logistics, the techniques and the management of ice coring on a remote glacier in preparation of similar activities in

remote areas with greater logistical difficulties. The sites chosen for ice core drilling need to meet many parameters in order to allow the reconstruction of climate and environmental features; of these at least two are essential: 1) the presence of a basically flat topography that may correspond to accumulation basins with plateau or saddle geometry; the Colle del Lys falls into this category, as it is a saddle in the area between the accumulation basin of Lys Glacier and Gorner Glacier (Switzerland); 2) mean annual temperatures need to be low enough to reduce or avoid surface melting (Haeberli and Alean., 1985). Alpine areas with glaciers that meet both requirements are few, usually located in the mid-western part of the chain. Among them, the best ones are the Colle del Lys and Colle Gnifetti, in the Monte Rosa and the Col du Dome, on the French side of Mont Blanc (all in Valle d'Aosta). Drilling sites with high accumulation rates permit to determine changes at a seasonal scale and to effectively compare the resulting records with climatic data from weather stations and global-to-local scale modelling. It is important to choose a reliable topography, with a surface as flat as possible and without important ice movements. This selection will be performed using measurements by aerial or satellite images (in collaboration with WP 2.4) and radar surveys (of which part has already been completed). The sites also need to be located at altitudes high enough to reduce melting. Some sites which have been evaluated are a saddle close to the Breithhorn Mnt at 3700 m and the Pian di Neve (3200-3400m) in the Adamello group, both below 4000 m.

The ice core site selection is based on the need to have a sufficiently high temporal resolution to be able to obtain a closer comparison with climatic data from weather stations and models. It is clear that the high accumulation of Colle del Lys (from 2 to 6 meters of snow per year, 1 to 3 m w.e), on the one hand giving the possibility of resolving the seasons (summer and winter), is also responsible for a shorter duration of the time records (about 100 years). In the Alpine area, only sites located generally over 4000 m above sea level, where average annual temperatures are generally lower than -10 ° C, are suitable for ice core activities. The Colle del Lys is the best Alpine site with these characteristics. The choice of the ice core drilling site was also carried out using data from radar measurements made in previous projects. In particular, the drilling at the Colle del Lys has produced a 32 m borehole with ice cores of 8 mm in diameter, allowing also for the sampling of chips for low contamination analysis and establishing the procedures for drilling in mountainous areas. The field activities have allowed to test the equipment and to determine the critical points of the drilling system. The ice core obtained at the Colle del Lys was logged for visual stratigraphy, where some ice lenses thicker than 10 cm were observed, and it was measured to obtain a density profile. The density analysis indicated that the first 11 m of the core are affected by packing processes which lead to very scattered data, while the following 21 m have a more regularly increasing density, associated with sintering processes, up to the maximum value of 0.76 g/cm^3 at the bottom of the core. To evaluate the close-off depth, a linear correlation revealed that the value 0.85 g/cm^3 is estimated to be at 44-46 m depth. Using the density profile, a water equivalent depth was calculated, and using the annual accumulation rates obtained in previous ice cores a depth-age relationship was calculated. For the upper 32 m, the estimated age at the core bottom is between 1994 and 2000, while for the entire glacier, estimated to be about 120 m deep, the bottom age is estimated to be in the period 1910-1930. In collaboration with WP 2.3, three glaciers for possible ice coring were identified. The Colle Gnifetti at 4550 m asl (Valle d'Aosta, Italy) in the European Alps, a location in the accumulation basin of the Baltoro Glacier (6700 m asl), close to the Gasherbroun I Mount in the Pakistan Karakoram and the ChoYou Glacier, at 7000 m asl, in the Nepal Himalaya. Because of the different logistic and working difficulties, the detailed drilling strategies for the individual ice cores will be evaluated also by dedicated field surveys.

The WP1.4 activities have sinergies with other international initiatives such as SHARE-Ev-K2-CNR, , IPICS 2K Array (International Partnership in Ice Core Science - Network of ice core climate and climate forcing records for the last two millennia) and HIMICE, a new french perforation project in the Himalaya.

3.2 Applications; technological and computational aspects

In the first year, a test of the logistics of setting up a remote camp on a glacier was performed at the Colle del Lys, providing insights for the future drilling activities in the Himalaya and Karakoram. Additionally, the possibility to use solar panels for electricity production at high altitude was confirmed. This part of project permits to improve energy production and storage, through new high performance batteries.

3.3 Formation

During the activities at the Colle del Lys, two technicians from Nepal and Pakistan were hosted, in order to provide them with a training on the technical and logistical aspects of ice drilling. This has allowed us to build an initial working group for future activities in the Himalaya and Karakoram. In this perspective 3 PhD grants have been activated at the Doctorate School of Environmental Sciences, University of Milan-Bicocca. The three grants were planned according to the needs of the two WP's of UNIMIB working in NEXDATA (WP 1.4 and WP 2.3). The three topics are:

1) **Modeling, development and climate interpretation of Alpine and Himalayan glacier mass balances**. This doctorate plans to explore the information contained in the record of climatic fluctuations of Alpine and Himalaya glacier mass balances that are being studied as part of the CNR NextData project. In order to understand the dynamic response of glaciers to climate change, starting if possible from the Little Ice Age, it will use a combination of an energy model for the calculation of the mass balance of glaciers and a linear flow model. The data must then be compared with the results from regional and global climate models;
2) **Integration and development of glaciological databases suitable for study and identification of drillable glaciers**. This project involves the verification of existing glaciological databases concerning both the geometrical aspects and previous drilling activities. These data will be counted, organized and structured according to the requirements of the NextData project, creating a specific geodatabase. The PhD project is expected to develop methods of analysis and for assessing statistical probability, aimed at identifying which glaciers are suitable for the drilling of ice cores;
3) **Development of a procedure for the determination of drillable glaciers by means of indicators produced by multisource remote sensing and morphometric parameters.** This research is aimed at defining a procedure for the selection and location of drillable glaciers at different scales of investigation. Through an empirical approach applied to small-scales, based on scoring systems and cluster analysis, it will define classes likely to score and evaluate them in the light of existing datasets acquired during drilling.

3.4 Dissemination

The drilling at the Colle del Lys has been the subject of great media attention, that widely advertised the activities of the NextData project.

3.5 Participation in conferences, workshops, meetings

None in the reference period.

4. Results obtained during the reference period

4.1 Specific results (Data libraries, Measurements, Numerical simulations, etc)

Definition of the layout of field activities to perform ice core drilling in remote areas. Evaluation of the problems related to drilling in high mountain areas and testing of the electrical power system needed for drilling probes.

Reconstruction of visual stratigraphy and density profile of the ice core sampled at Colle del Lys. Preliminary estimate of the depth-age relationship down to the depth of 32m, which was reached by the ice core, and its extrapolation to 120 m, the estimated depth of ice at the drilling site.

Definition of three new ice core sites in the European Alps, the Karakoram and the Himalaya.

4.2 Publications

None in the reference period.

4.3 Availability of data and model outputs (format, type of library, etc)

None in the reference period.

4.4 Completed deliverables

D1.4.1: Report on the field activities and drilling sites selection. Completed.

5. Comment on differences between expected activities/results/deliverables and those which have been actually performed.

In addition to the activities scheduled for the first year, which included only the definition of the field activities, an actual drilling activity was performed at the Colle del Lys glacier, which provided storage of ice cores and testing of logistics, technical issues and management of glacier ice cores. The drilled core was analysed to obtain visual stratigraphy as well as density and depth-age relationships. Three new possible drilling sites were also defined.

6. Expected activities for the following reference period

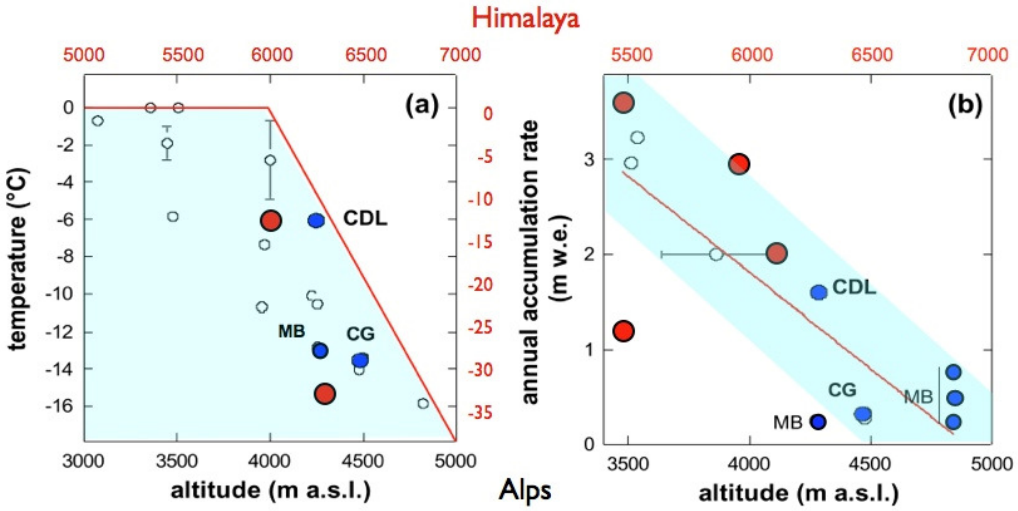
Atmospheric dust measurements of the 2012 ice core at Colle del Lys; new ice core drilling at Colle Gnifetti, planning of the next Himalaya-Karakoram ice core drilling activities and exploration of the logistical possibilites for the South Gasherbrum (Karakoram, Fig. 3) and ChoYou (Himalaya, Fig. 4) glaciers. Visual stratigraphy, density profile and preliminary depth-age relationship for the Colle Gnifetti 2013 ice core (Fig. 2). The Colle Gnifetti will provide longer records respect Colle del Lys (300-1000 years) with the possibility to compare data with the Greenland ice cores (GRIP, GISP II, NGRIP, EEM). The lower resolution is related to a lower annual accumulation rate respect the Colle del Lys (ca 40 cm w.e.). In any case the topography is reliable for ice coring, because it is a saddle at 4450 m asl, related to the

catchment basin of the Gorner Glacier (Switzerland) just drilled in the past by Swiss and German groups.

The two Asian glaciers potentially considered in the drilling activities are characterized by rather different conditions. While the Karakoram site is mostly influenced by winter precipitation carried by the Western Weather Patterns coming from the Mediterranean and the Middle Est, the Himalayan glaciers are mainly influenced by the summer monsoon system. So it is important to understand the relationship between the monsoon system, strongly influencing the Himalayan glaciers, and the oriental branch of the westerly perturbations reaching the Karakoram chain (Fig. 5). Despite the fact that circulation models can provide regional transport pathways, the complicate topography of this part of the world can modify significantly the trajectories of air masses. While this is less important for the Himalaya, for the Karakoram the topography can have a strong influence on the deposition rates. Ice core records can provide information on the past deposition and provide data on human/natural relationships in these mountain areas.

The activities will include the development of solar power systems, to improve the ice core drilling system and to reduce the impact on high mountain glaciers, and the development of non-destructive measurements directly on ice cores, mainly related to dielectrical properties and infrared measurements.

Figure 1



Relationship between altitude of the drill sites and -10 m temperature (a) and annual accumulation rate (b). CDL: Colle del Lys; CG: Colle Gnifetti; MB: Mont Blanc (from Haeberli, 1983, modify) (Maggi pers. comm.)

Figure 2. Drilling sites at Colle del Lys and Colle Gnifetti

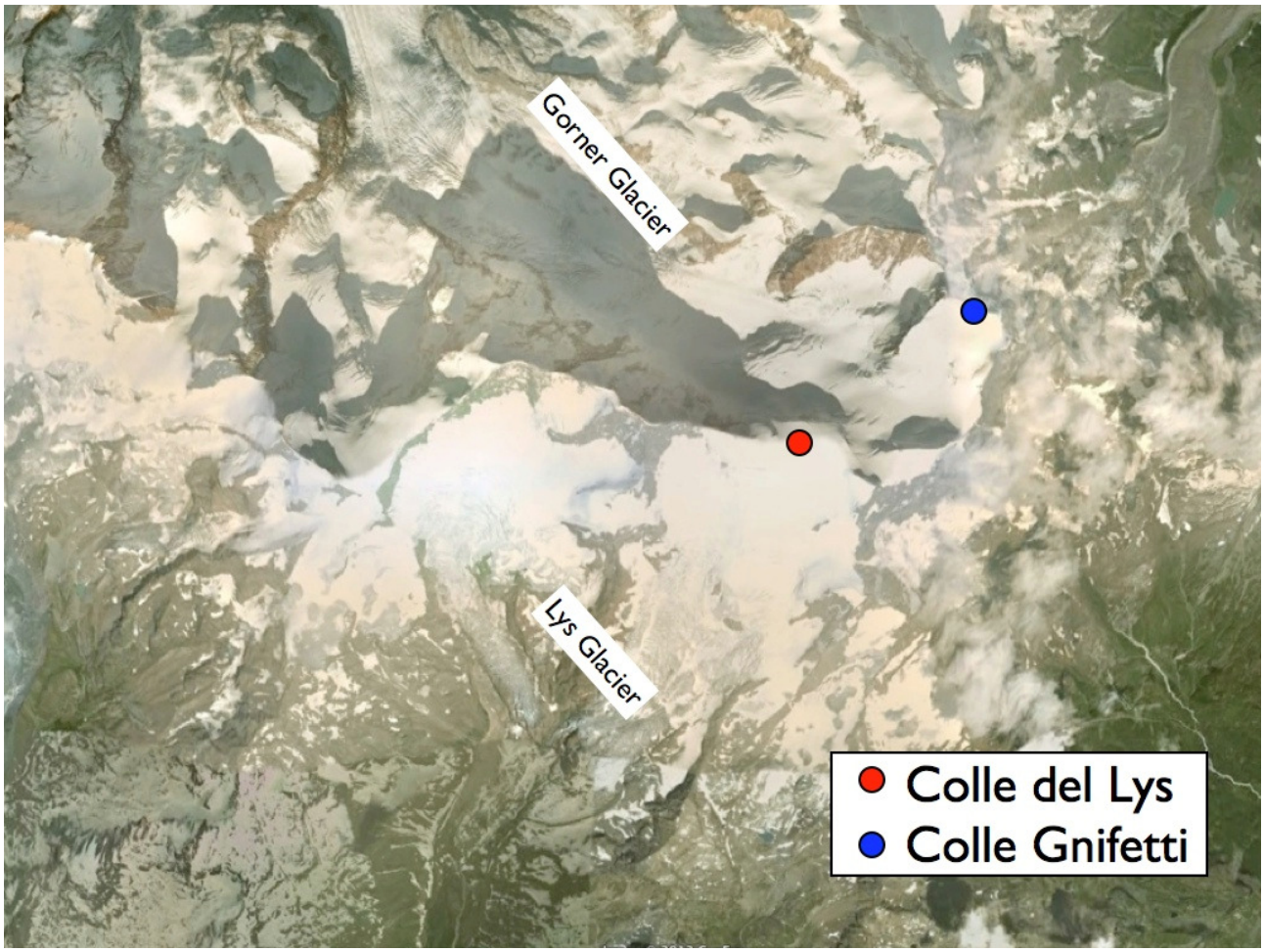


Figure 3. Potential drilling site at Gasherbrum (Karakoram)

Figure 4. Potential drilling site at Cho Oyu Glacier plateau (Himalaya)

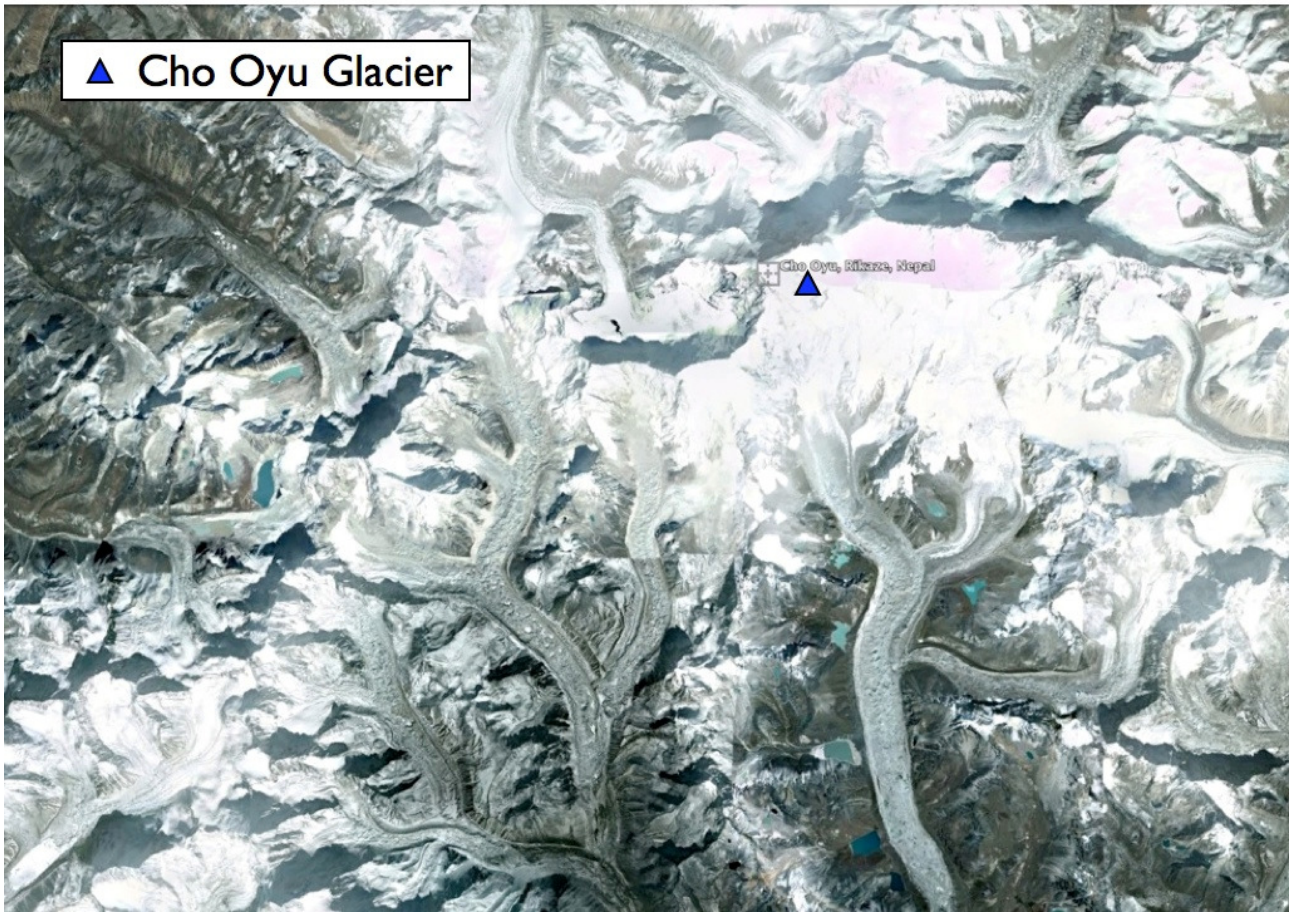


Figure 5. The wind pattern characterising the Karakoram - Himalaya mountain chain. Sites of the main ice core drillings (blue triangles), the site of the HIMICE collaboration ice core project (red triangle) and potential ice drilling sites of the NEXTDATA project (purple triangles).