Project of Strategic Interest NEXTDATA

Deliverables D1.4.4, D1.4.5, D1.4.6, D1.4.7, D1.4.10a, b, c

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D1.4.4
Reconstruction of the mineral dust record from Colle del Lys ice core drilled in 2012 (CdL/12), with preliminary dating by seasonal variability (annual counting)

D1.4.5
Complete reconstruction of the 1930-2012 stacked record with overlapping of CdL/03 and CdL/12 dust records

D1.4.6
Reconstruction of the decadal climatic and environmental variability using data from Monte Bianco, Monte Rosa, Fiescherhorn and other ice cores

The Mediterranean area is surrounded by mountain chains such as the Pyrenees, the European Alps, the Dinarides, the Carpathians and the Taurus northward, and the Atlas and Akhdar southward; it also includes other “inner” mountain chains, such as the Apennines in Italy and the Pindos in Greece. A limited number of these mountain chains reach or exceed altitudes around 3000 m a.s.l. and can host glaciers.

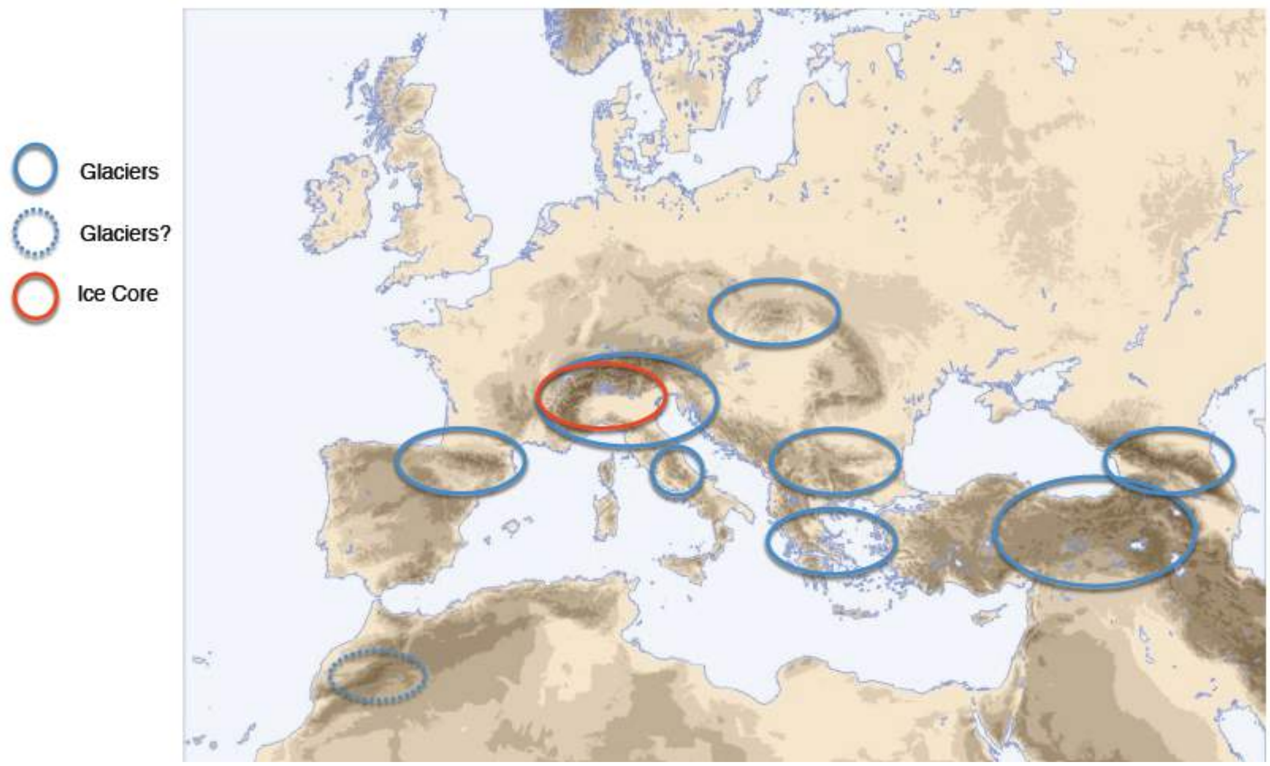

Fig. 1. The distribution of Glaciers and Ice cores in Europe.

Despite the large number of glaciers (more than 5000) existing in the European Alps, only the cold ones can be used for climatic and environmental purposes based on ice core drilling. In the Euro-Mediterranean area these glaciers, suitable for climatic reconstructions, are located at or above 4000 m a.s.l: one is found in the Mont Blanc massif, two in the Monte Rosa massif, two more in the Central Alps, one in Central Switzerland and one in Austria. Overall, only six glaciers are considered to be suitable sites for ice core drilling, or sites where ice cores likely provide unperturbed climate and environmental information.

With only a few exceptions, the depth on the accumulation area of these high altitude glaciers spans between 100 and 150 m of ice. As defined in the 2012 Deliverables, the upper 40 m are represented by firn with density below 0.85 g/cm^3 while the remaining part is glacier ice. Density at the surface, characterized by the annual snow cover, normally ranges between 0.3 and 0.4 g/cm^3, while the bottom part can reach densities up to 0.9 g/cm^3 and higher. Only the melting layers where the stratigraphy is destroyed by percolation will reach a maximum ice density of

0.927 g/cm^3. The annual accumulation rate can range from 0.3-0.4 m of water equivalent (w.e.) up to more than 3 m w.e. These differences define the resolution of the records provided by the ice cores.

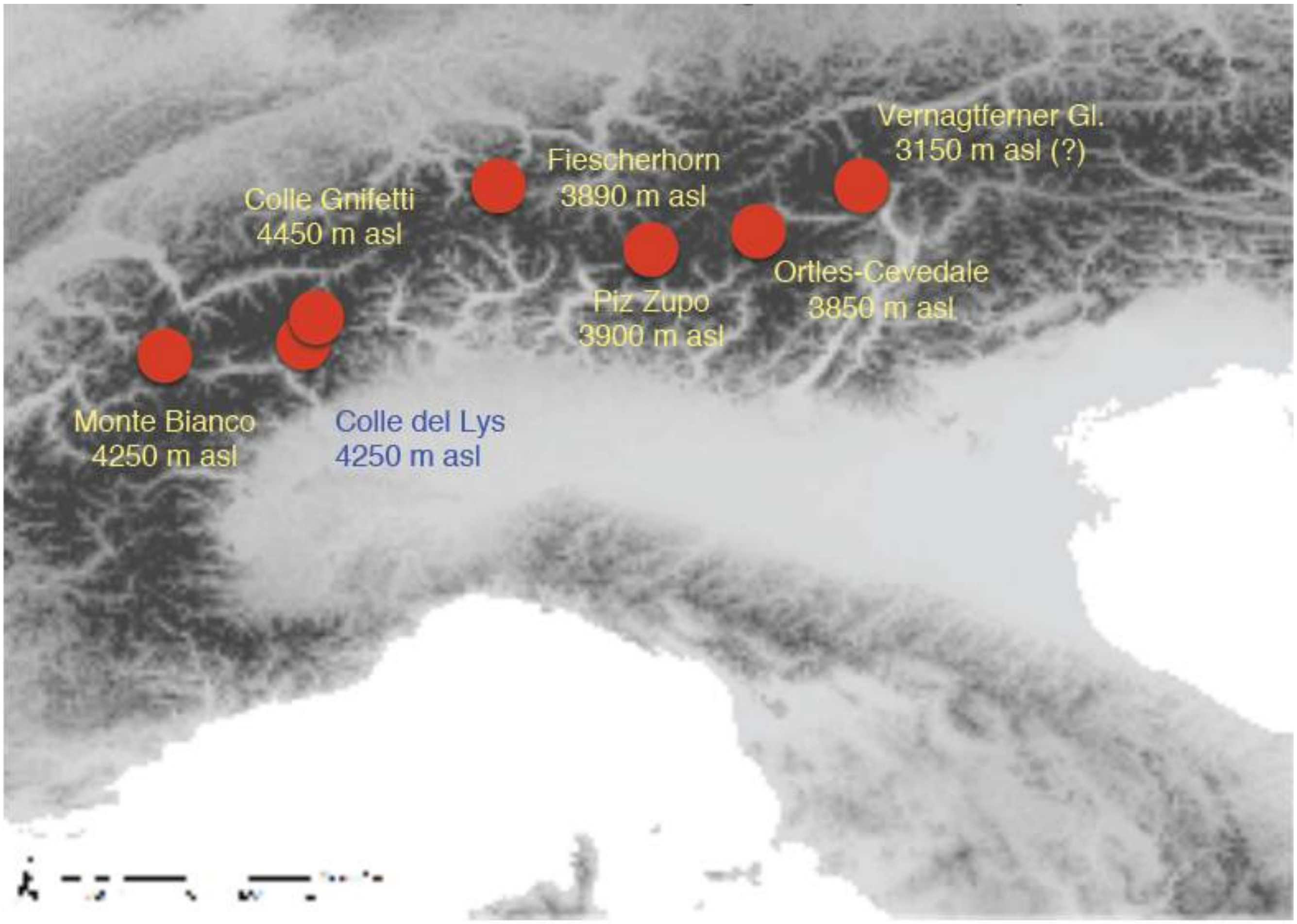

Fig. 2. Ice core sites for the Greater Alpine Region.

Large changes in the accumulation rate make some sites, such as Colle del Lys (Monte Rosa), suitable for preserving the seasonal pattern of climate and environmental proxies, and other sites such as Colle Gnifetti (Monte Rosa) suitable for providing long-term records at lower resolution. The very high elevation of these drilling sites makes them sentinels of climate change in the free troposphere. This accounts for the difficulties sometimes encountered in linking these glaciological records to other climatic parameters, such as instrumental or dendrochronological series. Alpine ice core records do not provide only a clear overview of the climate variability in the whole Alpine and Mediterranean areas, but preserve also unique records of climate change in the free troposphere above the high Alpine area.

Within NextData, a national system for environmental and climate data recovery, storage, accessibility and dissemination has been setup. Collection and analysis of non-polar ice cores represent a fundamental issue for obtaining novel environmental and climate data, together with preservation of these archives for future studies. A number of proxy data including stable isotopes, ions, mineral dust and geochemical data, therefore, have been recently collected and stored in a structured database. Table 1 shows a list of 44 ice cores and their main specifications (see also WP2.3 description for details).

Name	Location	Place name of Drilling site	Drilled	Year top	Year bottom	coverage
CDB 6	Alps, Mont Blanc	Col de Brenva	1984	1984	1982	2
CDD 10	Alps, Mont Blanc	Col du Dome	1994	1994	1918	76
CDD 11	Alps, Mont Blanc	Col du Dome	1994	1994	1844	150
CDD 12	Alps, Mont Blanc	Col du Dome	1997	1997	1992	5
CDD 2	Alps, Mont Blanc	Col du Dome	1973	1976	1940	36
CDD 2b	Alps, Mont Blanc	Col du Dome	1976	-	-	-
CDD 3	Alps, Mont Blanc	Col du Dome	1974	1974	1948	26
CDD 5	Alps, Mont Blanc	Col du Dome	1980	1980	1971	9
CDD 7	Alps, Mont Blanc	Col du Dome	1986	1986	1955	31
CDD 8	Alps, Mont Blanc	Col du Dome	1991	1991	1984	7
CDK	Alps, Mont Blanc	Col du Dome	2004	2004	1920	84
DDG 2	Alps, Mont Blanc	Dome du Guter	1999	-	-	-
MB 73	Alps, Mont Blanc	Mont Blanc Summit	1973	1973	1970	3
MB 99	Alps, Mont Blanc	Mont Blanc	1999	-	-	-
CdL 96	Alps Monte Rosa	Colle del Lys	1996	1996	1954	42
CdL 00/1	Alps Monte Rosa	Colle del Lys	2000	2001	1999	2
CdL 03/1	Alps Monte Rosa	Colle del Lys	2003	2003	1933	70
CdL 03/2	Alps Monte Rosa	Colle del Lys	2003	2003	1933	70
CdL 03/3	Alps Monte Rosa	Colle del Lys	2003	2003	1933	70
CdL 12/1	Alps Monte Rosa	Colle del Lys	2012	2012	2002	10
CG B76	Alps Monte Rosa	Colle Gnifetti	1976	1976	1901	75
CG B77/1	Alps Monte Rosa	Colle Gnifetti	1977	1977	1778	199
CG B77/2	Alps Monte Rosa	Colle Gnifetti	1977	-	-	-
CG B82/1	Alps Monte Rosa	Colle Gnifetti	1982	1982	0	1982
CG B82/1b	Alps Monte Rosa	Colle Gnifetti	1982	-	-	-
CG CC B82/2	Alps Monte Rosa	Colle Gnifetti	1982	-	-	-
CG KCH B95/1	Alps Monte Rosa	Colle Gnifetti	1995	1995	1864	131
CG KCS B95/2	Alps Monte Rosa	Colle Gnifetti	1995	1995	1747	248
CG 03/1	Alps Monte Rosa	Colle Gnifetti	2003	2003	-8000	10003
CG 03/2	Alps Monte Rosa	Colle Gnifetti	2003	2003	550	1453
CG KCI 05	Alps Monte Rosa	Colle Gnifetti	2005	2005	1836	169
CG KCI sup	Alps Monte Rosa	Colle Gnifetti	2005	-	-	-
Ortles Ice core	Alps Ortles-Cevedale massif	Alto dell'Ortles	2009	-	-	-
Ortles 1	Alps Ortles-Cevedale massif	Alto dell'Ortles	2011	-	-	-
Ortles 2	Alps Ortles-Cevedale massif	Alto dell'Ortles	2011	-	-	-
Ortles 3	Alps Ortles-Cevedale massif	Alto dell'Ortles	2011	-	-	-
Ortles 4	Alps Ortles-Cevedale massif	Alto dell'Ortles	2011	-	-	-
Piz Zupo PZ02/1	Alps Morteratsch	Piz Zupo	2002	-	-	-
Piz Zupo PZ02/2	Alps Morteratsch	Piz Zupo	2002	-	-	
Fiescherhorn FH89	Alps Grossfiescherhorn	Fiescherhorn Glacier	1989	1989	1946	43
Fiescherhorn FH02	Alps Grossfiescherhorn	Fiescherhorn Glacier	2002	2002	1660	342
Vernagtferner_I	Oetztal Alps	Vernagtferner	1979	1979	1896	83
Vernagtferner_II	Oetztal Alps	Vernagtferner	1979	1979	1896	83
Vernagtferner_III	Oetztal Alps	Vernagtferner	1979	-	-	-

Table 1. Dataset of Alpine ice cores with the time coverage of the entire records.

While long-term climate records, such as the glaciological ice core record from Colle Gnifetti, provide information about climate change in the Alps during the little ice age (from the mid-XVI century to the end of XIX century) and show a temperature increase in modern times, other ice core records provide information for the last century only, but with an exceptionally high resolution (see Fig. 3). The Alpine ice core records do not allow to obtain a continuous climatic reconstruction of the last 2000 years, achievable using other proxy data. However, the exceptional capacity to preserve information on several physical parameters of the atmosphere and of its chemical composition allows to gain knowledge on the Greater Alpine Region climate variability.

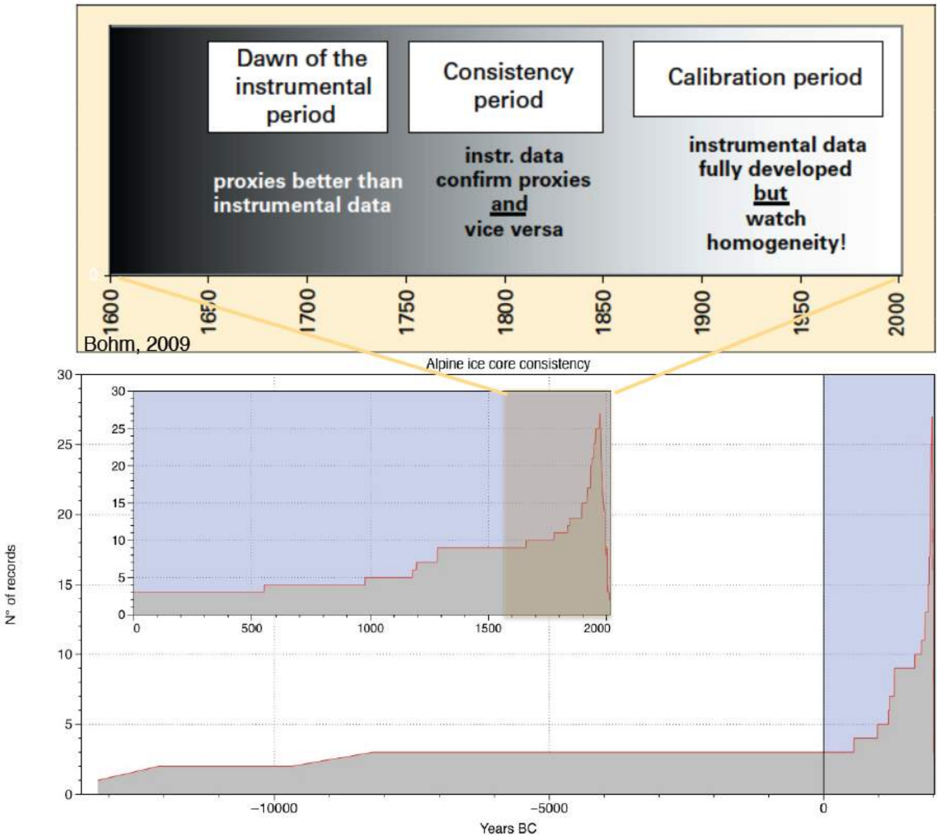

Fig. 3. Data consistency of Alpine ice cores.

As an example, the Colle del Lys stable isotope record shows a very pronounced seasonal pattern and provides a detailed climate reconstruction of the last ~80 years (since about 1930). Other proxy data from the same site, such as mineral dust and chemical records, allow to reconstruct the seasonal variability of background tropospheric dust as well as of events of long-range dust transport from North Africa. At the Colle del Lys, preliminary results show higher concentrations of Saharan dust during the 1970s and the 1980s than during the first half and the end of the XX century. This increase seems to be related to an enhanced transport of desert dust from North Africa to Southern Europe, which could be ultimately related to pressure patterns in the Mediterranean area (Fig. 4).

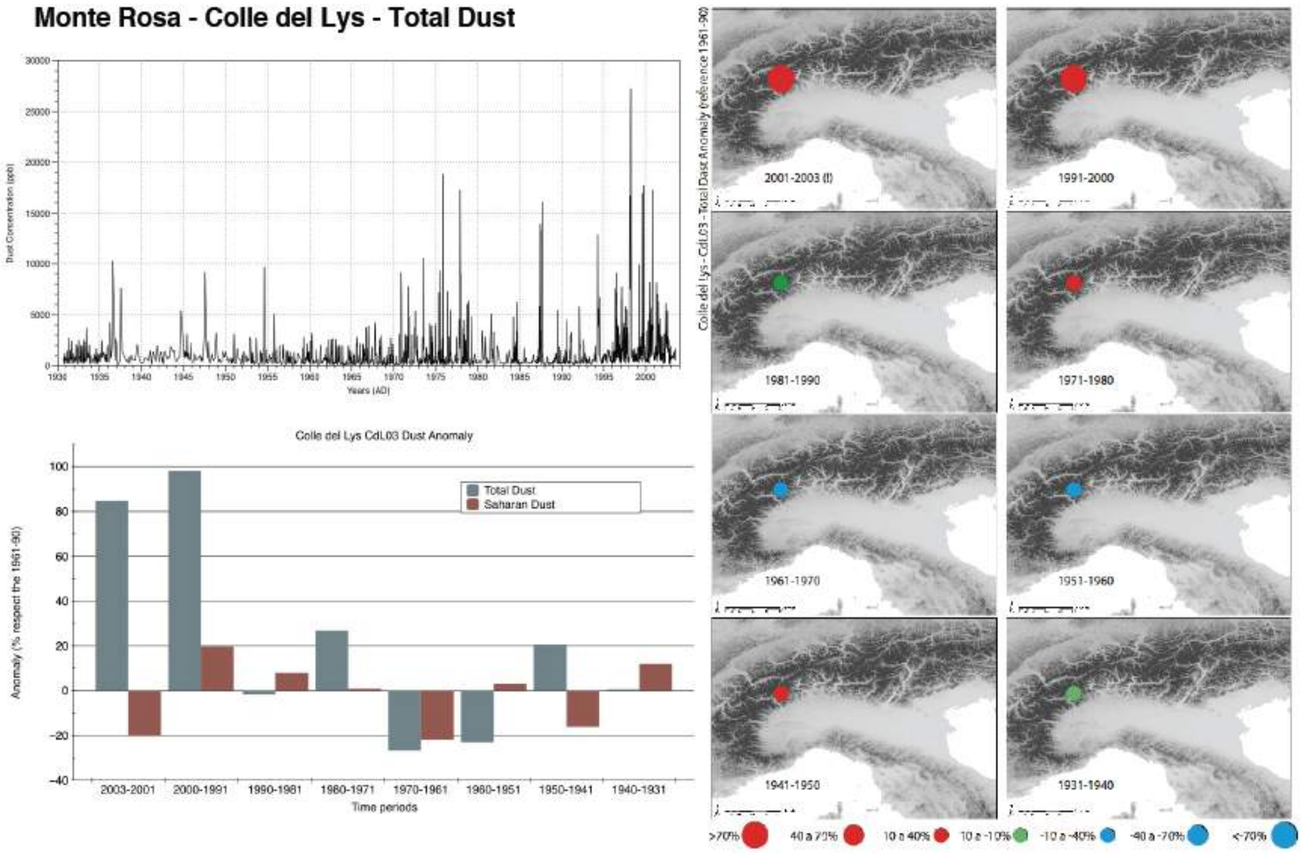

Fig. 4. Colle del Lys ice core mineral dust record from 1930 to 2003 and the mean decadal dust anomaly from total dust and from Saharan events. The maps report the decadal total mineral dust anomaly.

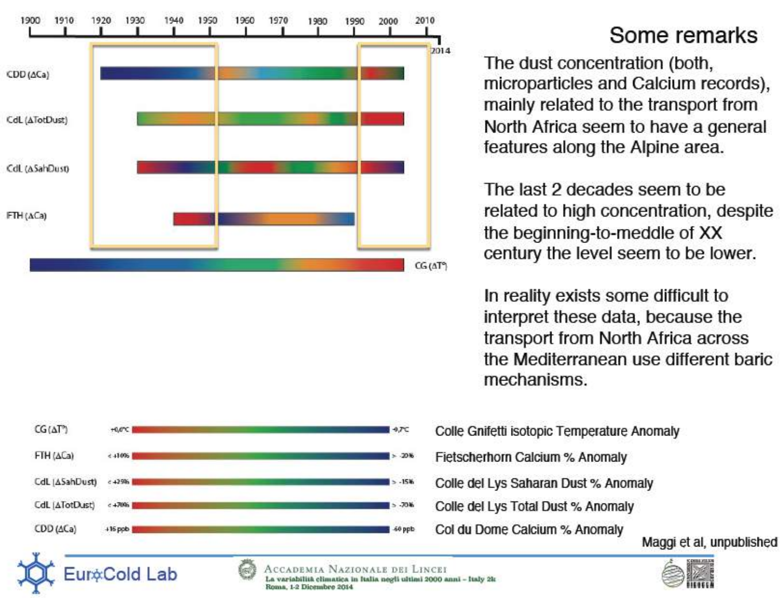

Fig. 6. Reconstruction of dust transport events from the main ice core mineral dust record for the Alps.

Records from Col du Dome, Colle Gnifetti, Colle del Lys and Fleitscherhorn show mineral dust data, mainly Calcium ion data, which provide a proxy for the mineral transport to the Alpine area.

All of these ice cores are close to 4000 m a.s.l. and can be considered as a record of mean tropospheric dust transport (fig. 6). The dust concentration (both microparticles and Calcium records) is mainly related to the transport from North Africa. The last 2 decades seem to be characterized by high concentration, while at the beginning-to-middle of the XX century the level seems to be lower. Actually we have difficulty with the interpretation of these data, because the transport from North Africa across the Mediterranean uses different pathways.

The high resolution of the Colle del Lys ice cores permit to recognize seasonality also in records different from the stable isotopes. An example is provided by atmospheric dust, where concentration is high during the spring-to-summer periods and low during fall-to-winter (fig. 7).

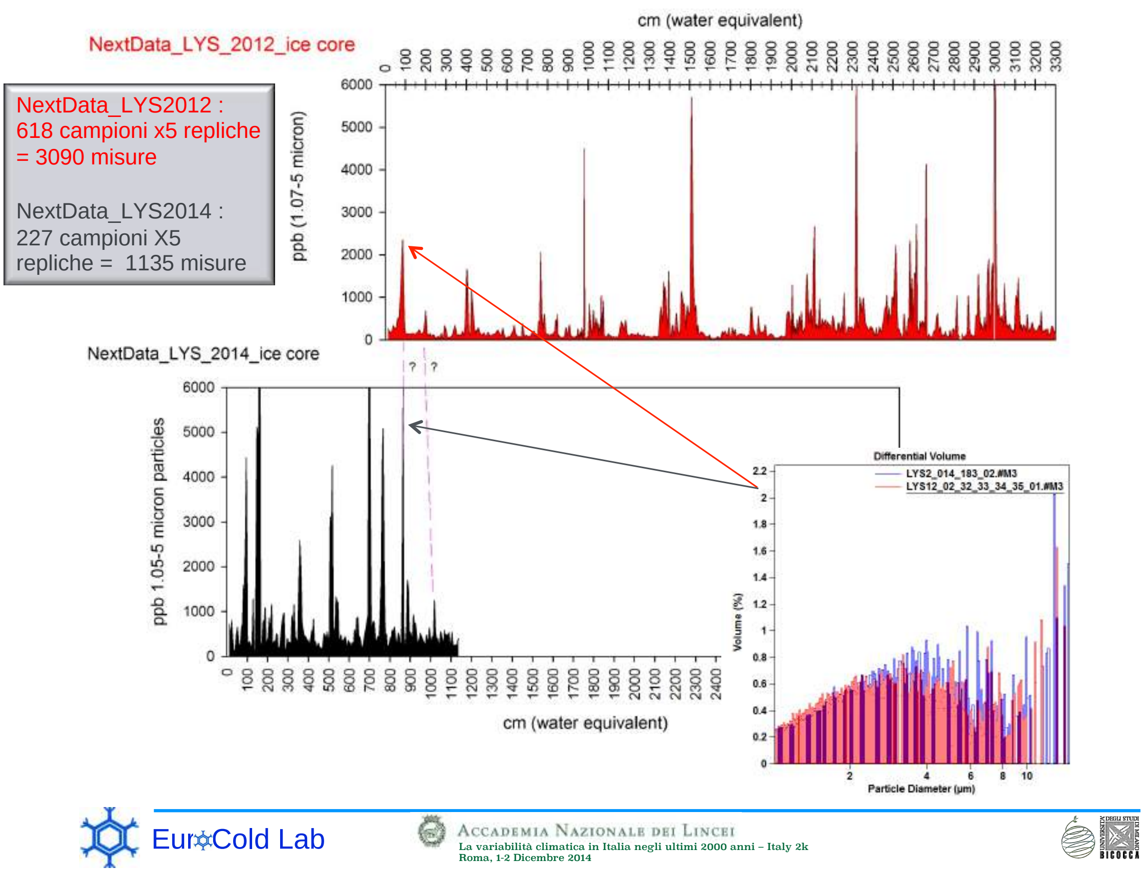

Fig. 7. Correlation between mineral record from Colle del Lys ice core 2012 and mineral record from Colle del Lys ice core 2014. Is possible to see the seasonality related to the high accumulation of the site.

D1.4.7
Application and validation “Minimal Glacier Model” models for simulate the historical retreat of the Careser glacier (Ortles-Cevedale, North-East Alps).

Minimal Glacier Model

A minimal glacier model (MGM) is used to reduce the complexity of glacier dynamics to a very simple description based on basic physical laws. The glacier evolution is obtained from an integrated continuity equation over the entire volume, assuming that the glacier has a constant width and accepting a crude representation of the real glacier geometry. The starting point is:

$$\frac{dV}{dt} = \frac{d}{dt}(WH_m L) = W\left(H_m \frac{dL}{dt} + L\frac{dH_m}{dt}\right) = B_S \qquad (1)$$

where V is the ice volume and B_s is the total surface balance rate. The volume is the product of the width W, the mean ice thickness H_m and the glacier length L.

MGM assumes perfect plasticity, an approximation of how the horizontal glacier flow line varies following the glacier thickness variations, and an instantaneous relationship between the glacier length and thickness. Starting from these assumptions, H_m is given by (Oerlemans 2011):

$$H_m = \frac{\alpha_m}{1+n\bar{s}} L^{1/2} \qquad (2)$$

where $\bar{s}$ is the mean bed slope over the glacier length and a_m and n are constants.

The scheme in Fig. 1 represents the iterative process of a MGM integration. The combination of eq. (1) and (2) describes the variation of glacier terminus along the flow-line direction, dL/dt, shown in Fig. 1 as the core of the algorithm.

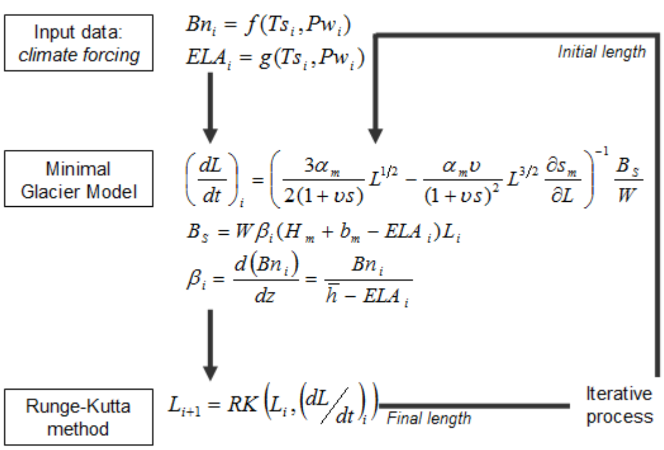

Fig.1. Minimal Glacier Model scheme.

Considering a linear balance profile, the surface balance B_S expression includes $\bar{b}$, the mean bed elevation, E, the Equilibrium Line Altitude (*ELA,* the line that divides the accumulation from the ablation areas), and b, the mass balance gradient along the glacier. This gradient is estimated from the annual net mass balance B_n, which is the most important driver of glacier behaviour and describes the amount of mass gained or lost in meters of water equivalent.

In this formulation, the input data are B_n and the ELA, which depend on two main climatic forcings: winter precipitation and summer air temperature (although, in principle, a contribution from the net incoming solar radiation should be accounted for). The analysis of the correlations between climatic variables and snout fluctuations on several glaciers (Bonanno et al., 2013) revealed that the most significant contributions come from for winter precipitation in the period

November–March and from summer (July – October) air temperature. Therefore, we adopted a bivariate fit to relate climate forcing to the model inputs (Fig. 1, *Climate forcing*):

$$\dot{b}_i = aT_{s,i} + bP_{w,i} + c \qquad (3)$$

$$E_i = uT_{s,i} + vP_{w,i} + z \qquad (4)$$

where i represents the *i-th* year, $T_{s,i}$ is the summer 2m air temperature and $P_{w,i}$ is the winter precipitation. The glacier length, that is, the output variable, is then obtained by numerically integrating equations 3 and 4 (Hamming 1986). The output length for a given year is input data for the further cycle, giving rise to an iterative process.

GIS algorithm to calibrate Minimal Glacier Model

A geodatabase called IceCore Database 2.0 (IDB2.0) has been specifically arranged in the framework of WP2.3 containing also geomorphological data from glaciers coming from other geodatabases such as GLIMS RGI and WGI. This data could be used as input sources to set a 2D model that would allow to move from a deterministic approach to a spatial approach in glacier modelling. The morphometric parameters could provide detailed information to calibrate a 1D deterministic model using 2D or 3D spatial approach. GIS analysis, to apply theoretical MGM on glacier flow lines, could increase the accuracy of the model. The glacier evolution in a MGM is calculated from an integrated continuity equation over the entire volume, based on the perfect plasticity principle. A MGM requires some geomorphic parameters to set boundary condition (BC): the flow line length, maximum and minimum elevation and slope are the most important ones. The glacier geomorphology could be gathered from a Digital Elevation Model (DEM) using GIS instruments.

DEMs allow to:

- Reconstruct the evolution of a glacier with a multitemporal analysis.
- Draw the flow lines that follow the accumulation-ablation dynamics on which the model is applied.
- Obtain the geomorphic parameters useful to calibrate the MGM.
- To extrapolate, from DEMs, in a GIS environment, all the features to calibrate the BC of the MGM, a python algorithm was prepared.

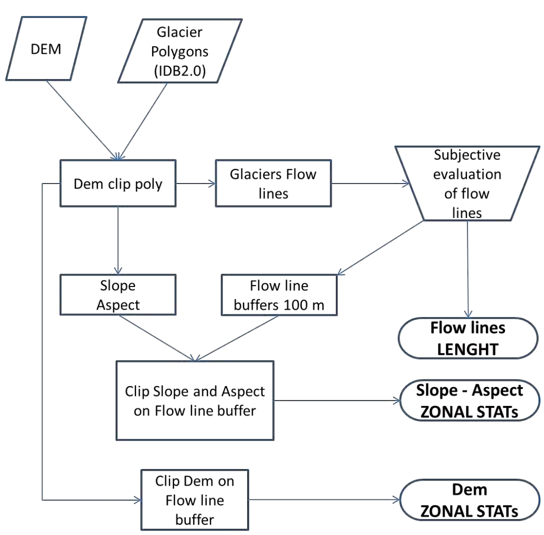

Fig. 2. GIS algorithm to calibrate Minimal Glacier Model.

Developed in QGIS, using several libraries and the interoperability of different open source softwares such as GDAL, GRASS, and SAGA, the algorithm requires the following input data - DEMs, POLYGONs and FLOW LINEs - and returns the geomorphological parameters useful to calibrate the boundary condition of the MGM – the slope along the flow line (Fig. 3), the altitude range along the flow line and statistics on slope. The algorithm was calibrated on the Careser glacier, one of the most studied glaciers in the Alps, (Frizsch 1898; Frizsch 1899; Frizsch 1902; Frizsch 1903; Reishauer 1908; DÖhler 1917).

All datasets used are derived by TESAF, University of Padova (Carturan et al., 2007; Carturan et al., 2012; Carturan et al., 2013).

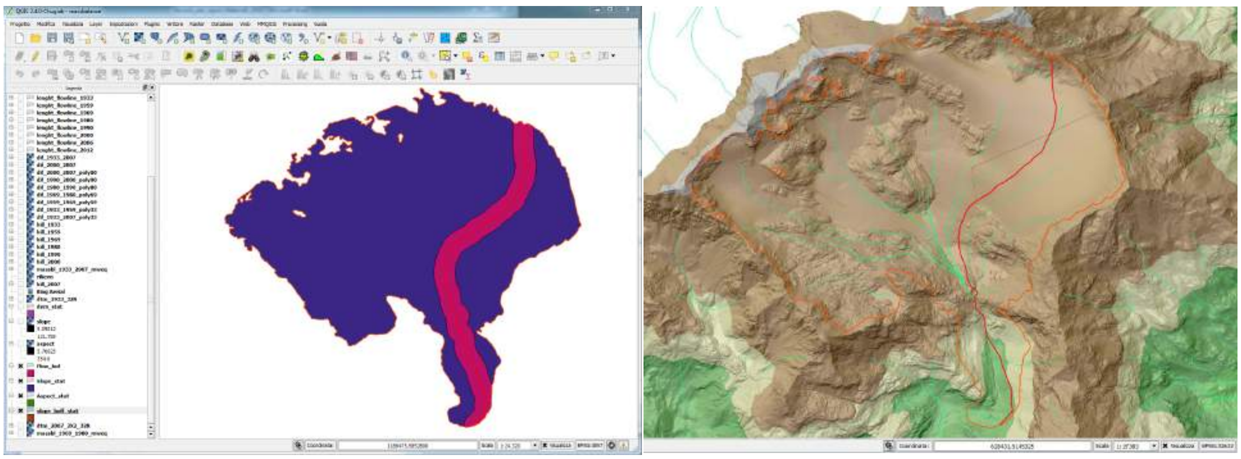

Fig. 3. Flow line selection and algorithm results on Careser Glacier. Flow lines were firstly calculated with Grass r.flow and after corrected by a geomorphological analysis to choose the most probably one following the glacier evolution and retreat.

After an accurate calibration on the Careser glacier, the algorithm was applied to the Rutor glacier. As shown in Fig. 4, the application of the new algorithm has considerably increased the accuracy of the MGM results. The evaluation of the algorithm was performed with a back analysis by performing a twofold model calibration: using data from the literature on the one side and using the results of the GIS algorithm on the other side. Calibration was made for the year 1954 and the simulation was performed for the period 1954-2013.

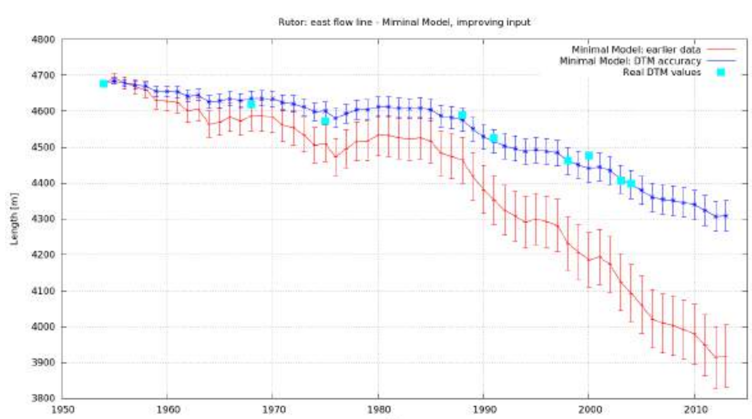

Fig. 4. Comparison of model results in back analysis. Blue dots represent the flow line length measured on DTM, the blue line represents the results of the model calibrated using the GIS algorithm while the red line shows the results of the model calibrated using the data derived from the literature.

Application of a GRASS GIS module to the Minimal Glacier Model: r.glacio.model

Subsequently, we integrated the MGM with a GIS module to obtain a spatial representation of the glacier retreat and in particular to produce a geospatial evaluation of flow line fluctuations, to make an useful and simple tool available for users and to set the basis for the development of a method to apply Minimal Models on a large scale.

GRASS GIS is an open-source software used for geospatial data management and analysis, image processing, graphics and maps production, spatial modelling and visualization. An easy and powerful environment using the Python programming language and GRASS GIS was set up allowing for the development of the module called r.glacio.model. The last formulation derives from a rigorous validation with different types of glaciers and the module will be released as a GRASS-addon under the GNU General Public License (⩾ v.2).

The core of this algorithm is based on the equation reported in Fig.1. It requires that the following input data (Fig. 2) are included in the model: the glacier maximum altitude, the mean slope around the flow line, the length of flow line, the α_m constant for thickness, the mass balance, and the ELA.

The first two parameters are derived from a DTM analysis, the third needs the flow lines and polygons as an input vector layer. The parameter α_m can be set by the user as a constant or it can be calculated from eq. 2, retrieving H_m using the following equation (Linsbauer et al., 2012):

$$H_m = \frac{\tau}{f \cdot \rho \cdot g \cdot \sin(\gamma)} \qquad (5)$$

where f = 0.8 is the shape factor, related to the lateral drag on the glacier through friction at the valley walls and to the general form of the glacier cross section (Paterson, 1994), ρ = 900 kg m^{-3} is the mean ice density, g = 9.81 m s^{-1} is the gravity acceleration, γ is the glacier surface slope along the flow line and τ is the basal shear stress (Linsbauer et al., 2012).

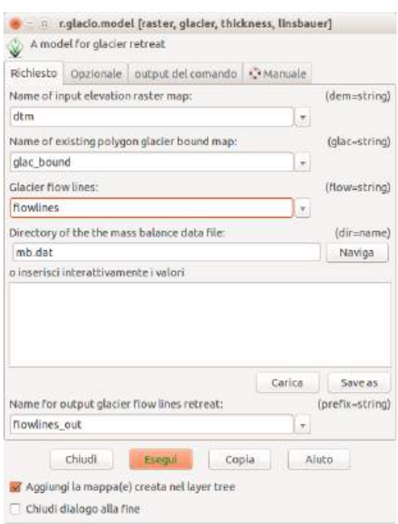

Fig. 5. User mask of the r.glacio.model. The inputs are the raster map (DTM), the polygon vector layer, the glacier flow line vector layer created by the user and the data file or the manual insertion of mass balance values for the years under consideration.

The climatic inputs of the Minimal Model are the annual mass balances, which are included in the r.glacio.model. To increase the usability and versatility of the model, we decided not to include the ELA data that are often difficult to retrieve. Fig. 5 shows the user mask of the module.
In order to provide an illustrative example, we applied the r.glacio.model to the Rutor glacier, for which the algorithm was already calibrated. Results are shown in Fig. 6, showing the glacier retreat along the flow lines from 1954 to 2003.

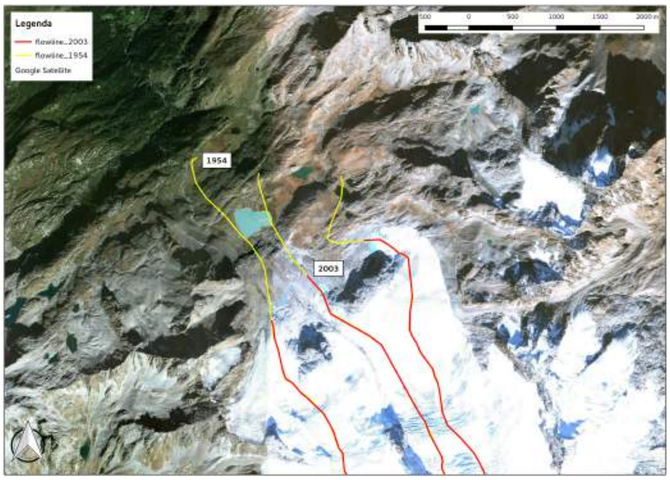

Fig. 6. Glacier retreat along Rutor flow lines: results of the r.glacio.model.

Climate drivers

Glacier models can be tuned and driven by a set of climatic variables that can be taken from observations, from reanalysis data as well as from global climate model (GCM) outputs when future projections have to be produced.
In our study we used the ERA-40 reanalysis data, produced by the European Centre for Medium-Range Weather Forecasts (ECMWF), for the period 1957-2002. These data have a spatial resolution of 1.125 degrees latitude-longitude, corresponding to about 120 km in the mid-latitudes (Uppala et al., 2005). We also considered a small ensemble of 16 GCMs that participated in the Coupled Model Intercomparison Project phase 5 (CMIP5) effort (Knutti et al., 2013; Taylor et al., 2012). Both historical simulations and future projections have been considered taking into account, for the latter, the RCP 4.5 and RCP 8.5 scenarios (Van Vuuren et al., 2011).

Future projections of glaciers retreat

We applied the minimal glacier model driven by the climatic inputs provided by the GCMs under two future scenario conditions (RCP 4.5 and RCP 8.5) for the time period 2006-2100. Uncertainty in climate model projections can be measured looking at the spread of the multi-model ensemble around the multi-model mean (Tebaldi and Knutti 2007; Knutti et al., 2013).

CARESER

All the assessments have been cut off at a minimum flow line length of 200 m, both because the error bars for the minimal model are estimated to be around 200 m, and because when a glacier becomes too small it gets covered by debris and its volume is mixed up with rubble, warping its thickness and glacial dynamics. The climate model ensemble highlights a significant resolution on the local climate of Ortles-Cevedale and Val de La Mare (Fig. 7).

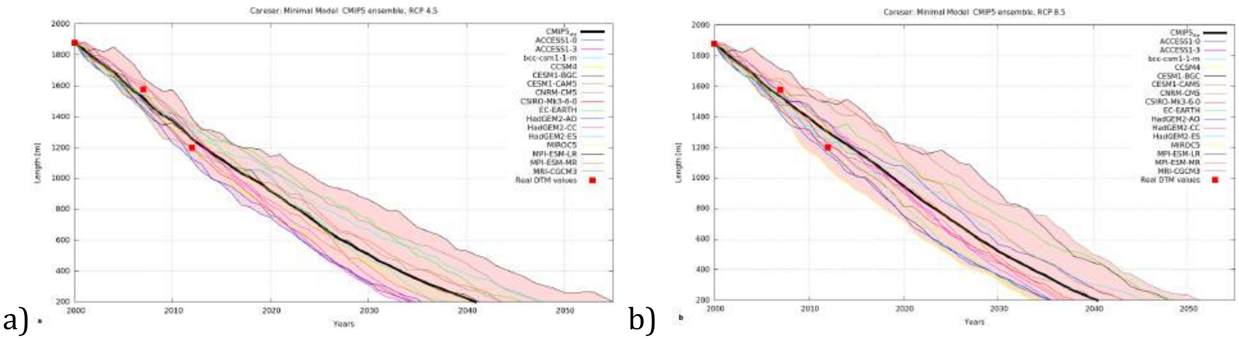

Fig. 7. Minimal model-CMIP5 results: a) RCP 4.5 scenario; b) RCP 8.5 scenario.

In Tab. 1, all the results on the expiration date are indicated reporting error bars at one standard deviation.

GCMs	Emission scenarios	Year of expiration	Standard deviation (1s)
CMIP5	RCP 4.5	2040	6
	RCP 8.5	2039	6

Tab. 1. Careser glacier: results of minimal model assessments. The expiration dates are referred to a threshold length of 200 m.

RUTOR

The model results identify the forecast length in 2100 in RCP 4.5 and 8.5 scenarios, driven by CMIP5 models (Fig. 8) and CSIRO ensemble (Fig. 9) values.

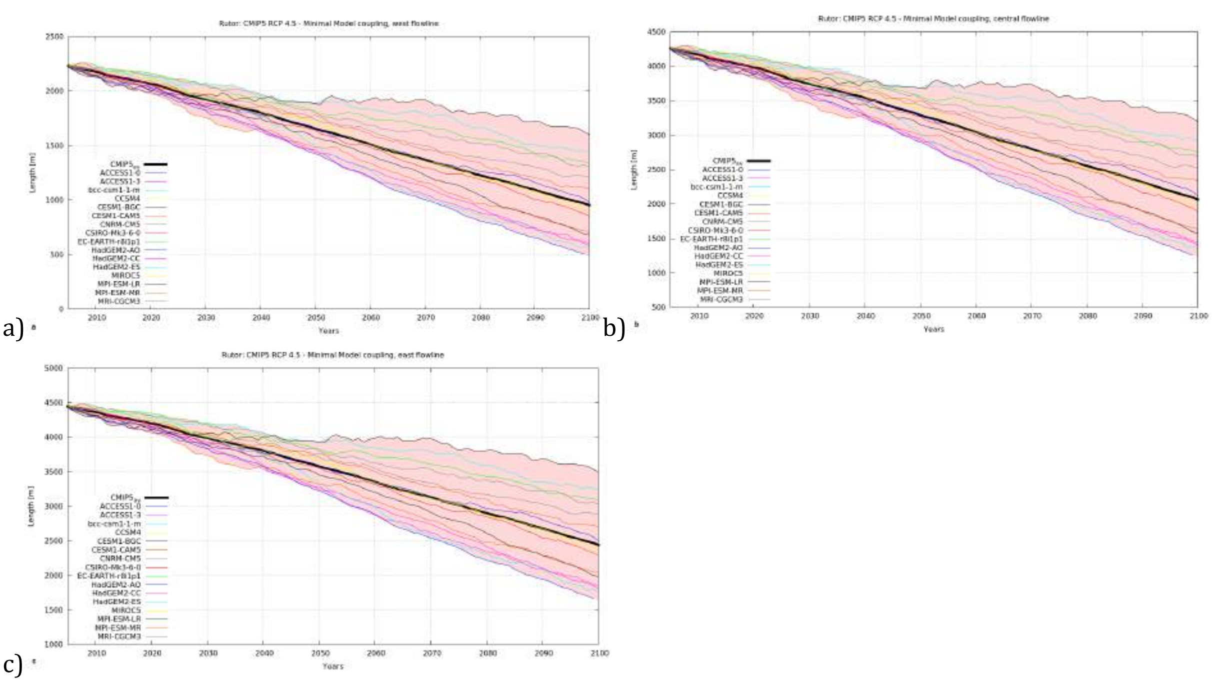

Fig. 8 Minimal model results, driven by CMIP5 models in RCP 4.5, on: a) west, b) central and c) east flow lines.

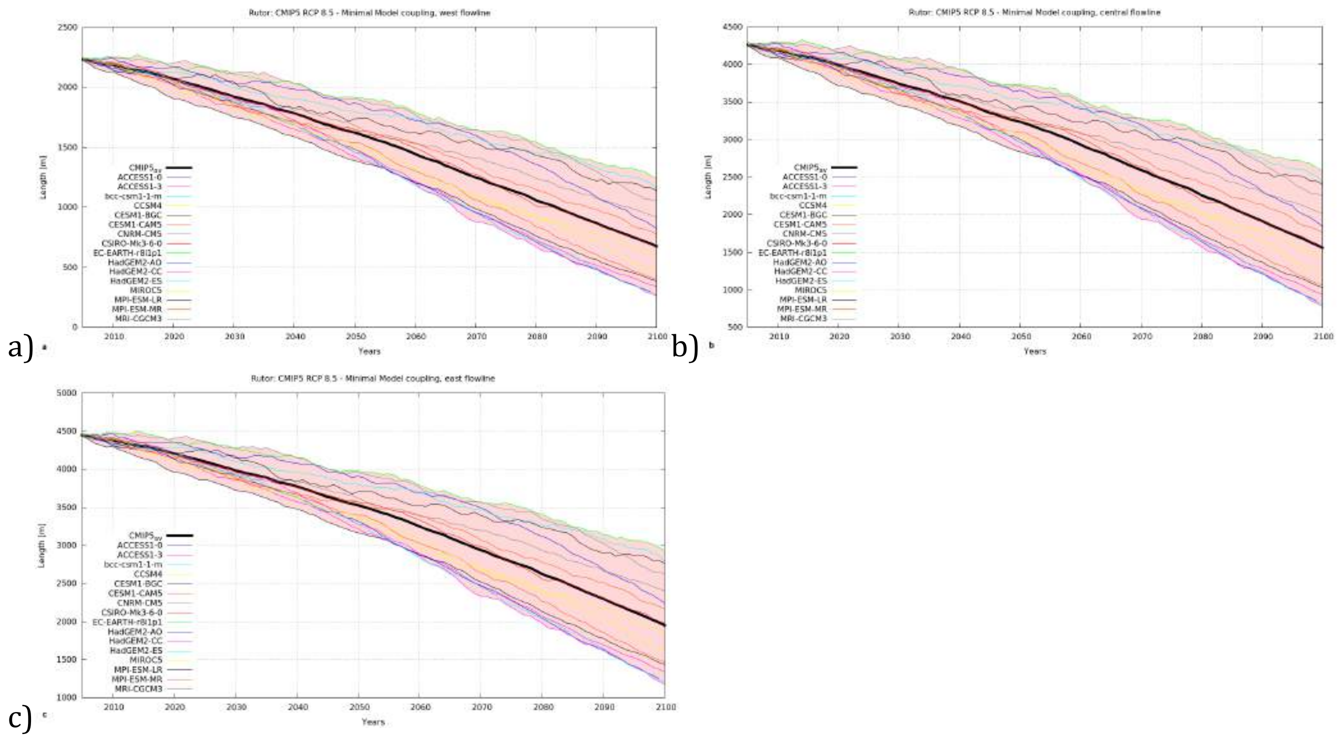

Fig. 9. Minimal model results, driven by CMIP5 models in RCP 8.5, on: a) west, b) central and c) east flow lines.

The results are reported in Table 2, reporting error bars at one standard deviation (Tab. 2).

GCMs	Emission scenarios	Flow line	Initial length at 2004 [m]	Final length at 2100 [m]	Standard deviation (1s)
CMIP5	RCP 4.5	West	2243,70	953,68	346,13
	RCP 8.5			676,76	347,08
	RCP 4.5	Central	4279,97	2067,35	614,53
	RCP 8.5			1560,23	639,81
	RCP 4.5	East	4463,48	2441,99	579,86
	RCP 8.5			1950,45	623,82

Tab. 2. Rutor glacier: results of minimal model assessments. The values are the final length of the studied flow line at the end of simulations, 2100.

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D1.4.10.a
Collection of available palynological studies in Northern Italy and Alpine area from different chronological context.

D1.4.10.b
Revision and harmonization of data from EMPD (*European Modern Pollen Database*), for pollen data quantitative reconstruction.

1. Introduction: Pollen as paleoclimate proxy

Pollen analysis is applied since decades on sediments from marine and continental settings to reconstruct the history of environments and climate over short to very long time span. The potential of pollen as a proxy for quantitative estimations of climate parameters (temperature, precipitation) has not yet been fully understood and explored. The basic biological assumptions for pollen as paleoclimate proxy are the followings: **(i)** pollen is a function of regional vegetation; **(ii)** regional vegetation is a function of climate; **(iii)** then pollen is an indirect function of climate and can be used to reconstruct past regional climate.

2. Aims

The NextData group working on palynological data in Milano is developing researches aiming at: **1)** checking the availability of pollen data from limnic sedimentary environments covering the last 3 kyr; **2)** preparing a database-data repository and tool to address future researches, **3)** reconstructing the pattern of plant species distribution and past ecosystems structure through pollen data (in collaboration with the NextData group in Rome; the first outcome of this research is presented in Magri et al., in press); **4)** providing quantitative paleoclimate estimations to be used for the multiproxy "Italy 2k" reconstructions. The first aim has been achieved. The other three are "work in progress".

3. What has been done. Part one: The palynological fossil records available in Italy

The survey of existing data revealed a huge number of palynological records available in Italy and covering the Holocene (last ~11,7 kyr). 211 sites (199 continental and 12 marine) were counted, made by published or unpublished data. The geographical distribution of these sites guarantees the representation of all altitudinal belts though not evenly spaced within the country. In order to select sites documenting the past 3 kyr (or part of this interval) we evaluated the chronological robustness (available ^{14}C ages), the chronostratigraphic resolution (less than one hundred years) and the comparability with the regional biostratigraphic model of each pollen record available. This way, 23 pollen records obtained from lacustrine and palustrine successions were selected to constitute the best N-Italy pollen datasets which will be part of the larger Italian NextData database for the past 3 kyr (Fig. 1).

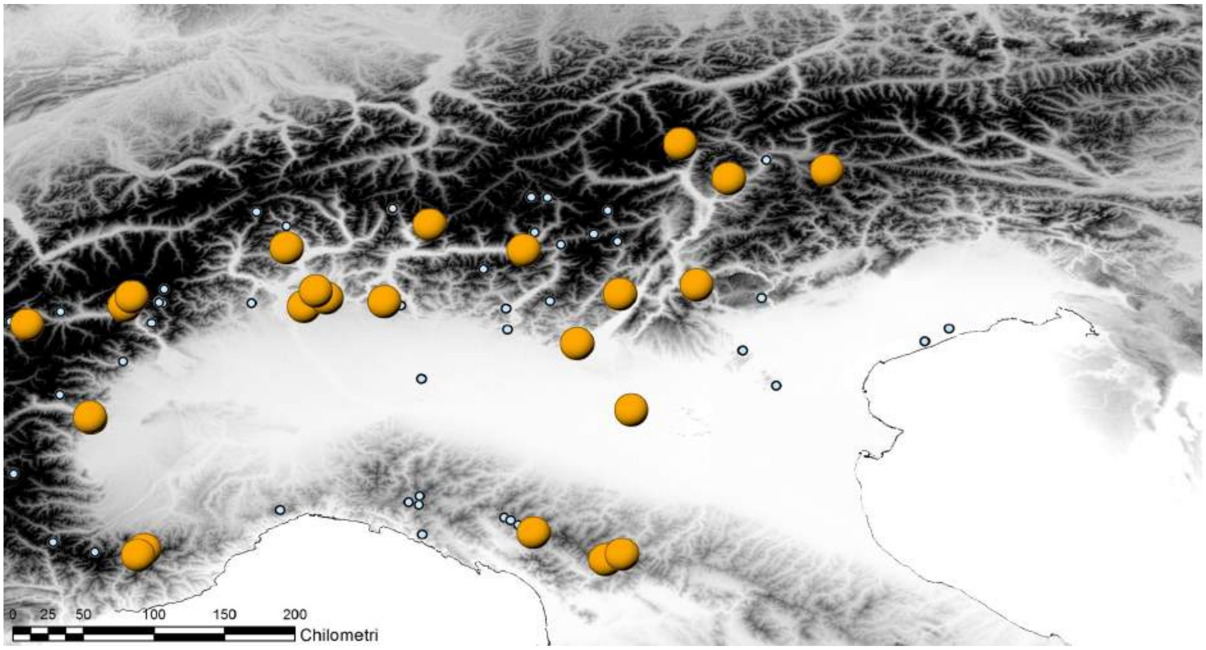

Fig. 1. N-Italy best pollen datasets. Big yellow circles are the 23 sites selected as best fossil pollen record.

A first application/use of fossil pollen data: tracing past distribution and dynamics of tree taxa

Past distribution and dynamics of nine tree taxa (*Picea, Abies, Betula, Fagus, Carpinus betulus, Corylus,* deciduous and evergreen *Quercus,* and *Olea*) during the last 11 ka have been reconstructed from fossil pollen data (Magri et al., in press).

3. What has been done. Part two - Preliminary Climate reconstruction
A three-steps approach to reconstructing paleoclimate from pollen data

A wide literature is available on the state-of-the-art of quantitative climate reconstructions from pollen data. A three-steps approach is required (Fig. 2). The first necessary step is to acquire a modern training set which is used to develop the transfer functions to reconstruct the paleoclimate variables. The NextData group obtained the whole European Modern Pollen Database (EMPD) (Davis et al., 2013) as modern training set. This database includes modern pollen samples and related climate data from nearly 4800 sites across Europe and part of N-Africa. Statistical multivariate analysis (Detrended Corresponce Analysis, DCA) was applied on the EMPD dataset to explore the sites distribution in relationship with climate parameters available for each site. The second step was the application of numerical techniques to develop the transfer functions which model numerically the relationship between modern pollen data and the modern climate data (temperatures and precipitations). Three numerical tecniques were used:
- wMAT = weighted Modern Analogue Technique. Using similarity/dissimilarity coefficients, this method is able to find k- analogues of each fossil pollen sample in the modern training set. Values of environmental variables are then calculated as weighted means from the K-analogues.
- LWWA = Locally Weighted Averaging. Similar to MAT, but a larger number of analogues is taken into account (30-40). Environmental optima and tolerances are then estimated by weighted

mean of the values expressed by the k analogues. This method is based on dynamic training sets: for each pollen sample, calibration methods are applied to the nearest k analogues.
- LWWA-PLS = Locally Weighted Weighted Averaging Partial Least Square. Similar to LWWA but principal components are searched for to reduce collinearity effects.

The third step consisted in testing the model developed in step 2, on fossil series covering the last 200 years.

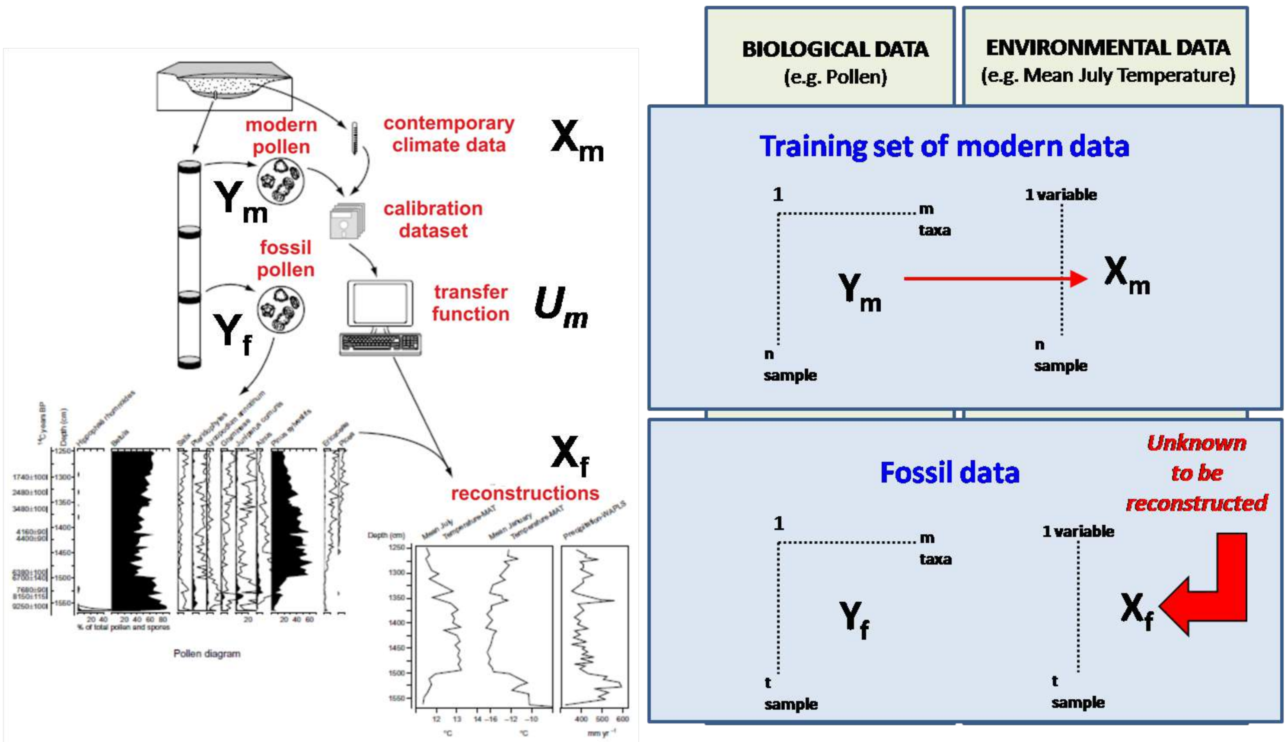

Fig. 2. Scheme of recostrunction of past environmental data "Xf" (e.g. past Temperature) from fossil pollen data "Yf". The calibration is done by using transfer function "Um" which is based on the relationship betwen modern pollen data "Ym" and modern climate data "Xm".

First tests and results obtained up to now

a) Testing pollen transfer function for the last 200 years

Pollen - climate transfer functions were tested on pollen sequences covering the last 200 years, in order to compare reconstructed T series with centuries-long instrumental records available for the same sites, provided by M. Brunetti (CNR-ISAC). A positive correspondence is observed between instrumental series and pollen-inferred Temperatures (Fig. 3).

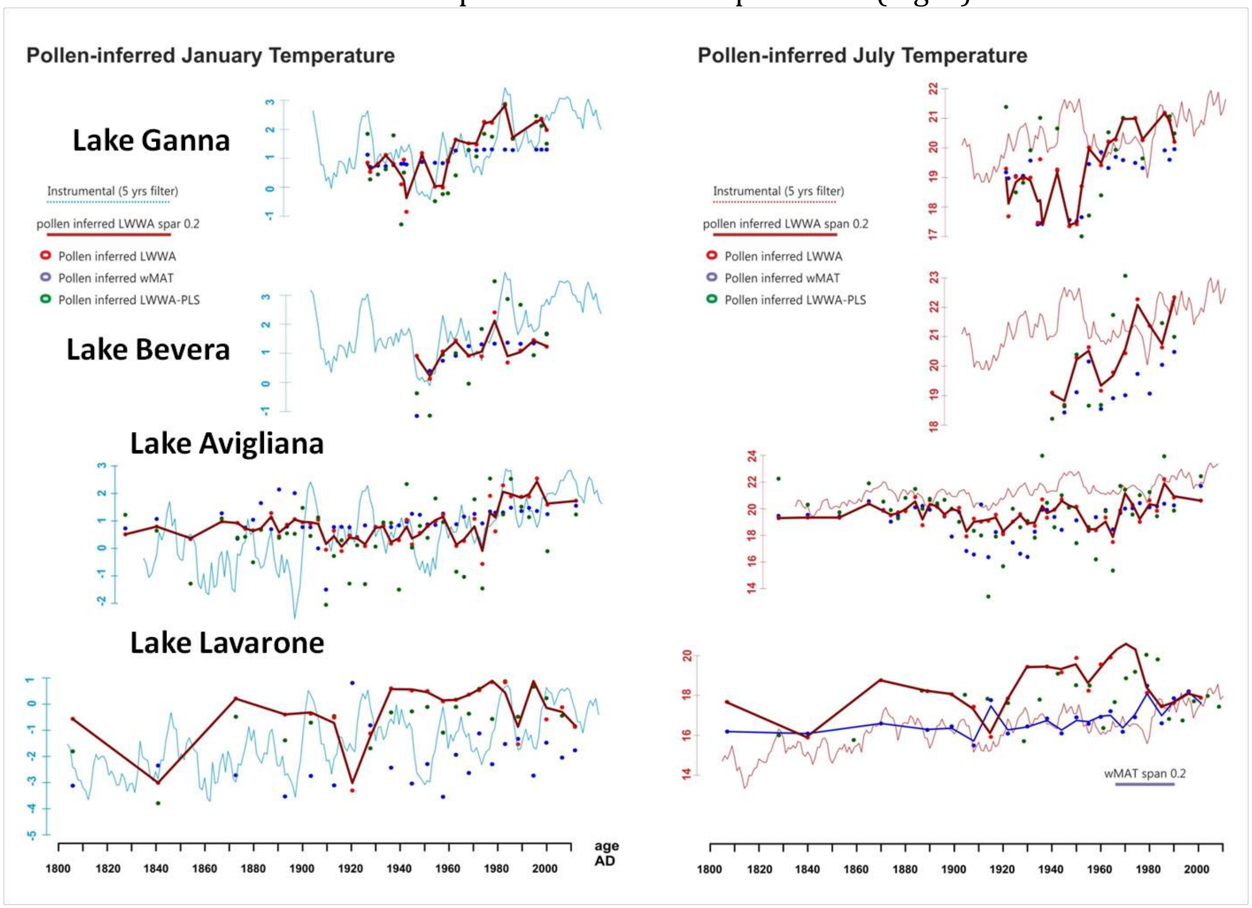

Fig. 3. Comparison between pollen-inferred Temperatures (January and July) obtained with transfer functions for four N-Italy sites, Lake Ganna, Lake Bevera, Lake Avigliana and Lake Lavarone over the last 200 years and instrumental climate data (instrumental data are kindly provided by M. Brunetti, ISAC-CNR).

b) Testing pollen transfer function over the Holocene

Pollen - climate transfer functions were then applied on few longer Holocene series to retrieve the signal of climate variability along a longer time interval (Fig. 4). First comparisons between our pollen-inferred temperatures and other temperature proxy records show that pollen-inferred T can reconstruct strong climate events (e.g. the 8.2 kyr BP cold event).

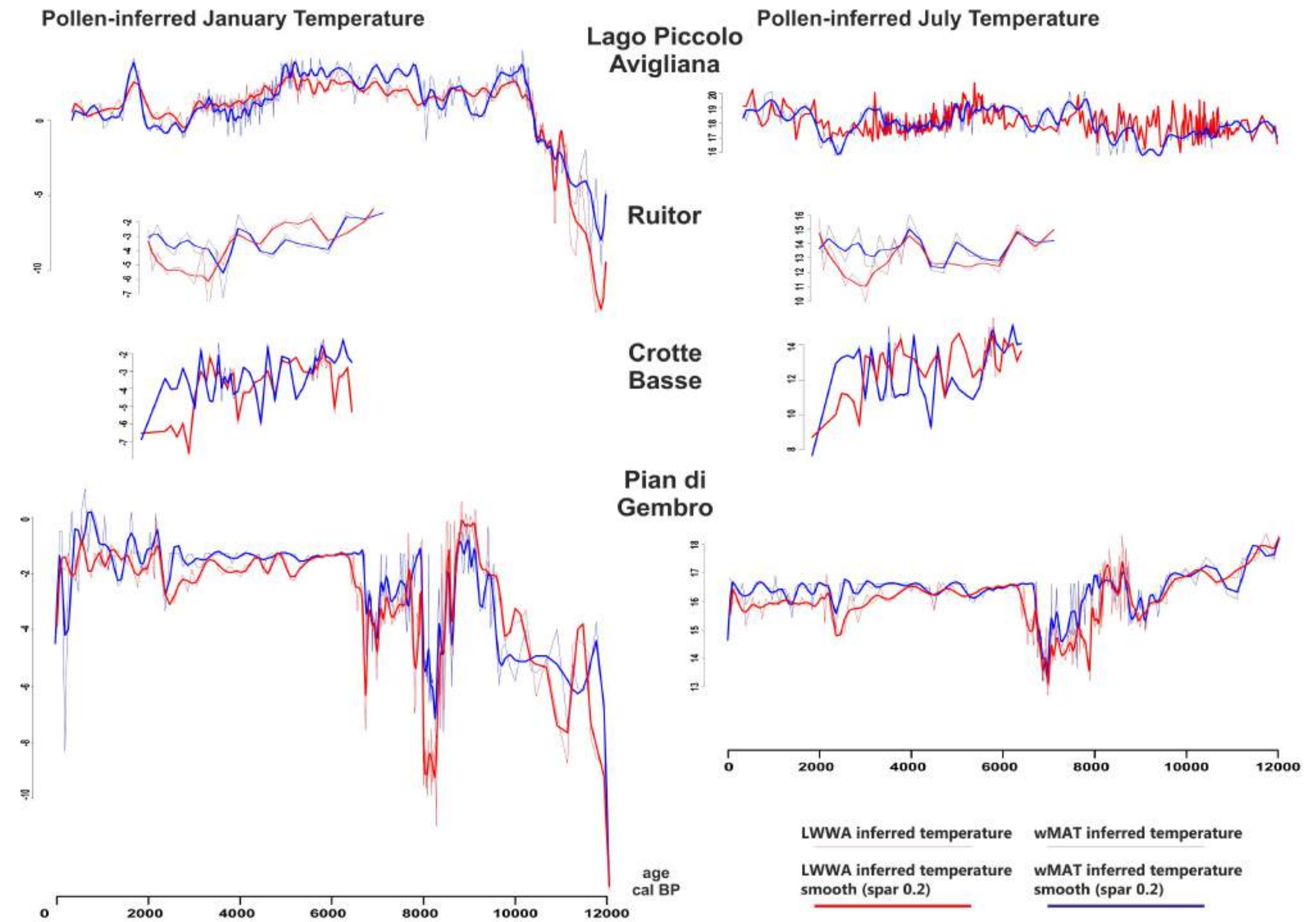

Fig. 4. Pollen-inferred Temperatures (January and July) obtained for four N-Italy sites, covering the whole Holocene (Lago Piccolo di Avigliana, Pian di Gembro) or a shorter section (Ruitor and Crotte Basse).

4. Conclusions from first tests, reconstructions and next steps

The first results of the climate reconstructions showed the main issues of reconstructing climate variables for N-Italian sites, especially for high altitude pollen records where there is also a pollen component coming from long-distance transport. The main problems are related to the available modern training set and the difficulty of the transfer functions to find analogues which could well represent the past conditions. Thus, we are currently improving the available training set by creating local training set especially designed for mountain regions.

D1.4.10.c
Dendrochronological data provided by Universities and Research Centres will be structured and organized according to the requirements of NEXTDATA and then incorporated into the project database.

The dendrochronology activities developed within the NextData Project from July 1st to December 31st, 2014, include four main groups: data analysis, creation of a database for collecting dendrochronological metadata and data at the national level, publications, communication.
As for the data analysis, the activities were mainly focused on the definition of a methodology for increasing the temperature signal in tree-ring chronologies from high-altitude Alpine sites. High-resolution land surface temperature from these environments, primarily impacted by variations in climatic regimes, may be derived from the trees growing there, that may record century-long climatic information with annual resolution. Indeed, most of the annually-resolved climatic reconstructions performed for periods prior to the instrumental records are largely based on tree-ring information.
One of the main challenges when dealing with tree-ring series for past climate reconstructions is the selection of chronologies with a stable signal in the low-frequency domain and especially the selection of only those chronologies holding a strong climatic signal, thus discarding less sensitive chronologies from sites likely impacted also by non-climatic factors.
For this purpose, the analyses were focused on the 1° x 1° grid point lat. 46°N long. 10°E, a portion of territory of the Central Alps comprising Italy, Switzerland and Austria, particularly rich in tree-ring data. Overall 42 chronologies from high-altitude (>1800 m a.s.l.) sites were collected for a total of 1259 tree-ring series of three conifers species:
-LADE (*Larix decidua*) 11 sites, Presena (2160 m a.s.l.), Val d'Avio, Sils-maria gr. Blais dal fö, Valfurva, Val solda, Bergün gr. Val Tuors, Obergurgl, Val di Fumo, Presanella, Sils Maria gr Resgia, Rabins (1850 m a.s.l.);
- PCAB (*Picea abies*) 5 sites, Bergün gr Val Tuors (2065 m a.s.l.), Val Trafoi, Obergurgl, Davos gr Dischma-fluela, Davos gr Sertig (1800 m a.s.l.)
- PICE (*Pinus cembra*) 26 sites, Valfurva Cune (2250 m a.s.l.), Val di Pejo Verdignana, Val D'ultimo Lago Verde, Val Martello Colle Cirmoli, Val di Pejo Pian Venezia, Muottas da Schlarigna, Tamagur, Mt Confinale, Valle Forni Losseda, Celerina, Val Martello Lago Gioveretto, Val Zebru Mt. Forccellino, Valle Forni Stella Alpina, Val Trafoi, Val D'ultimo Lago Pesce, Val Martello Paradiso di Cevedale, Sils-maria gr Blais dal fö, Silvaplana, Val Solda, Passo Gavia, Val Trafoi Borletti, Obergurgl Tyrol architectural timbers, Lawiner grant, Obergurgl, Engadin, Sils Maria, Gr Resgia (1850 m a.s.l.).

These chronologies were obtained from the database of University of Milan, of University of Pisa and from the ITRDB (http://www.ncdc.noaa.gov/). For each site a quality control on all individual series was applied in order to keep only those series showing growth patterns that were compatible with the ones of the other series within each site. The subsequent method applied for the selection of highly sensitive to temperature (HSTT) series was based on the comparison of each indexed series against the summer temperature series in the first step, and against the growing reference series in the pre-instrumental period. Only the series showing a high and statistically significant synchronicity (given by a Glk index at $p<0.001$) and a minimum correlation of $r>0.3$ with the reference series were saved and included in the pool for the construction of the regional chronology HSTT. In this specific approach, the HISTALP dataset (high-altitude series; Auer et al., 2007) was used.

This multi species approach has the specific objective of constructing a chronology, within a region, holding the strongest as possible signal of summer temperature (JJA) for the longest period as possible: the obtained chronology spans from AD 1388 to 2007, with a good stability of the signal (EPS>0.85) from AD 1480 up to 2007. This approach has also the advantage of checking and potentially using any individual series from trees growing in a determined region, thus opening the possibility of fully use all the in information available in large dataset.

Parallel to this approach, a regional chronology for each species was constructed by means of the Regional Curve Standardization (RCS), a type of chronology that can hold low-frequency signals of climate variations (Esper et al., 2007). For each species, only the site chronologies showing r>0.3 with the JJA temperature series over the period 1780-2007 were kept for constructing the final regional chronology: for LADE therefore only 6 site chronologies over the initial 11 were kept, for PICE only 5 over the initial 26 were kept. For PCAB only 1 chronology satisfied the required restriction, however all the 5 chronologies were kept in order to have datasets of similar consistency, but the different quality signal of the PCAB chronology was taken in consideration in the subsequent elaborations.

This classical approach leads to the construction of species chronologies that have shorter time extension than the HSTT over the domain of an EPS>0.85: LADE from (1675-2008), PCAB (1654-2005) and PICE (1650-2004).

Regression approaches as well as simple scaling (Esper et al., 2005) were applied to the HSTT, avgALL (average of all species) and avgLADE-PICE (average of LADE and PICE) chronologies for reconstructing annually-resolved summer temperatures for periods before instrumental records, reaching AD 1580, 1675 and 1725 respectively. Understanding past climatic variability in the Alps and providing century-long high-resolution temperature reconstructions may be extremely useful for modeling past climatic variability in remote sites and for correctly predicting the future impacts of ongoing climate change on the Alpine environment and its resources. Therefore the proposed approach will be replicated in other grid points comprising the Italian territory, starting from those ones rich of long series of dendrochronological data. For the Alps the temperature reconstructions should be generally easier than in the Apennines and in the Mediterranean regions given the higher number of chronologies available and the strongest signal of temperature recorded in the tree-ring chronologies. Going south, less data is available, the recorded signal is more related to drought periods and it is generally a mixed signal of temperature and precipitation.

The creation of a database for collecting dendrochronological metadata and data at the national level took place from July to December. The activities were subdivided in a first phase for organizing the collection of the various information, the subsequent involvement of the different tree-ring groups operating in Italy and finally the collection and organization of all metadata and data obtained.

The system for collecting dendrochronological metadata and data has been planned since the beginning of the activities, in July. This collection has been strategic for depicting the spatial distribution of data currently available in Italy and potentially available for reaching the Italy-2k objective of climate reconstruction.

By directly contacting the various groups operating in Italy, the NextData Project objectives have been promoted also to groups external to the Project thus widening the possibility of new collaborations. Overall, up to December 31st, 6 groups have sent their metadata, other information on Italian sites where derived from the ITRDB and other groups (University of Pavia and University of Padua) have promised their incoming participation.

In particular it was possible to collect metadata of 89 sites: University of Milan (24 sites), ITRDB (17 sites), University of Molise (13), Second University of Naples (13), University of Basilicata

(12), University of Pisa (5), Civic Museum of Rovereto - former Italian Institute of Dendrochronology - (5). Overall data of 25 site chronologies were collected: ITRDB (17 chronologies), University of Milan (4), University of Pisa (4). Both metadata and data have been periodically elaborated, ordered and passed to the Project partners for further elaborations. In particular, a quality control was performed on each chronology before entering it in the NextData database. For enhancing the visibility of the dendrochronological information collected from the various groups, a web site has been implemented (http://geomatic.disat.unimib.it/dendro). From this website it is possible to download the metadata relative to each chronology by clicking over any of the points on the map. In particular, for each site it is possible to have information on Chronology name, Site name, Coordinates, Altitude, Cores extraction date, Chronology time span, Measured parameter, Species, Author (or group), Institution owner of the data, Address of the Institution, Contact name, e-mail, Bibliographic reference and Abstract (when available).
The system is prepared to receive new information at any time, so that if new data is sent by some of the groups, it is possible to easily update the information by adding the new points on the map. In December the collection of all metadata and data available in the ITRDB for Italian sites was started so that within few months all information in this open database will be checked for quality and then transferred to the NextData Project.
Regarding publications, some elaborations in GIS environment were undertaken from September to October for a paper dealing with the tree recolonization patterns in the Forni Glacier forefield (the largest Italian valley glacier) according to active geomorphological processes and glacier retreat phases since the end of the Little Ice Age (about AD 1850).
The estimation of the lag time between surface exposure after glacier retreat and the successful tree establishment (ecesis interval) has been assessed along a transect in the forefield and in the proglacial area. As we could demonstrate, tree ecesis intervals along the valley bottom linearly dropped from a mean of 64 years at about 2540 m from the glacier front position of 2011 (post Little Ice Age period), to a mean of 7 years at about 420 m. The spatial distribution of the ecesis anomalies has shown that where geomorphological processes are present or where unstable till and rock deposits characterize the substrate, then tree establishment and growth after glacier retreat are delayed with respect to the predicted values of ecesis. The study, by reporting linearly decreasing ecesis intervals, highlights a climate-driven dynamics which poses important implications in dating minimum ages of landform surfaces within glacier forefields, with unknown glacier front retreat patterns. It also demonstrates that ecesis anomalies may be used in glacier forefields also for detecting portions of territory where to study the impacts of active geomorphologic processes. In November the manuscript has been submitted to Arctic Antarctic and Alpine Research for the peer review process.
Since December the publication activities dealt with the data organisation for the paper of dendroclimatic reconstructions of summer temperature for the grid point 46°N 10°E.

Two main events took place for what concerns the communication, in September and in December. The first oral communication was given at the *SGI-SIMP* (Società Geologica Italiana & Società Italiana di Mineralogia e Petrologia) congress *The future of the Italian Geosciences of the future* at University of Milan, session Climate change and the Earth System: understanding the past, analyzing the present and predicting future scenarios. The communication entitled 'An innovative approach to high-resolution summer-temperature reconstructions for the last centuries using large tree-ring datasets from the Central Alps' (by LEONELLI G., COPPOLA A., BARONI C., SALVATORE M.C., PELFINI M.) dealt with the presentation of the HSTT approach for constructing chronologies holding a strong temperature signal. The dataset initially comprised only chronologies from the Ortles-Cevedale and the Adamello-Presanella Groups plus another 9 chronologies added from the ITRDB for a total of about 800 individual series of tree-ring growth series covering the period from nearly AD 1300 up to 2008.

The second oral communication entitled 'Tree-ring climate reconstructions in the Italian Alps' (by Pelfini M. and Leonelli G.) took place at the *Italy 2k - NextData* congress at Accademia Nazionale dei Lincei, in Rome. The presentation dealt with the several approaches that may be undertaken for reconstructing past climatic information using a dendrochronological approach: from the spot retrieval of subfossil logs included in till and moraines o some glaciers of the Central Alps (dendroglaciological approcah) to the reconstruction of past climate variability by analyzing long tree-ring series from large datasets. A particular attention was given to the need of starting a systematic approach for constructing century- to millennia-long tree-ring chronologies also in the Italian side of the Alps, following what already done in Austria and France, moving a step forward from the spot retrieval of subfossil logs. It was also the occasion to propose again a new version of the HSTT chronology including the approach starting from the 42 site chronologies and the derived summer temperature reconstruction for the grid point 46°N 10°E for periods prior to instrumental records. A special focus was also given to the potential of tree-ring stable isotopes for reconstructing past climate variability at the century scale, showing some results from the Mt. Blanc area, Italian side. The high potential of this climate proxy is already demonstrated by the construction of century-long chronologies that have been already constructed in the Swiss Alps and in Slovenia.
A combination of tree-ring widths and of stable isotopes ratios ($\delta^{13}C$ and $\delta^{18}O$) in the cellulose measured in long-living trees but also in dead wood like e.g. the subfossil wood retrieved in glacial environments, has the high potential of allowing more reliable climate reconstructions and to extend back in time for centuries up to millennia the chronologies also in the Italian side of the Alps.

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