



# Project of Interest
# "NextData"

## Research project :

## Multy-proxy reconstruction of Eastern Alpine Holocene climate

**Coordination: Prof. Carlo BARBANTE**

**IDPA-CNR**

**Work Pachage :**
WP 1.4 ; WP 2.3; WP 2.4

**TITLE OF THE PROPOSED PROJECT:**
Multi-proxy reconstruction of Eastern Alpine Holocene climate

**Project duration:** **2013-2015**
**start date:** **1 March 2013**
**end date:** **30 September 2015**

**Scientific coordinator of the proposed project:**
Prof. BARBANTE Carlo

**CNR Institute coordinating the proposed project:**
IDPA-CNR

**Participating units:**

**Unit 1 :**
IDPA-CNR, Jacopo Gabrieli (P.I.), Luisa Poto, Michela Segnana, Giulio Cozzi, Carlo Barbante.
IDPA-CNR is a world leader in the study of ultra-trace inorganic and organic markers in ice and environmental samples. In particular, IDPA-CNR has a huge experience in the analysis of trace elements, heavy metals, rare earth elements and other environmental proxies in glaciological and sedimentary records. IDPA-CNR is coordinating the administrative, technical and scientific activities of the project.

**Unit 2:**
University of Venice Ca' Foscari (UNIVE), Department of Environmental Science, Informatics and Statistics, Natalie Kehrwald (P.I.), Giuliano Dreossi, Andrea Spolaor.
The University of Venice houses necessary instrumentation for the completion of this project including an Orbitrap for determining organic molecules, and an ion chromatograph for determining major ions. The research team at the University of Venice will be responsible for analyzing all organic components of the ice cores as well as assisting with data dissemination and outreach.

**Unit 3:**
Ohio State University (OSU), Byrd Polar Research Center, Paolo Gabrielli (P.I.).
OSU is responsible for generating parallel climate histories determined from the Ortles ice cores. Due to the unique nature of Ortles ice, it is essential to provide parallel, independent compilations of these cores in order to determine that the climate records are repeatable and robust. No budget is required for this unit since the Ortles project has just been founded for that by NSF.

## 1. GENERAL INFORMATION

### Abstract of the proposed project

The Eastern Italian Alps are located near one of the areas in the world with some of the longest records of extreme environmental use by human activity including metal smelting for thousands of years, intense logging, heavy industry, and extensive agriculture. Ice and peat bog cores record this anthropogenic environmental change as well as archiving climate variables that may be separate from any human activity. Few continuous high-resolution Holocene climate records exist in the Eastern Italian Alps. Here we will examine the only regional ice cores to bedrock in Ortles (46°30' N, 10°32 E, 3850 m a.s.l.) and an ombrotrophic peat bog record extending back 11,000 years before present (Danta di Cadore, 46°34' N, 12°33 E, 1400 m a.s.l.). We seek to place the recent rapid melting of Alpine glaciers into the context of regional human history to better understand human and natural vulnerability and adaptation to climate change.

### Main goals of the project

We aim to quantify the temporal and spatial changes in Eastern Alpine climate using the Ortles ice core and the Danta di Cadore peat bog records. Preliminary radiocarbon results demonstrate that the Ortles record is < 2000 years old, while the Danta di Cadore record encompasses ~11,000 years. These Holocene histories include the change from a post-glacial environment to the recent rapid warming. This area has been subject to 1000s of years of human activity such as Roman and Venetian smelting, logging, agriculture, and industry. These climate histories archive climate and human activity, and place recent Alpine warming into a context of 1000s of years.

We intend to answer the following key questions:

1. Is the current Eastern Alpine warming unprecedented in the Holocene?
2. How did Eastern Alpine climate change through time and space?
3. What human activities are recorded in regional ice and sediment records?
4. What evidence exists for pre-Industrial Revolution human environmental impacts?

### Expected results of the project

We expect to generate the following results from the project:

1. Two complete parallel climate and environmental records from the Ortles ice cores to bedrock. These climate records will examine past atmospheric chemistry, temperature and circulation changes, biomass burning and possible land use change.

2. Compare these results with the Ortles ice cores studied at Byrd Polar Research Center, University of Ohio (BPRC) in order to determine the robustness and repeatability of these climate records.
3. Two local low-altitude 11,000-year climate records from the ombrotrophic Danta di Cadore peat bogs.
4. Determine regional environmental change from pollen assemblages, diatom stable isotopes, and trace elements in the peat bog records to examine possible human impacts on local ecosystems.

**Role of the different units**

**Unit 1 IDPA-CNR** is responsible for the following aspects of the project:

- Coordination of the administrative, technical and scientific activities of the project; preparation of periodical technical and financial reports.
- Processing of the peat-bog and ice core sections; sample preparation.
- Reconstruction of the past climate history archived in the Ortles and Danta di Cadore cores through the determination of several climatic and environmental proxies such as dust, trace elements (TEs), rare earth elements (REEs), Pb isotopes.
- Investigation of changes in past atmospheric circulation patterns and impact of anthropogenic pollution on Eastern Alpine ecosystems.
- Reconstruction of climatic and ecological variations during the Holocene through the determination of biological proxies such as pollen and diatoms.

**Unit 2: The University of Venice, Ca' Foscari** is a world leader in the study of ultra-trace inorganic and organic markers in ice and environmental samples. The University of Venice houses necessary instrumentation for the completion of this project including an Orbitrap for determining organic molecules, and an ion chromatograph for determining major ions. The research team at the University of Venice will be responsible for analyzing all organic components of the ice cores as well as assisting with data dissemination and outreach.

**Unit 3: The Byrd Polar Research Center, Ohio State University** is responsible for generating parallel climate histories determined from the Ortles ice cores. Ortles is a unique climate record in that the upper meters of the glacier are water-saturated, while the deeper sections contain cold ice with intact climate records (Gabrielli et al., 2012). Due to the unique nature of this ice, it is essential to provide parallel, independent compilations of these cores in order to determine that the climate records are repeatable and robust.

## 2. DETAILED PROJECT DESCRIPTION

### State of the art and motivations

Human activities including fossil fuel burning are currently altering the global climate system at rates faster than ever recorded in geologic time. The temperature rise associated with anthropogenic climate change is causing glaciers to melt worldwide, and to release their melt water into nearby valleys, eventually contributing to sea level rise. Thus both high elevation sites and valley systems are important indicators of climate change, and it is imperative to gather and analyze these climate records while the records themselves still exist.

Snow pit and initial shallow ice core studies demonstrate that the Eastern Italian Alps glaciers are thinning from the top down, essentially "decapitating" the glaciers, as well as melting quickly at lower elevations. Few to no continuous climate records exist from the Eastern Italian Alps, and it is unknown if similar changes have occurred during human history in the region, or if this sudden decrease in stored freshwater is anomalous. Our research group at IDPA-CNR has drilled two of the only continuous climate records from this region: a series of ice cores to bedrock on the summit of Ortles and 11,000-year peat bog records from Danta di Cadore. These histories can provide essential insight into the interplay between climate and human activity through time.

The Ortles ice cores are the only continuous high-altitude proxy from the Eastern Alps. The glaciers are rapidly thinning to the point where the upper ~ 40 m are water saturated, but cold ice remains below this boundary. Preliminary studies (Gabrieli et al., 2012) demonstrate that the ice below this water saturated upper section contains intact annual to decadal-scale climate information. This rapid retreat and surface ablation is present throughout the Eastern Alps, as demonstrated by snow pit and cores studies on Marmolada (46° 26' N; 11° 51' E, 3343 m a.s.l.) and Piz Boè (46° 30′ N, 11° 49′ E, 3152 m a.s.l.). Mountaineers climbing Ortles during the summer of 2012 noticed meltwater flowing on the glacier surface and melting ice destabilized structures including the summit cross. This rapid surface melt suggests that the archived Ortles ice cores may contain ice that is no longer present in nature, and the cold ice and water saturated boundary may have extended deeper into the glacier. When this ice melts, vital climate proxy records will disappear forever. The investigation of this irreplaceable ice and the incorporation of innovative methods guarantees the originality of the project. The Ortles ice cores contain distinctive organic material that allows for radiocarbon dating of the core (Gabrielli et al., 2012). The joint BPRC and IDPA-CNR research teams drilled a series of deep ice cores from Ortles during the autumn of 2011. Three of these cores (~ 76 m) reach bedrock, and the other (~ 74 m) is within meters of bedrock. The paleoclimatology research group at IDPA-CNR is archiving these ice cores and will analyze their climate variables (elemental and organic markers, indicators of past atmospheric chemistry and circulation) under the scope of this project.

In summer 2011, an IDPA-CNR team drilled a 7.0 m long core from the Danta di Cadore bog. Preliminary dating from radiocarbon analysis of organic fragments indicates that this record continuously covers last 13,000 years with the possibility of extending into the late Glacial period when lake sediments present at the base of the peat strata are incorporated into the record. This core will be analyzed through an innovative multi-disciplinary approach which combines geochemical (ash, TE, REE, isotopes, organic carbon) and biological (pollen, diatoms, plant macrofossils, chironomids, etc.) proxies. If enough is known about the biology and ecological tolerances of a taxon, that taxon provides an indicator species for the reconstruction of past habitat, community, and environment, including climate. Similarly, if a taxa assemblage resembles a modern community that lives in a defined ecological range today, that assemblage may be used to infer past conditions. These assemblages will also be compared with other glacial and sedimentological Alpine archives, providing the first such quantitative study in Southern Eastern Alps. This proposed combination of climate tracers expands the limits of proxy information gleaned from ice cores and peat bogs and provides data for one of the least understood areas of the European climate system.

**Detailed description of the project, including the work plan, deliverables and milestones (explicitly indicating the activities of the different years)**

The paleoclimatology research group at IDPA-CNR is archiving two deep Ortles ice cores and two Danta di Cadore peat bog cores and will analyze their climate variables (elemental and organic markers, indicators of past atmospheric chemistry and circulation) under the scope of this project. In order to achieve these goals, we will utilize a four-tiered approach of 1) field activities, 2) sample preparation and data acquisition, 3) data interpretation, 4) dissemination of results.

1) FIELD ACTIVITIES: Although the majority of the outlined goals use samples collected during previous drilling campaigns, it is necessary to conduct additional field work in order to obtain as much information as possible about the modern climate system in the study areas. We will perform year glaciological surveys on the Ortles glacier in order to sample the seasonal snowpack and to download data from the automatic weather station. These surveys will take place at the beginning (September) and end (June) of each accumulation season. We will collect the lake sediment layers present 2-3 m under the 7 m Danta di Cadore bog in order to extend the climate reconstruction into the Last Glacial . We will sample ~30-40 local springs and bogs, to determining modern hydrochemical parameters and diatom taphocenosis. This modern survey is necessary to calibrate the fossil diatoms with ecological and microclimatic wetland characteristics.
2) SAMPLE PREPARATION AND DATA ACQUISITION: Peat and ice cores will be processed will be processed at their highest achievable resolution and will contain multiple parallel subsamples. We will cut the peat cores into 2 sub-cores where one section will be analyzed by X-ray fluorescence core

scanner (XRF-CS) to determine 29 chemical elements at a nearly continuous resolution (< 2.5 mm) and the other core will be used for trace elements (TE), rare earth elements (REE), Pb isotopes by ICP-MS analyses and for physical determination (water content, ash, organic matter content). Pore-water pH, electrical conductivity (EC), soot and micro-carbon particles will be also measured. Biological markers will be studied at the same resolution of chemical constituents. In particular, we will determine pollen assemblages and diatoms taphocenosis at resolutions ranging from 10 to 25 mm. The age/depth relationship will be based on radiocarbon (14C) and radiogenic (210Pb and 137Cs) analyses. We will develop, test, and validate a new analytical method to determine the isotopic composition (δ2H, δ18O) of diatoms valves and peat-organic material (δ13C, δ14N). The presence of anthropogenic organic pollutants (e.g. PAHs, PCB, pesticides, stanols, etc.) in the surface layers will also be also determined. We will analyze pollutants extracted in organic solvents using GC-MS and HPLC-MS.

The firn and ice cores will also be cut into two sub-cores. We will decontaminate and analyze the first core using a continuous melting system developed at the IDPA-CNR laboratories. The concentration of 20 TEs, black carbon (BC), dust as well as electric conductivity will be continuously measured, reaching a resolution < 5 mm. We will also directly collect discrete samples from the melting device at high resolution (20 to 50 mm) for heavy metals, Pb isotopes, and levoglucosan. The other sub-core will be subdivided to provide samples for stable isotopes (resolution ranging from 10 to 30 mm), terpens and persistent organic pollutants. For these organic compounds the resolution will be constrained by the analytical sample requirements, likely ranging from 3 to 5 samples per meter.

3) DATA INTERPRETATION: A multidisciplinary approach integrating the geosphere, atmosphere, cryosphere and biosphere is the only way to examine environmental cause and effect mechanisms. The Ortles ice core represents the only reasonable possibility to obtain a preserved glaciological record from the Eastern Alps. Similarly, the Danta di Cadore peat bog offers a unique possibility to study the climatic and environmental variations from the last glacial through the present interglacial in the southern slope of the Eastern Alps. In particular, the ice core profile will better define the climatic conditions over the last two centuries, while the terrestrial record will permit contextualizing climate change over a millennial time-scale. The comparison between these results and those obtained from other Alpine archives, including the northern slope and the Western Alps will provide new elements to better interpret the puzzle of the global climate system.
4) DISSEMINATION OF THE RESULTS: Explaining climate change to a wide variety of audiences is necessary to clarify both the scientific and societal effects of climate change. We believe in the importance of making scientific research accessible to as many people as possible and so strive to continue public education well as to disseminate our results through traditional scientific

media. Peer-reviewed journals remain the gold-standard by which science is evaluated. Our researchers have published similar studies in journals such as Science, Nature, Nature Geoscience, Environmental Science and Chemistry, Atmospheric Chemistry and Physics, and Geophysical Research Letters. In the past two years, our paleoclimate group has been invited to give keynote addresses at the IPICS, Destination Europe (ERC semi-annual conference), and Chinese Academy of Science conferences and we have presented multiple talks at INQUA, AGU, EGU and other international conferences. We organized a PAGES conference in June 2012 to combine ice, sediment and global climate models. This track record demonstrates that we are capable of continuing such internationally-recognized, interdisciplinary science dissemination in the future. We also seek to involve the public in our science. In the past two years alone, our researchers have instructed a field camp for Italian high school students, contributed to Beyond Penguins and Polar Bears which won the Science prize for online resources in education (SPORE) (Science 28 January 2011), published a general audience article in Ligabue, gave climate change talks to community action groups, and contributed to climate change literacy blogs (www.climerati.it, http://antarcticaslw2013.blogspot.it/). We anticipate continuing such outreach activities under the auspices of the NextData program.

*Table 1 Project indicators and milestones*

| **PROJECT INDICATORS** | Indicator unit | n. | Milestone |
|---|---|---|---|
| **FIELD ACTIVITIES** | | | |
| Glaciological survey, snowpit sampling | Number | 6 | 09/2015 |
| Peat bog coring | Number | 1 | 06/2014 |
| Spring and wetland sampling and datalogger installation | Sampling sites | 40 | 06/2014 |
| **SAMPLE PREPARATION AND DATA ACQUISITION** | | | |
| Ice core logging and stratigraphy | Meters | 75 | 12/2013 |
| Ice core processing for continuous analysis | Sample number | 100 | 12/2013 |
| Ice core processing for discontinuous analysis | Sample number | 4000 | 12/2013 |
| Ice core processing for pollen analysis | Sample number | 1500 | 12/2013 |
| Ice core processing for organics analysis | Sample number | 200 | 12/2013 |
| Ice core continuous chemical analysis (TE, dust, BC) | Meters | 60 | 10/2014 |
| Ice core isotopic analysis | Sample number | 4000 | 06/2015 |
| Ice core Pb isotopes, TE and REE analysis | Sample number | 700 | 10/2014 |
| Ice core organic analysis | Sample number | 400 | 03/2015 |
| Peat core logging and stratigraphy | Meters | 10 | 06/2014 |
| Peat core processing and sub-sampling for XRF-CS | Sample number | 30 | 07/2014 |
| Peat core processing for discontinuous analysis | Sample number | 900 | 07/2014 |
| Peat core $^{14}C$ analysis | Sample number | 40 | 09/2014 |
| Peat core $^{210}Pb$ and $^{137}Cs$ analysis | Sample number | 50 | 09/2014 |
| Peat core ash, density, organic material analyses | Sample number | 800 | 06/2015 |
| Peat core Pb isotopes, TE and REE analyses | Sample number | 300 | 06/2015 |
| Peat bog pollen analyses | Sample number | 800 | 06/2015 |
| Peat bog diatom analyses | Sample number | 300 | 06/2015 |
| Peat bog isotopic analyses | Sample number | 200 | 04/2015 |
| Spring and wetlands chemical and biological analysis | Sample number | 500 | 09/2014 |

## Link to other NextData Projects

This proposal is closely linked with many other activities already present in NextData and especially in the frame of the following Working Pagages:

- WP 1.4 Environment and climate data from ice cores
- WP 2.3 Archive of data from non-polar ice cores and long-term biological data
- WP 2.4 Archive of paleoclimatic data from sediment cores

Several agreements have been already taken to assure the best synergies within NexData.

## REFERENCES:

Gabrielli, P., Barbante, C., Carturan, L., Cozzi, G., Dalla Fontana, G., Dinale, R, Dragà, G., Gabrielli, J., Kehrwald, N., Mair, V., Mikhalenko, V., Seppi, R., Spolaor, A, Thompson, L.G., Tonidandel, D. (2012) Geografia Fisica e Dinamica Quaternaria, Discovery of cold ice in a deep drilling site in the Eastern European Alps. 35, 101-105, DOI 10.4461/GFDQ.2012.35.10.