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DETECTING INDICATORS OF CLIMATIC AND ENVIRONMENTAL CHANGES USING DENDROGLACIOLOGICAL ANALYSIS, STABLE ISOTOPES AND VOCs AT THE MIAGE GLACIER (AOSTA VALLEY, ITALY)

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INTRODUCTION

The Miage Glacier (Aosta Valley) is the largest debris-covered glacier in the Italian Alps (Pelfini *et al.* 2012) and it has been the object of several investigations about its changes, its morphologic and glaciological features and its relations with the environment (*e.g.* Deline and Orombelli 2005; Mihalcea *et al.* 2008; Caccianiga *et al.* 2011; Leonelli and Pelfini 2013).

Some innovative information supporting the geomorphological investigations can be obtained through the study of the trees growing in the area. For instance, by comparing the properties of the trees growing on stable substrates at the glacier's proximity with the ones growing on the supraglacial debris layer, insights can be deduced about the glacier's dynamics and the region's past climate.

In this thesis I aimed at testing a way for supporting the identification of climatic and environmental signals in the trees, through the aggregation of three methods:

a) The analysis of the morphological and dimensional characteristics of tree rings;
b) The study of the stable isotopes ($\delta^{13}C$ and $\delta^{18}O$) in the tree rings;
c) The analysis of VOCs (Volatile Organic Compounds) emitted from the leaves.

The obtained results suggest the potential of reconstructing and analyzing medium and long-term environmental changes in a glacial area by means of these methods.

STUDY AREA

Samples were collected from two selected study areas on the Miage Glacier (fig.1).

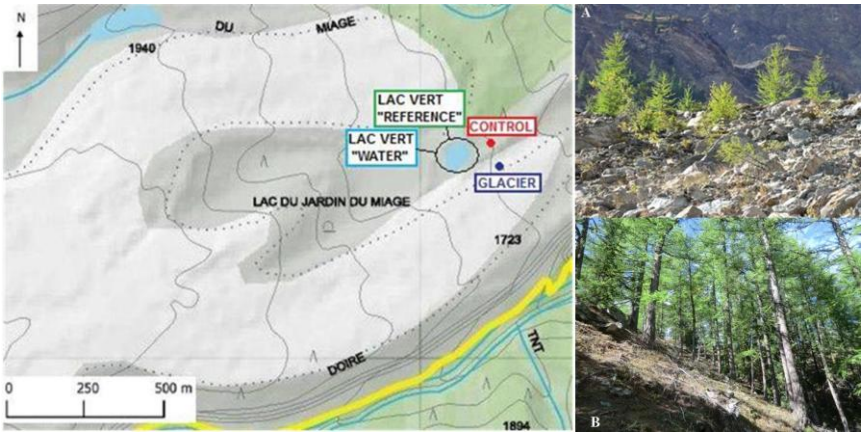

Figure 1. The Miage Glacier and the selected study areas: the study area 1 includes the sites "Control" and "Glacier", the study area 2 includes the sites "Lac Vert WATER" and "Lac Vert REFERENCE". Examples of trees at the "Glacier" site (A) and "Control" site (B) are reported on the right.

1) The first study area included two sites placed at the same altitude, one on the glacier ("Glacier" site) and the other on the moraine ("Control" site). While the "Glacier" site featured remarkable diurnal temperature ranges and was characterized by the very unstable debris covering the glacier surface, the "Control" site featured reduced diurnal temperature ranges and was located over a more stable forest soil. Dendrochronological samples and samples of leaves were collected from trees of similar height (3-5 m) of the species *Larix decidua* Mill. placed at these two locations. Methods a), b) and c) were applied to the samples collected at this study area.
2) The second study area comprised a small intra-morainic lake called Lac Vert, placed on the left internal moraine of the southern lobe of the Miage Glacier. Dendrochronological samples were collected from trees of the species *Larix decidua* Mill. located very close or subemerged by the lake's glacial water, which has been known to be a factor influencing their growth (Vezzola 2010). Method a) was applied to the samples collected at this study area.

ANALYTICAL TECHNIQUES AND DATA ANALYSIS

The dendrochronological samples collected at the "Glacier" and "Control" sites were prepared and analyzed, and morphological and dimensional characteristics of tree rings were detected. These samples were also analyzed at the IRMS mass spectrometer in order to identify the isotopic values $\delta^{13}C$ and $\delta^{18}O$ in the tree rings. The samples of leaves were prepared using the HS-SPME (Headspace Sampling Solid-Phase MicroExtraction) method and analyzed using the GC/MS (Gas Chromatography-Mass Spectrometry) technique (Giorgi *et al*. 2012), in order to evaluate the differences in VOCs emissions at the two studied sites.

The dendrochronological samples collected at the Lac Vert were also prepared and analyzed, and the morphological and dimensional properties of tree rings were identified. The obtained growth chronologies were integrated with the data collected in a previous study (Vezzola 2010). The average chronologies of trees influenced by the water of the lake and trees growing in the proximity of the lake but not influenced by its water were compared to the isotopic values $\delta^{13}C$ and $\delta^{18}O$ collected in tree rings of trees at the Lac Vert (data obtained from Gabrieli 2011) and to the monthly climate data of temperature and precipitation. Using this data the climatic signal registered in tree rings was analyzed.

RESULTS AND DISCUSSION

Trees at the "Glacier" and "Control" sites showed different growth characteristics. Average higher ring width was observed at the "Glacier" site compared to those at the "Control" site (fig.2A). This result suggests an influence of environmental factors as substrate instability inducing strong growth release in bent trees. Instead, the average indexed chronologies "Glacier" and "Control" showed similar ring width (fig.2B), which suggested an analogue influence of the climate on the tree growth at the two sites.

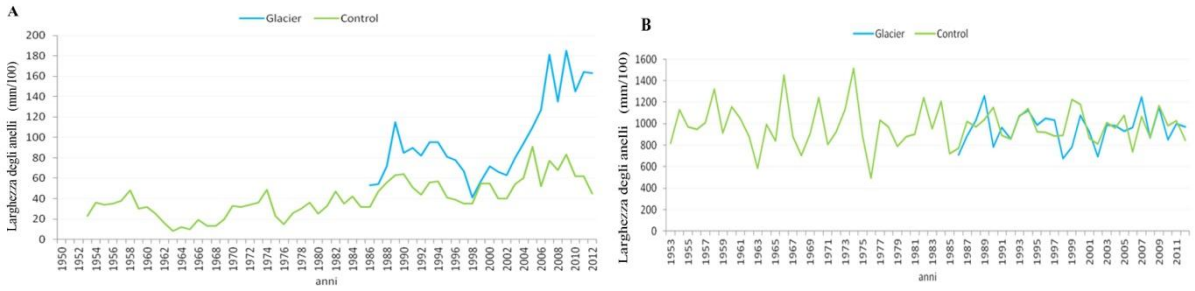

Figure 2. Ring-width mean chronologies (A) and ring-width mean indexed chronologies (B) at the "Glacier" and "Control" sites.

The analysis of the isotopic values $\delta^{13}C$ and $\delta^{18}O$ over the period 2003-2012 showed statistically significant differences between the two series. Average higher values both for $\delta^{13}C$ (fig.3A) and $\delta^{18}O$ (fig.3B) were

observed in the tree rings of trees at the "Glacier" site when compared to the "Control" site. This result suggests higher stress in the tree growth of trees located at the "Glacier" site.

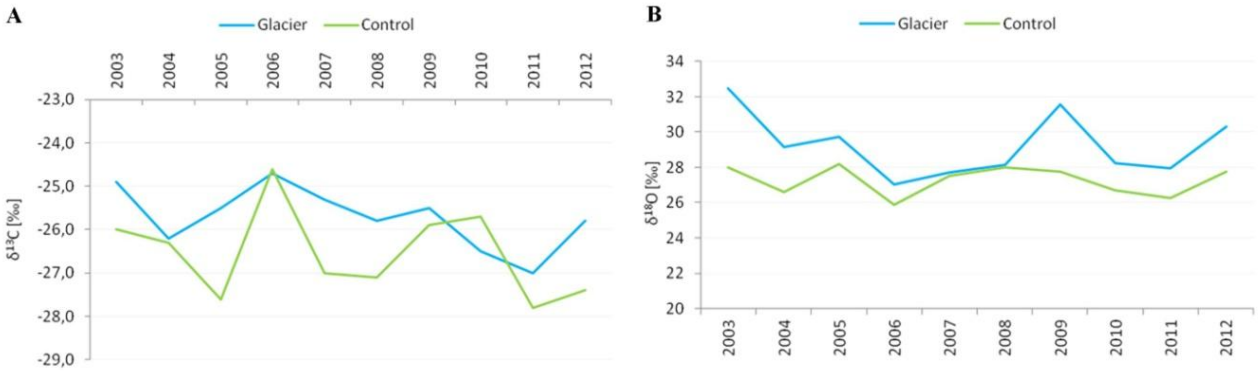

Figure 3. Isotopic values $\delta^{13}C$ (A) and $\delta^{18}O$ (B) in the tree rings at the "Glacier" and "Control" sites.

Statistically significant differences were also found in some VOCs emissions at the "Glacier" and "Control" sites. In particular, the monoterpene β-myrcene and the sesquiterpene estragol showed higher emission rates at the "Glacier" site (fig.4).

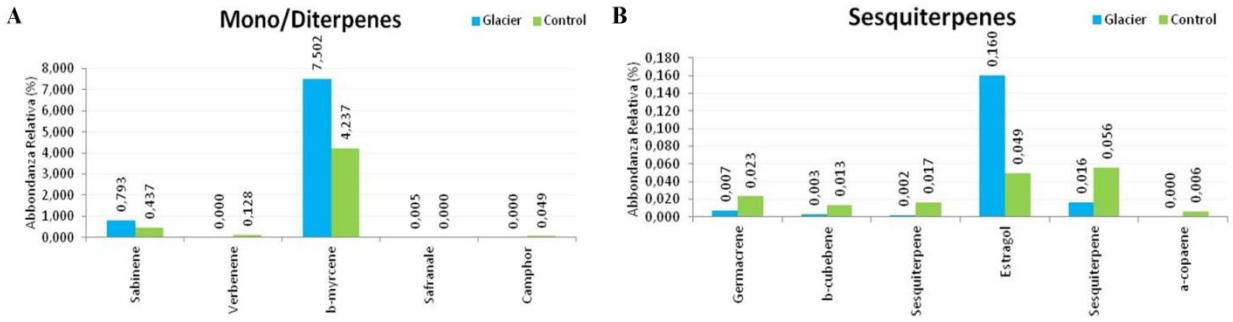

Figure 4. Monoterpenes and diterpenes (A) and sesquiterpenes (B) emissions from leaves collected at the "Glacier" and "Control" sites.

These results were likely due to water and thermal stress conditions at the "Glacier" site.

The tree-ring growth chronologies of trees influenced by the Lac Vert water and of trees fed only by precipitation showed the same climatic signal. The correlation coefficients obtained by the climatic analysis show peculiar correlations between the WATER- $\delta^{13}C$ values and the temperature data of June (fig.5A): this result suggests the absence of stress in the trees influenced by the water of the lake in the month of June, due to the increase of the temperature values. No statistically significant correlation coefficients were obtained for the $\delta^{18}O$ values and the precipitation data (fig.5B).

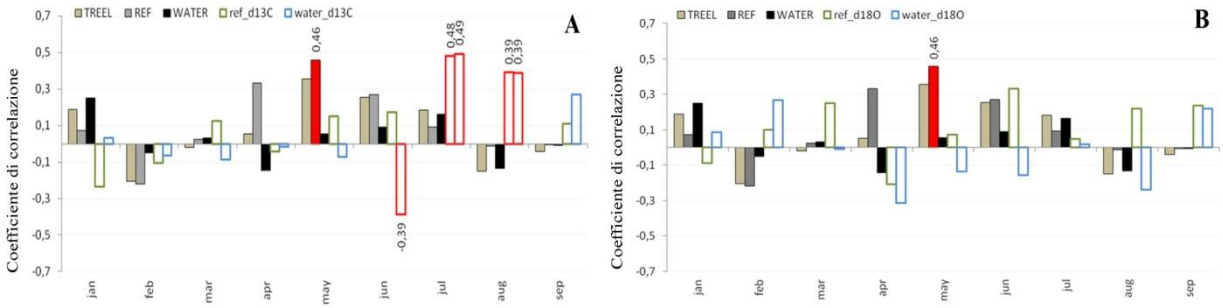

Figure 5. Correlation coefficient obtained over the period 1980-2009 by comparing the ring-width mean indexed chronologies WATER, REFERENCE and TREELINE, the temperature data and the isotopic values $\delta^{13}C$ of the trees at the Lac Vert (A) and correlation coefficient obtained by comparing the ring-width mean indexed chronologies WATER, REFERENCE and TREELINE, the precipitation data and the isotopic values $\delta^{18}O$ of the trees at the Lac Vert (B).

CONCLUSIONS

The environmental characteristics, like the debris instability and the presence of glacial water, may influence the tree growth, the isotopic values $\delta^{13}C$ and $\delta^{18}O$ in the tree rings and some VOCs emissions. The results of this thesis suggest that the environmental and climatic changes may be investigated in the trees, through the aggregation of three methods:

a) The analysis of the morphological and dimensional characteristics of tree rings;
b) The study of the stable isotopes ($\delta^{13}C$ and $\delta^{18}O$) in the tree rings;
c) The analysis of VOCs (Volatile Organic Compounds) emitted from the leaves.

These results suggest the benefits of the methods tested and the exposed techniques are general enough to be applied in other contexts, where trees are influenced by climatic and environmental stresses.

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