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TESTING POLLEN-CLIMATE MODELS OVER THE LAST 200 YEARS IN N-ITALY USING INSTRUMENTAL DATA

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ABSTRACT: We evaluated pollen-climate models developed for past temperature reconstruction in northern Italy by comparing pollen-inferred temperature series with site-specific instrumental series in two records covering the last 200 years and provided with a pollen sample resolution of 5/9 years. Moderate to good correlation is found. We discuss the methodological approach and the possible influence of human activities in the pollen-inferred reconstructions.

KEYWORDS: North Italy, pollen data, instrumental temperature, pollen-climate models, quantitative summer temperature, last 200 years

1. INTRODUCTION

During the last 50 years, different procedures were developed to quantitatively estimate past environmental and climate variables from stratigraphical microfossil assemblages, including pollen data (Brewer et al., 2007, Juggins & Birks, 2012). The validation of pollen-climate models and the climate reconstructions obtained from palynological data for intervals older than the instrumental data are only possible using statistical tests and procedures (e.g. Juggins & Birks, 2012 and reference therein). So far, only one paper presented climate reconstructions based on pollen spectra and their validation against instrumental data (St. Jacques et al., 2015). No attempts have been done in Italy.

In this paper we present the first results concerning the development and testing of pollen-climate models to reconstruct summer temperatures over the last 200 years in northern Italy. We use two previously published high-resolution pollen records, discuss methodological issues and validate the pollen-inferred reconstructions based on the direct comparison with instrumental data obtained for the same sites.

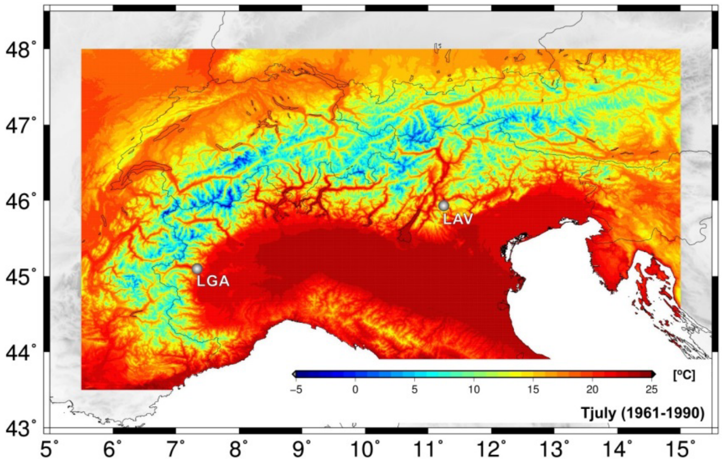

Fig. 1 - Map showing the location of the two study sites on T july climatology (1961-1990), adapted from Brunetti et al. (2014). LGA: Lago Grande di Avigliana (353 m a.s.l.) at the foothills of the western Alps and LAV: Lago di Lavarone (1115 m a.s.l.) in the eastern side of the pre-alpine region.

2. MATERIALS AND METHODS

2.1 Study sites and pollen data

The two study sites are located at different altitudes and are characterized by different mean climatological conditions (Fig. 1). Lago Grande di Avigliana (353 m a.s.l.) lies at the foothills of the western Alps: mean July temperature (reference period 1961-1990) is around 22° C. Lago di Lavarone (1115 m a.s.l.) is located in the pre-alpine region: mean July temperature is around 16°C. Sediment cores covering part of the Late Glacial and the whole Holocene were extracted from both lakes and studied for their pollen content to reconstruct the vegetation history, also including land-use changes in the two pollen source areas. Pollen records covering the last 200 years from Lago Grande di Avigliana and Lago di Lavarone are presented respectively in Finsinger et al. (2006) and in Arpenti & Filippi (2007). The sequence from Lago Grande di Avigliana has a good chronological control, based on varves counting, ^{210}Pb and ^{137}Cs dates: mean temporal resolution of the pollen record is

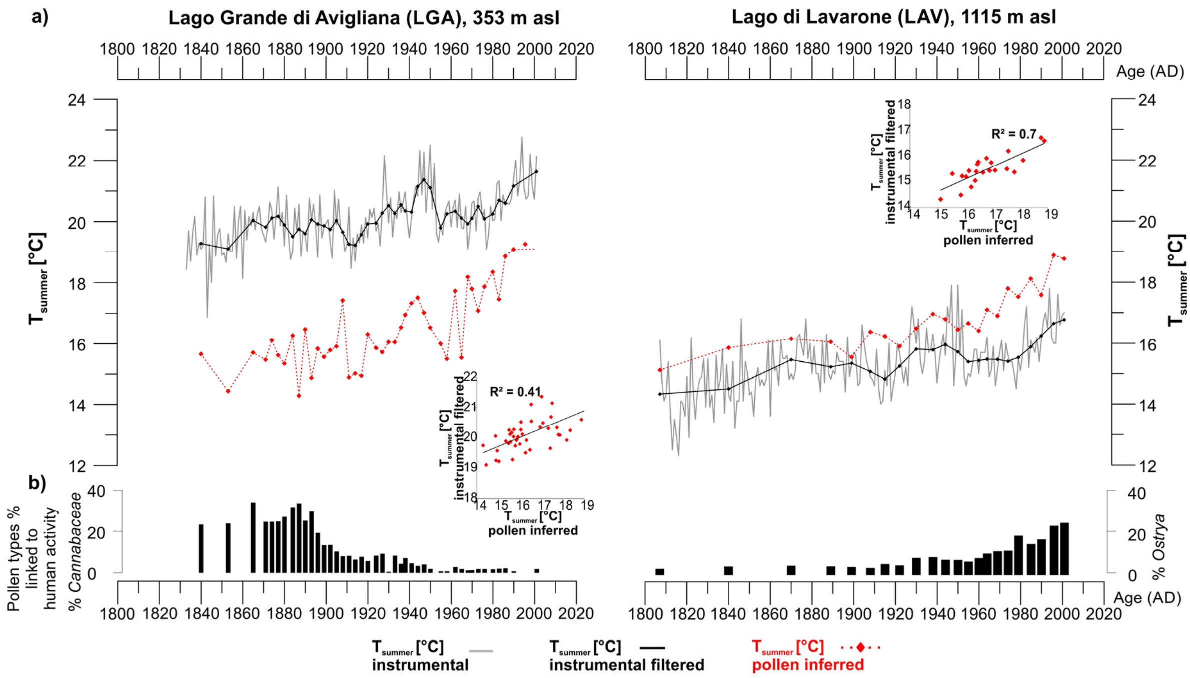

Fig. 2 - a) Comparison between instrumental T summer series (grey curves) and the pollen-inferred T summer reconstructions (red dotted curves) obtained for LGA and LAV with the WA method. The instrumental summer T series were smoothed with loess regression (for LGA span=0.05, for LAV span=0.1) according to the pollen resolution (black curves). Coefficient of determination between the two series are also shown. b) Percentages of two anthropogenic pollen *taxa,* Cannabaceae from LGA and *Ostrya* from LAV, which might influence the pollen-inferred temperature reconstructions.

~4 years for the last 200 years. A good age control is available also for the Lago di Lavarone sequence: its pollen record has a mean sample resolution of ~9 years for the last 200 years with higher temporal resolution after ~1900 AD.

2.2 Site-specific temperature series for the last 200 years

To overcome the lack of representativeness at the local scale of the commonly-used global climatological datasets, monthly instrumental temperature series have been reconstructed for Lago Grande di Avigliana (1833-2010) and Lago di Lavarone (1807-2010). Series were obtained by means of the anomaly method (New et al., 2000; Mitchell & Jones, 2005), as described in Brunetti et al. (2012), and benefit from the availability of several long instrumental temporal series for Northern Italy (Brunetti et al., 2006). Specifically, the procedure consists in the independent reconstruction of the climatological normals over a given reference period (i.e. the climatologies) and the anomalies (i.e. the departures from the climatologies): the former, characterized by remarkable spatial gradients, require a high spatial density of stations (even if with a limited temporal coverage) and a sophisticated interpolation procedure (Brunetti et al., 2014; Crespi et al., 2018) to be reconstructed. Anomalies are more coherent being linked to climate variability and, therefore, a low spatial density is enough but long temporal coverage and accurate homogenization (i.e. the procedure that removes the non-climatic signals introduced by stations and instruments relocation, changes in measurement practices and so on) is mandatory. Finally, absolute values of temperature monthly series for each site can be obtained by the superimposition of the two fields. The summer temperature series have been calculated by averaging June, July and August series. In order to highlight the temperature trends and to facilitate the comparison and the correlation between the instrumental records and the pollen-inferred reconstructions, the instrumental summer temperature series were smoothed with loess regression (for LGA span=0.05, for LAV span=0.1) following the pollen resolution. PAST statistical software version 3.3 (Hammer et al., 2001) was used.

2.3 Pollen-based quantitative temperature reconstructions

A three-steps approach (Juggins and Birks, 2012) was applied to obtain quantitative estimates of summer temperature. As a first step we developed an Italian modern pollen-climate calibration set that could cover the summer temperature gradients displayed during the last two centuries. 265 modern pollen samples have been selected from the European Modern Pollen Database (EMPD, Davis et al., 2013); each sampling location was associated to site-specific instrumental temperature data, reconstructed for the period 1951-2000 following the same procedure described above. Pollen taxonomy has been harmonized, both in the calibration set samples and in the fossil records. The specific training set is the base for the second step, i.e. modeling the modern pollen-temperature relationship and create the transfer functions by means of two numerical methods: the weighted-averaging (WA) regression and calibration (Ter Braak & Barendregt, 1986; Juggins and Birks, 2012 and reference therein) and the weighted-averaging partial least square regression and calibration (WAPLS) (Ter Braak & Juggins, 1993). We finally applied the transfer functions to fossil pollen records to estimate the summer temperature values for the last 200 years. Before applying the transfer functions to the fossil records the statistical performances of the developed models were checked in cross-validation.

The goodness of the calibration set in terms of availability of modern analogues for each fossil pollen sample was also evaluated using the Modern Analogue Technique (MAT) and its diagnostics. The "real" validation of the pollen-inferred reconstructions has been obtained by comparing the pollen-based temperature series with the instrumental data. The development of WA and WAPLS models, the evaluation of their performances, the temperature reconstructions and the MAT diagnostics were carried out using R software (R Core Team, 2017) and the rioja, R package (Juggins, 2017).

3. RESULTS

Pollen-inferred summer temperature reconstructions obtained for Lago Grande di Avigliana and Lago di Lavarone are shown together with the instrumental series (Fig. 2). WA pollen-inferred summer temperature values obtained for LGA are almost constantly underestimated if compared to the instrumental series. They are instead slightly overestimated for LAV but, considering the sample specific errors (not shown in Fig. 2), they include the instrumental values. Despite the shift in the absolute values at LGA, the decadal variability and the long-term trend in summer temperature instrumental series are also detectable in the pollen-inferred reconstructions, and this is true for both sites. Interestingly, the LGA pollen-inferred summer T reconstruction recognizes the warmer interval recorded between 1940 and 1950 AD.

The direct comparison of the WA pollen-inferred summer temperatures with the instrumental series yielded a moderate correlation for LGA (R^2=0.41) and a good correlation for LAV (R^2=0.7).

4. DISCUSSION AND CONCLUSION

During the last two centuries mean air temperature in Italy shows an increasing trend of 1°C per century with an intensification occurred in the last decades (Brunetti et al. 2006, 2013). Beside this century-long temperature increase, negative trends over shorter periods have been observed at the beginning of the 19th century and between 1950-1970 AD (Brunetti et al. 2006, 2013). Pollen-inferred summer temperature reconstructions capture the general warming of the last centuries.

Fig. 2 also presents the pollen percentages of two important pollen-productors which were affected by human land use changes, i.e. Cannabaceae from the pollen record of Lago Grande di Avigliana (Finsinger et al., 2006) and *Ostrya* from the pollen record of Lago di Lavarone. *Cannabis sativa* was cultivated in northern Piedmont in the 19th century until ~1950 AD (Finsinger et al. 2006 and reference therein). Whether this *taxon* is included or not in the pollen sum used for the temperature reconstructions, it influences the reconstructed absolute values. This issue needs to be carefully considered because this pollen *taxon* is not well represented in the used calibration set. Concerning *Ostrya*, this species is today the main component of forest vegetation in the pollen source area of Lago di Lavarone. Its expansion started around 1965 AD, favoured by decreased human activities in the area (Arpenti and Filippi, 2005).

We are aware that WA methods are able to solve the "non-analogues" problems but suffer from the "edge effects" (Juggins & Birks, 2012 and reference therein). Being Lago Grande di Avigliana summer temperature values at the end of the calibration set summer temperature gradient, the constant underestimation of the LGA pollen-inferred summer temperature might be due to this reason. This rigid shift in absolute values (which does not affect the long-term variability) is reduced by using WAPLS model (not shown in Fig. 2).

Our results show that pollen records obtained from lacustrine sediment cores can be used to obtain pollen-inferred reconstructions with trends comparable to instrumental data over the last 200 years, provided that: **1)** pollen records have a robust age control and high sample resolution (ideally less than a decade), **2)** proper calibration sets and adequate numerical techniques are used to develop pollen-climate models and transfer functions to be applied to fossil pollen records. The human activities and their effects in the pollen relative abundances must be considered and evaluated in the process of *taxa* selection before applying quantitative methods.

A further perspective after the calibration of pollen-based reconstructions with instrumental data will involve the comparison between the pollen-inferred summer temperature reconstructions and the dendrochronological-based summer temperature reconstructions for common temporal intervals in the alpine region. If the climate signals from both proxies are comparable, those proxies might be combined to build an integrate multi-proxy temperature reconstruction for northern Italy.

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