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Climate of the Past

Tree-ring–based summer mean temperature variations in the Adamello–Presanella Group (Italian Central Alps), 1610–2008 AD

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Abstract. Climate records from remote mountain sites and for century-long periods are usually lacking for most continents and also for the European Alps. However, detailed reconstructions of climate parameters for pre-instrumental periods in mountain areas, suffering of glacial retreat caused by recent global warming, are needed in the view of a better comprehension of the environmental dynamics. We present here the first annually-resolved reconstruction of summer (JJA) mean temperature for the Adamello–Presanella Group (Central European Alps), one of the most glaciated mountain groups of the Italian Central Alps. The reconstruction has been based on four larch tree-ring width chronologies derived from living trees sampled in four valleys surrounding the Group. The reconstruction spans from 1610 to 2008 and the statistical verification of the reconstruction demonstrates the positive skill of the tree-ring dataset in tracking summer temperature variability also in the recent period.

1 Introduction

High-mountain environments are valuable study areas for climate reconstructions as they respond sensitively to climatic changes. The assessment of climate change effects over time on high-elevation physical and biological environments involves detailed reconstructions of climate parameters for the pre-instrumental periods. The identification of long-term climate variation is a key issue for the understanding of recent climate dynamics within the natural climate variability (Houghton et al., 1990, 2001; Bradley and Jones, 1992; Bradley et al., 2003). In the Great Alpine Region (GAR) of the European Alps, and in particular in the high-elevation environments, instrumental climate-parameter records are scarce and extend back in time for not more than a few centuries. The analysis of proxy climate records becomes therefore essential for studying such climate-sensitive environments and their evolution (Beniston et al., 1997). Tree rings are an excellent source of paleoclimate information, as proven by numerous studies (e.g. Fritts, 1976). In Europe and in the Northern Hemisphere, valuable reconstructions of past climate variability have been derived from the combination of tree-ring chronologies and other proxies (Jones et al., 1998; Casty et al., 2005; Mann et al., 1998; Moberg et al., 2005) and from pure tree-ring networks (Briffa et al., 2001; D'Arrigo et al., 2006). In the European Alps, the abundance of temperature-sensitive conifer species growing at the treeline led to the development of several dendroclimatic studies and temperature reconstructions. Frank and Esper (2005) used a large network of ring-width (TRW) and maximum latewood density (MXD) data from high-elevation sites across the Central and Western Alps developing June–August and April–September mean temperature reconstructions. Büntgen et al. (2005, 2006) published two of the longest mean summer (June–August and June–September) temperature reconstructions available for the European Alps (951–2002 and 755–2004), based on TRW and MXD from Switzerland and Austria. Corona et al. (2010) published a new reconstruction of summer temperatures over the GAR based on a larch/pine composite chronology that provides evidence of Alpine summer temperature variations back to 1000 AD. When performed on a regional scale, these reconstructions usually include and average a large number of site chronologies reflecting specific and local climate characteristics. It is widely recognized, however, that mountain climate, and also climate over the central-western Alpine region, is largely controlled by the specific topographic characteristics and environmental features of the different mountain areas (Beniston et al., 1994; Beniston, 2003; Leonelli et al., 2009). Therefore, the development of climate reconstruction from specific mountain groups can help in assessing the historical climatic trends as well as in understanding the climate influence on the environmental dynamics occurring over specific mountain areas. Environmental changes in these climate-sensitive areas may present different response times and be very quick and dramatic, as well documented for example by glacier shrinkage and collapse (Haeberli et al., 2007) and by changes in frequency and intensity of climate-related geomorphological processes (e.g. Stoffel and Huggel, 2012). The location and magnitude of biological and physical processes in high-mountain ecosystems are mainly governed by climate regimes. Climate warming may directly influence tree physiology and growth, but it may also drive forest dynamics, e.g. causing the upslope migration of species responding to higher temperatures (Beniston, 2005; Pauli et al., 2003; Leonelli et al., 2011) or causing forest ingrowth also in relation to land-use changes (e.g. Gehrig-Fasel et al., 2007; Chauchard et al., 2010). In the Alpine region the dendroclimatic reconstructions have been mainly performed on the northern sector of the Alps, and, at present, tree-ring–based reconstructions of climate parameters for the mountain group considered in this study are not yet available. We present here the first tree-ring–based reconstruction of mean summer (June to August, later JJA) temperature for the Adamello–Presanella area, in the Italian Central Alps. Larch tree-ring growth at the treeline forest belt in the Adamello–Presanella Group is mainly driven by June temperature, a climatic parameter whose relationship with tree-ring widths has varied over time (Coppola et al., 2012); the same paper identifies a more stable signal of seasonal parameters with respect to monthly parameters, with tree-ring width presenting a rather constant response to summer (JJA) temperatures over time. The study area is characterized by one of the largest glacial systems of the Italian Alps (CGI-CNR, 1959–1962; Ranzi et al., 2010). As mentioned before, one of the clearest effects of global warming on the Alps is the generalized reduction in glacier extension and thickness (Oerlemans, 2001; Haeberli et al., 2007). The reconstruction of century-long climate records represent therefore a strategic issue also for modelling glacier responses over time, for understanding the recent glacier dynamics and for better hypothesizing future scenarios of glacier retreat.

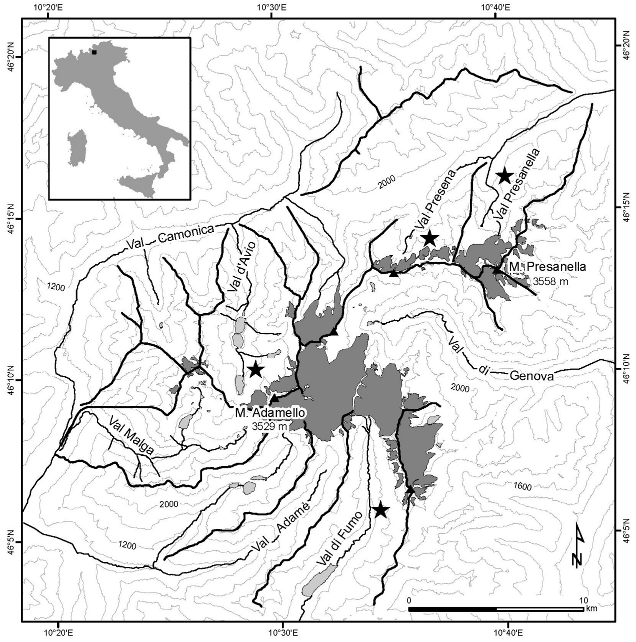

Fig. 1. Sketch map of the study area. Black asterisks indicate the location of the study sites.

2 Materials and methods

2.1 Study area

The Adamello–Presanella Group belongs to the central-southern sector of the Italian Central Alps (namely the Rhetian Alps, 45°54′–46°19′ N, 10°21′–10°53′ E), covering an area of more than 1100 km^2. The area hosts approximately 100 glaciers (CGI-CNR, 1959–1962), primarily in the northern and central sectors of the Group, among which are the Adamello Glacier, the widest of the whole Italian Alps (Ranzi et al., 2010), and the Lobbia Glacier; both high plateau glaciers whose active fronts stand at the head of valleys originating from the summit area (Baroni and Carton 1990, 1996; Baroni et al., 2004). The other glaciers are mainly located in small cirques and at the head of topographically protected valleys. The Adamello–Presanella Group shows a well-developed alpine glacial topography characterized by U-shaped valleys, sharp crests, cirques and horns. Valley floors show a longitudinal profile with overdeepened hollows and steps of glacial shoulder (riegel) representing inherited Pleistocene morphology, since the Holocene, and presently affected by fluvial processes. Furthermore, the steep slopes show evidence of widespread active mass wasting processes, underlined by debris flow channels and avalanche tracks, dissecting the upper portion of the slopes, and by scree slope, talus, debris flow cones and rock fall at their feet. The sampling sites involved in this study are located at the head of four different glacial valleys surrounding the Group (Fig. 1). Vegetation cover at the four sampling sites is quite similar and mainly consists of Norway spruce (*Picea abies* L. Karst) woodlands that dominate the forest cover and that, above about 1800 m a.s.l., give way to open European larch (*Larix decidua* Mill.)–Norway spruce (*Picea abies* L. Karst) mixed stands. In Val d'Avio and in Val di Fumo at approximately 2000 m a.s.l., Norway spruce

Table 1. Description and statistics of the four standard RCS (regional curve standardization) site chronologies of *Larix decidua* Mill.

Site	Val Presanella	Val di Fumo	Val d'Avio	Val Presena
Code	PRL	FUM	AVI	PRS
Lat./Long.	46°25′/10°40′	46°05′/10°34′	46°10′/10°28′	46°23′/10°38′
Elevation (m a.s.l.)	1910	1990	2150	2160
First year of chronology	1550	1710	1550	1645
Last year of chronology	2005	2008	2008	2004
Chronology length (yr)	456	299	459	360
Number of trees	16	13	11	11
Number of radii	32	26	22	22
Mean length of series	257	215	348	179
Mean ring width (mm)	1.16	1,27	0,78	0,99
Mean sensitivity	0.20	0.26	0.24	0.26
Standard deviation	0.30	0.37	0.36	0.30
Serial correlation	0.67	0.63	0.50	0.63
First year with EPS > 0.85 (min. number of samples)	1635(6)	1795(7)	1610 (5)	1875(4)

is replaced by an open mixed association of larch and stone pine (*Pinus cembra* L.) (Andreis et al., 2004; Baroni et al., 2007).

2.2 Tree-ring data and chronology development

This study is based on four European larch (*Larix decidua* Mill.) ring-width chronologies. As commonly found in the Alpine mountain environment, the investigated area is characterized by high-energy geomorphological processes affecting tree vegetation, which is frequently subjected to diverse growing disturbance factors such as avalanches and mass wasting movements (Baroni et al., 2007; Gentili et al., 2010). Therefore, sampling was conducted in the open forest below the treeline selecting dominant and undisturbed trees without stem or crown anomalies potentially biasing the climatic signal (e.g. Leonelli et al., 2009). The four tree-ring chronologies were obtained from core samples extracted by means of an increment borer and replicated within and between trees, following standard dendrochronological sampling procedures (Stokes and Smiley, 1968; Swetnam, 1985). At least two cores from each tree were obtained. Samples with evidence of mechanical disturbances were discarded. Therefore, among about 70 sample trees, 51 trees have been used for the development of the four mean site chronologies (Table 1). Tree-ring widths were measured to the nearest 0.01 mm by means of a LINTAB increment measuring table (RinnTech) and then visually and statistically cross-dated with the TSAP-win software (version 0.53; Rinn, 2005). The correct cross-dating between tree-ring series was then checked using the program COFECHA (Holmes, 1983; Grissino-Mayer, 2001). Initially, four different mean site chronologies were developed to verify the existence of a good synchronization between samples deriving from the four different sampling sites (Table 1). In order to preserve as best as possible low-frequency information, we computed the single site chronologies and the regional chronology with all samples by means of the regional curve standardization method (RCS, Esper et al., 2003) using the program ARSTANwin (Version 41_d; www.ldeo.columbia.edu). To allow the correct alignment of tree-ring series by cambial age, we estimated the "pith offset" (PO) for each core (Briffa and Melvin, 2011). PO is the number of missing years between the innermost visible ring and the pith of the stem at the breast height (Esper et al., 2003). All measurement series were aligned according to their cambial age, smoothing the regional curve with a cubic spline of 10 % of the series length (Büntgen et al., 2006). A biweight robust mean was then applied to all the series (Cook and Briffa, 1990). The similarity in signal between the four raw chronologies was then checked using the Gleichläufigkeit index (GLK, year-to-year agreement between interval trends, Schweingruber, 1988), the statistical significance level for the Gleichläufigkeit value and the Baillie Pilcher t-values (tBP, Baillie and Pilcher, 1973).

2.3 Climate data

In this study we decided to use monthly homogenized records of temperature from the gridded HISTALP dataset (Auer et al., 2007, http://www.zamg.ac.at/histalp). This dataset is composed by gridded station data with a resolution of 1° latitude × 1° longitude and represents anomalies referred to 1961–1990 mean. The last version of the HISTALP dataset is adjusted to take into account the warm bias in summer temperature related to the insufficient sheltering of thermometers during the "*early instrumental period*" prior of 1850 (EIP; Böhm et al., 2010; Frank et al., 2007). All temperature series available in the HISTALP database are currently present in the EIP-bias corrected version. The extension of all the gridded series in this last version is uniformed to the same extension that spans from 1780 to 2008. We used gridded monthly mean temperature anomaly records referring to the grid point 10° N, 46° E derived from high-elevation stations ($>$ 1500 m a.s.l.) and computing a JJA mean temperature series. Gridded monthly mean temperature anomaly records deriving from low-elevation stations as well as other reconstructions already available (www.ncdc.noaa.gov/pub/data/paleo) were used to further check the reconstruction here proposed.

2.4 Data processing and climate reconstruction

The relationships between climate and tree-ring growth for the four chronologies were evaluated by means of the standard correlation function (CF) and response function (RF) analysis (Coppola et al., 2012 for details). As reported in Coppola et al. (2012), the CF and RF analysis results show that larch growth at the treeline in our sampling sites is primarily driven by summer temperature. Moving response function analysis performed in Coppola et al. (2012) shows in the last decades decreasing values of correlation coefficients calculated between tree-ring width chronologies and June mean temperature. However, the response of larch growth to summer (June to August) temperature is overall stable over time. We then chose summer (JJA) mean temperature as the optimum climate predictand for the present reconstruction.

Both climate (JJA temperature) and the regional chronology (the “AdaPres” chronology) were checked for normality (Kolmogorov–Smirnof test) and the direct relationship between the two series verified by means of a linear regression and some related statistics.

We performed the reconstruction applying both simple regression and scaling of the composite AdaPres chronology against instrumental data (Esper et al., 2005). Within the instrumental time span (1780–2008), we chose two subsets (1818–1907 and 1908–1998) to perform calibration/verification procedures for both the reconstruction methods.

In the first version of the reconstruction obtained by simple regression, the regression assumptions (Ostrom Jr., 1990) were verified by the analysis of the residuals. Residuals were visually (histogram) and statistically (Anderson–Darling test) checked for normality.

The second version of the reconstruction was performed by simple scaling of the RCS AdaPres chronology against instrumental records. Scaling allows avoiding reduction of amplitude due to regression error (Esper et al., 2005), and was obtained by equalization of the mean and variance of the composite RCS chronology to the corresponding values of the JJA mean temperature series over the calibration period.

Several statistics were conducted to test the reliability of the two reconstructions and their long-term skills. Pearson’s correlation between instrumental and reconstructed values was calculated in each phase of the calibration/verification procedure. The explained variance (R^2) and the reduction of error statistic (RE) have been performed to measure the association between the series of actual values of monthly mean temperature and their estimates. The theoretical limits for RE values range from a maximum of $+1$ to minus infinity, but an RE value greater than 0 has to be considered as a positive skill (Fritts, 1976). Moreover, another statistical test was applied, the coefficient of efficiency (CE). The use of this statistic in dendroclimatology was introduced by Briffa et al. (1988), and, as for RE, its theoretical limits range from $+1$ to minus infinity, any positive values indicating positive skill, a minus value indicates no agreement. It is a very rigorous test to pass if there are important differences between calibration and verification periods means; similar RE and CE values can be considered indicative of high stability of the calibration and verification periods datasets. The lack of autocorrelation was verified by means of the Durbin–Watson statistic (DW, Durbin and Watson, 1951). A DW value of 2 indicates no first-order autocorrelation in the residuals.

The full overlapping period between instrumental data and the composite RCS chronology (1780–2008) was then used to produce the time series of reconstructed values.

To further verify the reliability of the climate data, a new reconstruction was obtained by scaling of the RCS AdaPres chronology against JJA mean temperature from the HISTALP low-elevation temperature dataset for the same grid point.

3 Results

The presence of a common signal of the four site chronology was evidenced by satisfying values of GLK and tBP; the best synchronization was found between the AVI and FUM chronologies (GLK = 73.3) (Table 2).

Totally, 102 series were used in the composite RCS chronology covering a time period of 459 yr, spanning from 1550 to 2008 (Fig. 2). The signal strength of the chronology was assessed by means of the interseries correlation (RBAR) and the “expressed population signal” (EPS; Wigley et al., 1984). We assumed the 0.85 EPS value as a threshold limit, limiting our reconstruction to the time period 1610–2008, corresponding to a minimum number series of 8 (Table 3).

Both reconstructions obtained with regression and scaling show positive statistical skill (Table 4). The calibration/verification statistics indicate positive skill of the reconstructions and the stability of the relationship over the halves of the chosen period (1908–1998 and 1818–1907) (Cook and Briffa, 1990). As expected, the reconstruction based on a scaling method presents wider amplitude and a better performance in tracking the long-term variations of temperature records (Fig. 3).

The reconstructions performed by scaling over the high-elevation (HE) and the low-elevation (LE) temperature HISTALP dataset for the chosen gridpoint are reported in

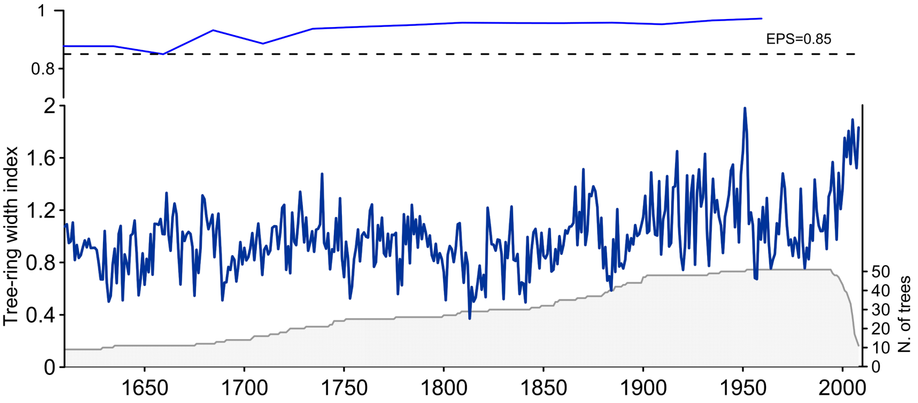

Fig. 2. The RCS AdaPres chronology with the expressed population signal (EPS) computed over 50-yr periods and shifted by 25 yr back in time. Sample depth is on the bottom of the graph.

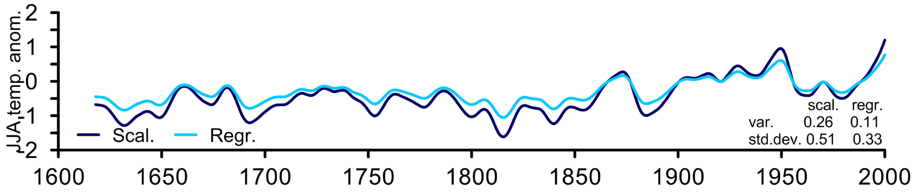

Fig. 3. Comparison of the two reconstructions obtained by scaling (Scal., dark blue line) and simple regression (Regr., light blue line). The two reconstructions were 20-yr low-pass-filtered.

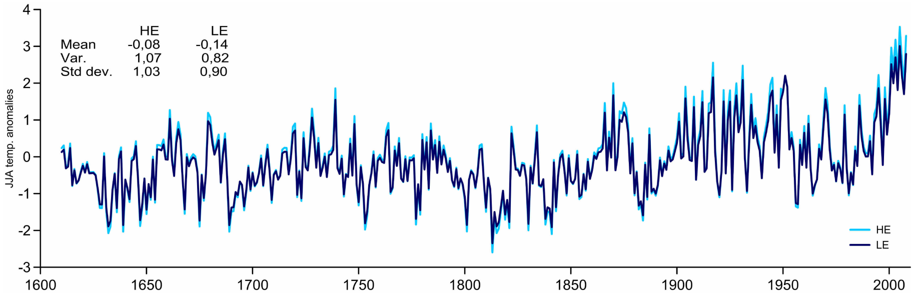

Fig. 4. The AdaPres JJA temperature reconstructions obtained after scaling against high-elevation (HE, light blue) and low-elevation (LE, dark blue) HISTALP datasets for the grid point 10° N, 46° E. In the table are reported mean, variance and standard deviation of the two time series.

Fig. 4. The two reconstructions show very similar patterns, so we decided to consider the HE temperature series as reliable for our purposes, even if it is based on a fewer number of stations than LE. The ongoing discussion will be then based on the reconstruction obtained by scaling and based on HE JJA mean temperature instrumental records. The reconstruction will be named AdaPres.

4 Discussion

Even if the calibration of tree-ring chronology was performed with the latest version of the HISTALP gridded dataset, on comparing the AdaPres reconstruction with instrumental proxy, the underestimation of early warm-season instrumental data is noticeable (Fig. 5). These findings are consistent with diverse summer temperature reconstructions based on the HISTALP dataset (e.g. Büntgen et al., 2006; Corona et al., 2011). Corona et al. (2011) consider this result as a consequence of a still inadequate adjustment made on the HISTALP summer temperature dataset to take into account sheltering-related biases before 1850.

Looking in detail to the AdaPres reconstructed series (Fig. 6) in the pre-instrumental period (1610–1780), relatively cool conditions are recorded during much of the 17th and early 18th centuries, with some decadal and multidecadal fluctuations. Relatively low temperatures are visible in the first part of the time series until about 1650; an increase

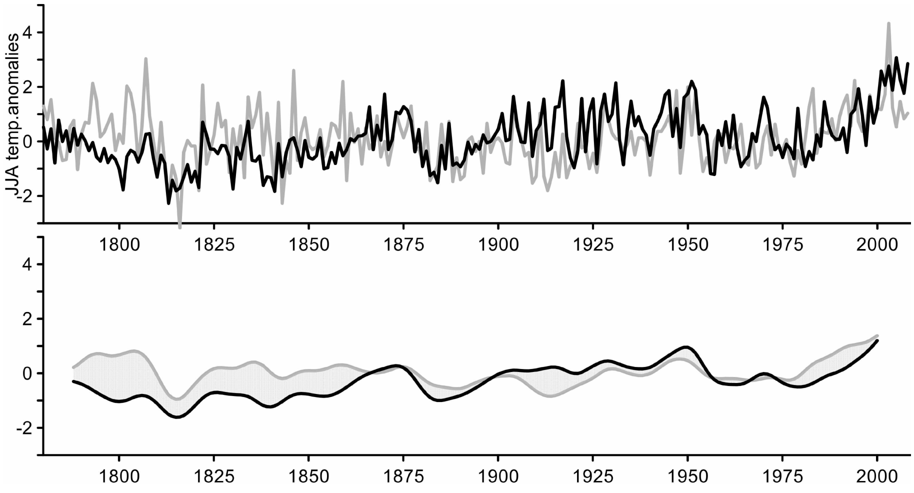

Fig. 5. Comparison of the AdaPres reconstruction of JJA temperatures (black) with the HISTALP JJA mean temperatures (1780–2008, grey) for unfiltered series (top) and after filtering with a 20-yr low-pass filter (bottom).

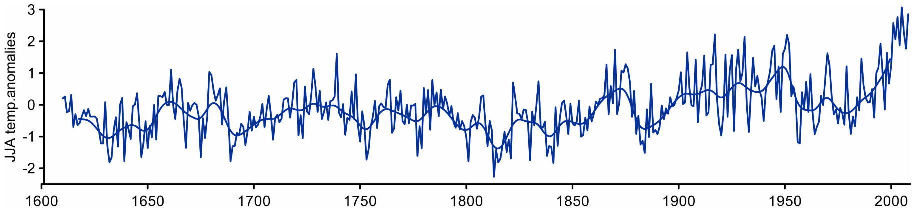

Fig. 6. The unfiltered and smoothed (20-yr low-pass filter) final AdaPres JJA temperature reconstruction.

in JJA mean temperature follows until about 1680. Another reduction follows until about 1700 when a regular increase starts and reaches the mid 1700s, when a progressive decrease occurs, with an early summer cooling trend that continues until 1821. In this phase, a little fluctuation centred on 1750 is visible in our reconstruction. The lowest recorded temperatures of the entire reconstruction are found in the 1813–1821 period. Actually, this decade is known as one of the coldest phases of the entire Little Ice Age (LIA, Bradley and Jones, 1993; Grove, 1988), characterized by the maximum Holocene extension of the Alpine glaciers (Oerlemans, 2001; Nicolussi and Patzelt, 2000; Holzhauser et al., 2005), which is also verified in the Adamello–Presanella Group (Baroni and Carton, 1990, 1996). The 1813–1821 period corresponds to the Dalton Minimum in solar activity (Wagner and Zorita, 2005; Wilson, 1998) and follows extensive volcanic activity, including the 1815 eruption of the Tambora, on the Indonesian Sumbawa Island (Crowley, 2000; Oppenheimer, 2003), resulting in a marked recrudescence of summer temperatures over the Northern Hemisphere (Briffa et al., 1998). The year 1816, known as "the year without a summer" at global scale (as consequences of the Tambora eruption occurred in 1815), does not reach the absolute lower value JJA temperature in our reconstruction, but is anyway among the lower values we found. The lowest value of our entire reconstruction temperature corresponds to the year 1812. The period after 1821 is characterized by an overall tendency to an increase in temperature, particularly evident after 1850, which is recognized in this sector of the Alps as the end of the LIA (Baroni and Carton, 1990, 1996). Following the registered temperature, the JJA tree-ring–based reconstructed temperature shows a post-LIA warming trend, with some minor fluctuations. Actually, the phase that follows the end of the LIA is clearly marked by a sharp rising of JJA temperatures, but the positive trend goes through a break in the early 1870s when a short, relatively cool period centred on 1885–1890 takes place. After that, the rising trend starts again ceasing in correspondence to a relatively cool phase centred on about 1970, which brings the reconstructed JJA mean temperatures to relatively lower values. This recent reduction of summer mean temperatures is well tracked and has been found in diverse reconstructions of summer temperatures reported for other sectors of the Alps (Büntgen et al., 2005, 2006; Corona et al., 2011), while it is less apparent in the large-scale tree-ring–based summer temperature reconstructions (e.g. Briffa et al., 2001; D'Arrigo et al., 2006). From this last relatively cool phase onwards, the JJA mean temperature rising trend appears constant, and goes on up to the end of the time series following the recent and persisting warming trend.

Table 2. Correlation matrix of the four standard RCS site chronologies, showing Gleichläufigkeit (GLK, year-to-year agreement between interval trends, Schweingruber, 1988), the statistical significance level for the Gleichläufigkeit value (GLKsig, *** 99.9 %)and Baillie Pilcher t-values (tBP).

	FUM	PRS	PRL	
PRS	71.9 *** 12.35			GLK GLKsig tBP
PRL	70.8 *** 13.1	67.5 *** 11.16		GLK GLKsig tBP
AVI	73.3 *** 13.6	73.5 *** 13.44	67.5 *** 12.41	GLK GLKsig tBP

Table 3. Statistical characteristics of the AdaPres RCS chronology.

Code	First year	Last year	Length (year)	Number of trees	Number of radii	Mean sens.	Std. dev.	Serial corr.	EPS > 0.85 (Min. no. of trees)
AdaPres	1550	2008	459	51	102	0.20	0.28	0.78	1610 (8)

Table 4. Statistical verification of the two JJA temperature reconstructions, performed by computation of RE, CE, R^2 and DW, after regression (A) and scaling (B).

Calibration			Verification			(A)
	R^2	DW		R^2	RE	CE
1908–1998	0.15	2.2	1818–1907	0.24	0.23	0.21
1818–1907	0.22	1.6	1908–1998	0.15	0.17	0.10
Calibration			Verification			(B)
	R^2	DW		R^2	RE	CE
1908–1998	0.28	2.2	1818–1907	0.25	0.26	0.22
1818–1907	0.25	1.6	1908–1998	0.28	0.17	0.15

The reconstructed JJA temperatures show an overestimation of the instrumental records in the early 20th century: This divergence between the reconstructed and actual data is not reported in other Alpine summer temperature reconstructions and seems to be specific to our sampling area. Since 1920 to present the AdaPres reconstruction strictly follows actual JJA temperature values.

In our study area and for the selected European larch chronologies, we have no evidence of the "divergence problem" (DP; D'Arrigo et al., 2008), concerning the discrepancy between reconstructed and instrumental temperature in recent times largely reported in numerous studies (Büntgen et al., 2006; D'Arrigo et al., 2006; Jacoby et al., 2000; Wilmking et al., 2004; Wilson et al., 2007). DP led to doubt of the efficiency of tree-ring–based reconstructions in tracking the recent warming trend in summer temperature. As demonstrated in Büntgen et al. (2008), divergence is not a systematic issue at temperature-sensitive conifer sites and is likely to be addressed at a local to regional levels.

The unfiltered and smoothed AdaPres reconstruction is directly compared with three other Alpine and European reconstructions of summer mean temperatures: Büntgen06 (Büntgen et al., 2006), Büntgen11 (Büntgen et al., 2011), and Trachsel12 (Trachsel et al., 2012). The Büntgen06 reconstruction covers the Eastern Alps and extends back to 753 AD. The Büntgen11 tree ring-based reconstruction of central European summer temperature covers the past 2500 yr (500 BC–2008 AD). The recent multi-proxy based Trachsel12 reconstruction for the European Alps covers the period 1053–1996 AD. Satisfying ($r > 0.6$, $p < 0.005$) Pearson correlation values were obtained after comparison of the reconstructions over their common period (Table 5, Fig. 7). The highest correlation between the unfiltered series is obtained with Büntgen11 (0.66, $p < 0.005$). After smoothing each reconstruction with 10-, 20- and 30-yr Gaussian low-pass filters, Pearson correlation values increase, reaching the maximum value for the 30-yr smoothed series where the AdaPres reconstruction correlates with $r = 0.76$, 0.64 and 0.75 ($p < 0.005$) for Büntgen06, Büntgen11 and Trachsel12, respectively.

These results reveal a common signal of the AdaPres reconstruction with the compared series on a low-frequency scale and the good potential of the European larch tree-ring chronologies from high-altitude sites in the Adamello–Presanella Group to be used as a summer temperature proxy of the region.

5 Conclusions

The European larch radial increment at the treeline in the glacial valleys surrounding the Adamello–Presanella Group is mainly driven by summer temperature. We have here performed the first attempt of a tree-ring–based JJA mean temperature reconstruction for the Adamello–Presanella area, an Alpine region hosting the largest glacier of the Italian Alps. This reconstruction may be potentially helpful for modeling alpine glaciers response to climate changes. The AdaPres

Table 5. Results of Pearson correlation values ($p<0.005$) computed over the overlapping period between AdaPres reconstruction and the three compared series (Büntgen et al., 2006 (Büntgen06), Büntgen et al., 2011 (Büntgen11), Trachsel et al., 2012 (Trachsel12)). Before and after applying a 10-, 20- and 30-yr Gaussian low-pass filter.

	Overlapping period	Unfiltered	10-yr low-pass filtered	20-yr low-pass filtered	30-yr low-pass filtered
Büntgen06	1610–2004	0.51	0.70	0.73	0.76
Büntgen11	1610–2003	0.66	0.63	0.73	0.64
Trachsel12	1610–1996	0.63	0.68	0.71	0.75

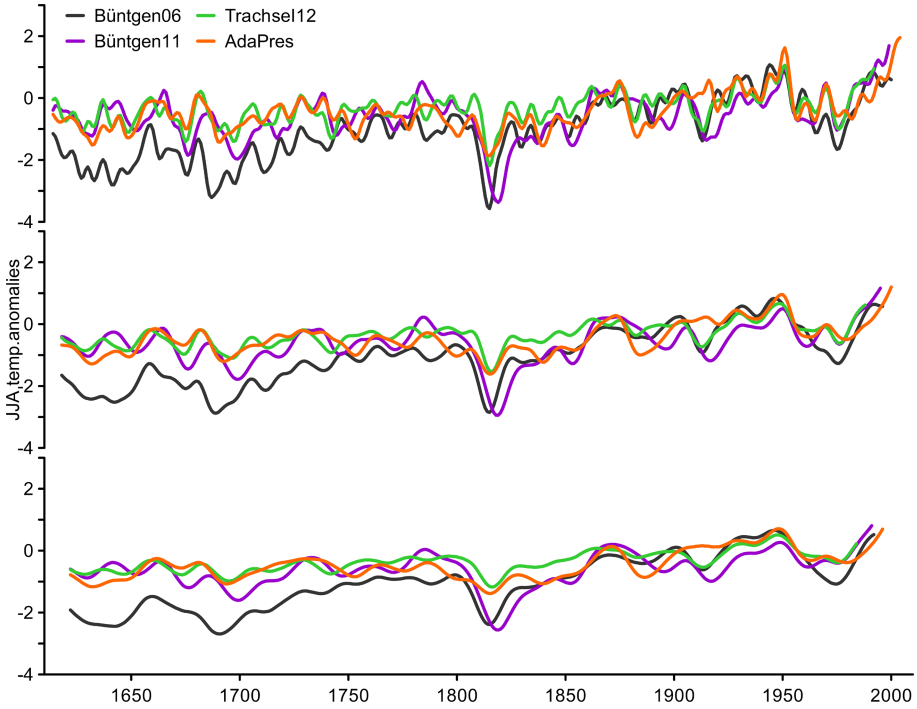

Fig. 7. Comparison between the AdaPres reconstruction and the three compared series (Büntgen et al., 2006 (Büntgen06), Büntgen et al., 2011 (Büntgen11), Trachsel et al., 2012 (Trachsel12)). All the series were smoothed by means of a Gaussian low-pass filter of 10 (top), 20 (middle) and 30 yr (bottom).

tree-ring–based reconstruction of JJA temperature has been calculated by simple scaling over the latest version of the HISTALP gridded database for the grid point 10° E, 46° N, spanning from 1780 to 2008. As in other recent summer temperature reconstructions based on the same climate dataset, a divergence is visible between the reconstructed and instrumental data prior to 1850. Therefore, the the warm bias in early instrumental period is still present in the adjusted new version of the HISTALP dataset.

The actual temperature variations characterizing the LIA are well evident also in the reconstructed data, particularly the coldest years of the 19th century (e.g. 1813, 1816 and 1821 AD). The reconstructed temperature dataset records the recent warming trend of summer conditions starting from about 1970, mostly following the measured instrumental trends. The proposed reconstruction tracks well actual summer temperature in the recent period; there is therefore no evidence of the well-known "divergence problem" mentioned in diverse tree-ring–based summer temperature reconstructions for the Northern Hemisphere. The good potential showed by our tree-ring dataset as a proxy for mean summer temperature encourages an extension of the record further back in time, improving sample replication in the earliest part of the chronology; moreover, we underline the importance of climate reconstructions related to single mountain groups for a better assessment of climate variability and the related glacier dynamics of specific regions.

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