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CLIMATE INFLUENCE AND RADIAL GROWTH OF SILVER FIR (*Abies alba* Mill.) IN TUSCANY: FIRST RESULTS

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The Context

In 2006, the School of Geography and Environmental Science of Monash University (Australia) signed a research protocol with the "Corpo Forestale dello Stato, Uffici per la Tutela della Biodiversità" at Pistoia, Pratovecchio, Vallombrosa, and the "Comunità Montana del Casentino, Settore Foreste". The aim of the research program was to study the effects of recent and historical variability of climate in the Tuscan Alps on the growth of silver fir (*Abies alba* Mill.).

In 2006-2007 we established a set of paired study sites at each of four forests (Fig. 1). The site pairs were located at the upper and lower limits of the distribution of silver in each of the forests (Fig. 2). The primary objective was to determine if growth responses to climate in silver fir have changed in recent decades as a consequence of modified environmental conditions associated with climate change.

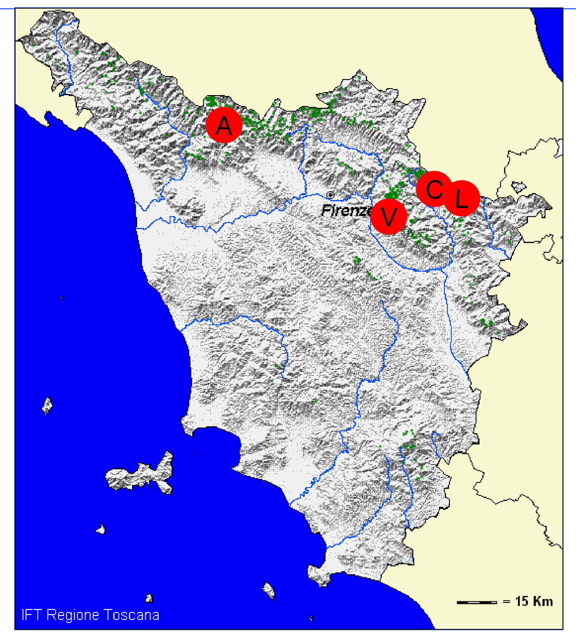

Fig. 1 – Location of the four silver fir forests and elevation of relative meteorological stations on tops of the Tuscan Apennines.

Table 1 – Elevation (m. asl), UTM coordinates, and period of data available for the four meteorological stations

Meteo Station	*Elevation (m. asl)*	*UTM (m) Coordinates*		*Period available*	
		E	*N*	*Temperature*	*Precipitation*
Abetone (A)	1340	633615.00	4889150.00	1872-2006	1872-2006
Camaldoli (C)	1111	727035.00	4853040.00	1885-2003	1931-1996
La Verna (L)	1120	736295.00	4843695.00	1956-2005	1924-2006
Vallombrosa (V)	955	706000.00	4845450.00	1934-1996	1921-2003

The forest sites

The four forest sites differ in geology, elevation, topography, aspect, and tree age (Table 2). The difference in elevation between the higher and lower forest stands is 540 meters.

La Verna forest **Camaldoli forest**

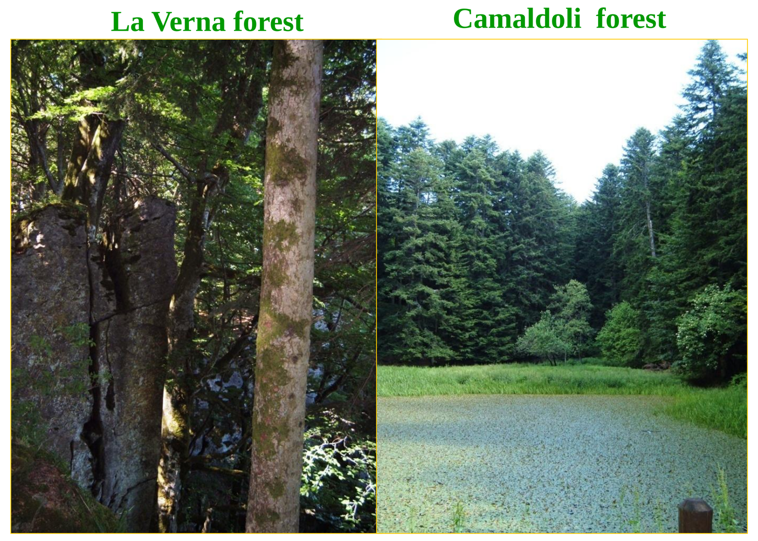

Fig. 2 – Views of site and forest structure of the La Verna forest and Camaldoli forest. Despite the short distance (13km) between sites and their similar elevations (LAV is 1120m asl, CAM is 1111m asl), seasonal mean temperatures differ; for example, summer mean temperature is 2°C higher at LAV. Variation in annual temperature is also higher at LAV.

Table 2 – Forest structure, elevation (m. asl), tree age (years) in the year 2007, aspect, and geology of the forest stands at the four forest sites.

Forest parcel	ABE38	ABE68	LAV19	LAV30	CAM162	CAM206	VAL521	VAL460
Forest structure	Even-aged, pure	Even-aged, pure	Uneven-aged, mixed	Uneven-aged, mixed	Even-aged, pure	Even-aged, pure	Even-aged, pure	Even-aged, pure
Elevation	1445	1280	1158	1130	1130	1060	1113	903
Tree age	170+	116	150+	150+	109	106	117	105
Aspect	SE	SE	Peak	Peak	S	S	N	N
Geology	Claystone	Claystone	Calcarous	Calcareous	Sandstone	Sandstone	Sandstone	Sandstone

Local and regional climate trends

Statistical analysis (Fig. 3) shows a positive trend in mean temperature amongst the four forest sites. However, at the local level differences in seasonal and monthly trends (Fig. 4), variability, and patterns of temperature amongst sites exist. This would suggest that tree growth/climate relationships may need to be analysed at the individual site level as differences in growth response might take place.

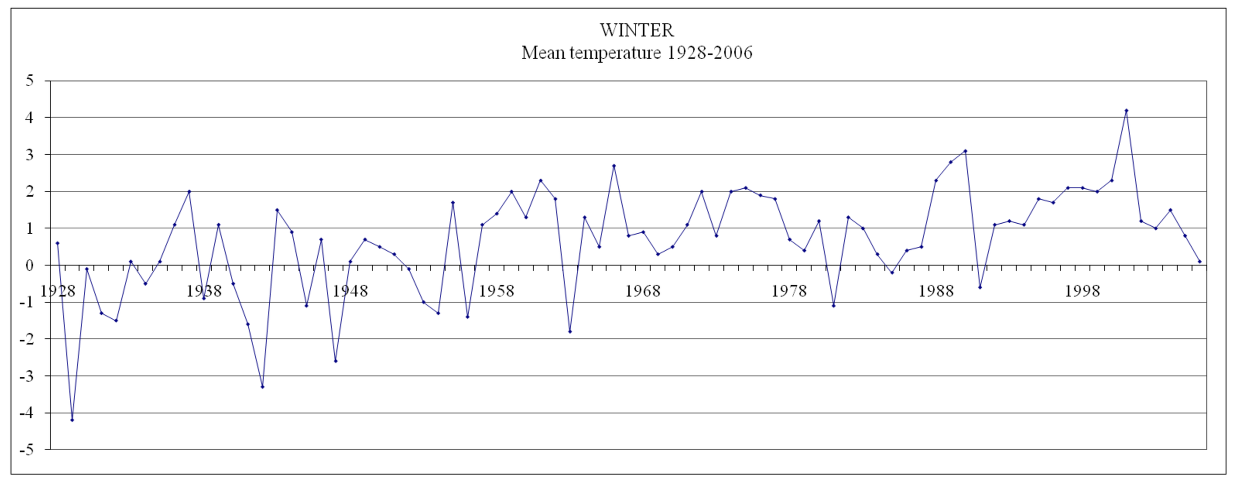

Fig. 3 - Trends in winter (Dec-Jan-Feb) mean temperature at the four sites from the year 1928 to the year 2006. Correlation between sites appears to be high, and a mean increase 2.5°C from the late 1920s to the 2000s.

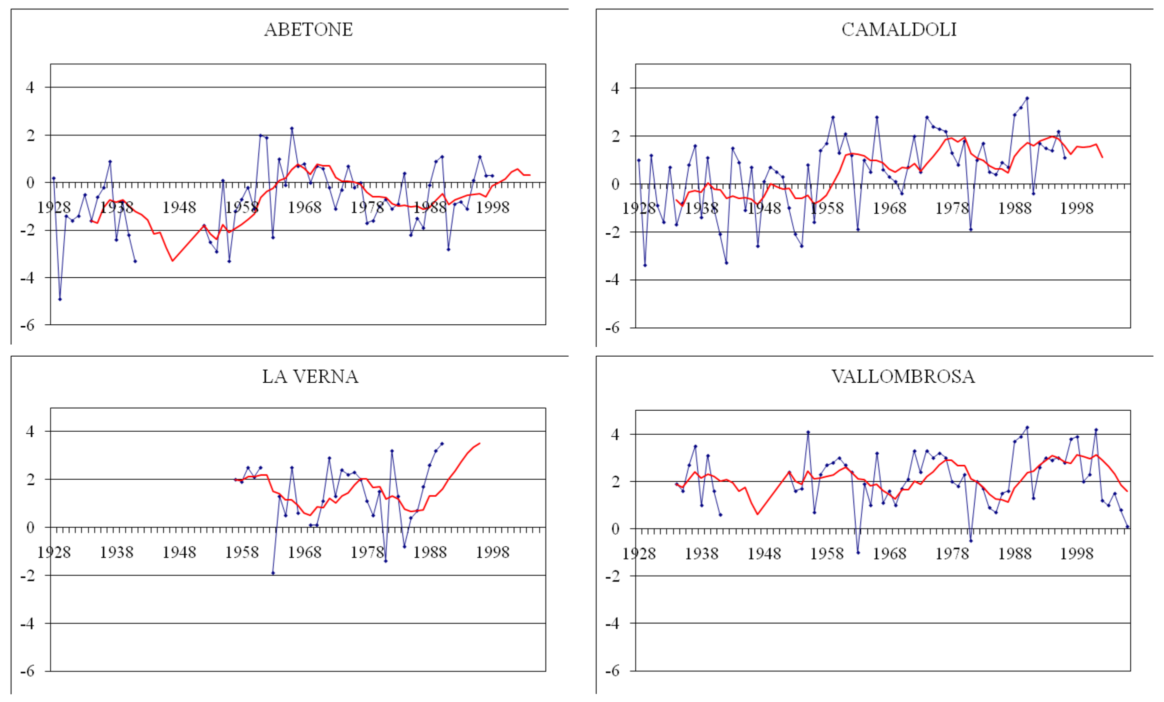

Fig. 4 – Trends (blue) and 7-year moving average (red) of winter mean temperature at the four study sites; *y*-axis is temperature (°C), *x*-axis is year (1928-2006).

Research Question

Are tree-ring/climate relationships in central Italy stationary over the 20th century?

Tree-ring/climate correlations

Figure 5 shows the Pearson's-*r* correlations between chronologies of monthly mean temperature and residuals of the standardized silver fir tree-ring series at each site. CAM, LAV, and VAL show relatively similar patterns, in which the residual tree-ring chronology is positively correlated with February temperature.

Comparisons of the entire tree-ring series and temperature data show relatively consistent, albeit mostly weak, correlation patterns. In general, the tree-ring chronologies are positively correlated with late winter temperature (esp. February) and negatively correlated with late summer temperature (esp. August). This pattern occurs at CAM, LAV, VAL. At ABE, the tree-ring chronologies are not significantly correlated with any monthly temperature variable except a marginally significant association with February temperature at the upper site. At CAM and LAV there are not differences in the temperature response between different elevations. At ABE and VAL, sites at higher elevation show higher correlation with temperature.

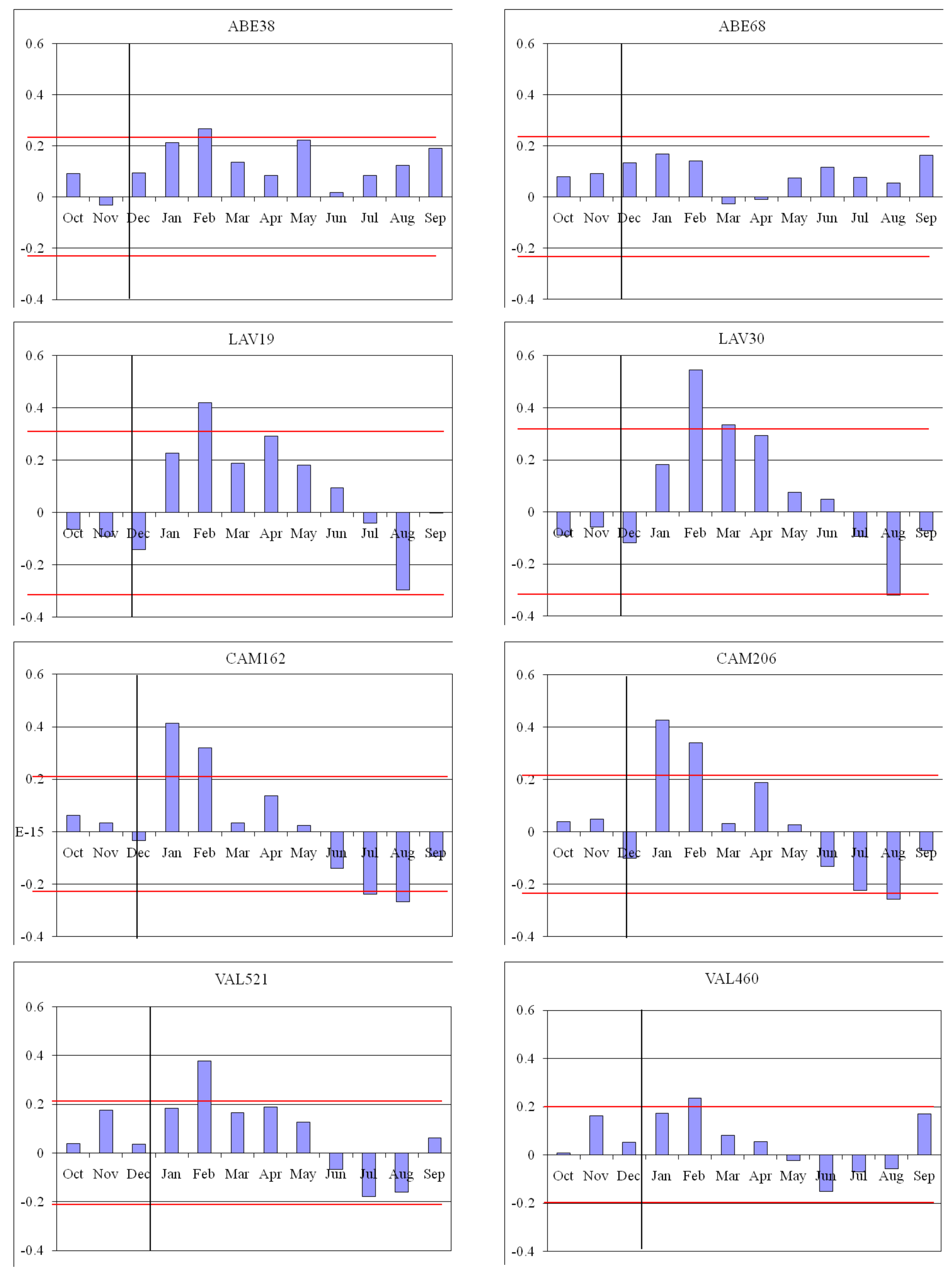

Fig. 5 – Pearson's-*r* (y-axis) of monthly mean temperature chronologies versus residuals of standardized tree-ring series of the silver fir stands. The red lines show the +/- 95% significance intervals. February is usually statistically significant, January and August are significant at CAM, and March at LAV30 (lower parcel at LAV). The bottom right graph shows the parcel at lower elevation, the upper left graph refers to the higher one; graphs on the left are the upper stands at each site.

Non-stationary correlation structures

We investigated the tree-ring/climate correlations more closely to determine if there have been temporal fluctuations in the strength of the associations. A 21-year running correlation analysis showed that the tree-ring/climate relationships have varied markedly over time. Surprisingly, our analysis demonstrated that correlations varied not only in strength, but in sign. For example, the VAL tree-ring chronologies were negatively correlated with July temperature before 1970 and positively correlated after 1970. The correlation structures varied among sites and across months providing strong evidence that tree-ring/climate relationship in the Tuscan Apennine Alps (Central Italy) have been non-stationary over the 20th century. Further analyses are underway to better understand these patterns.

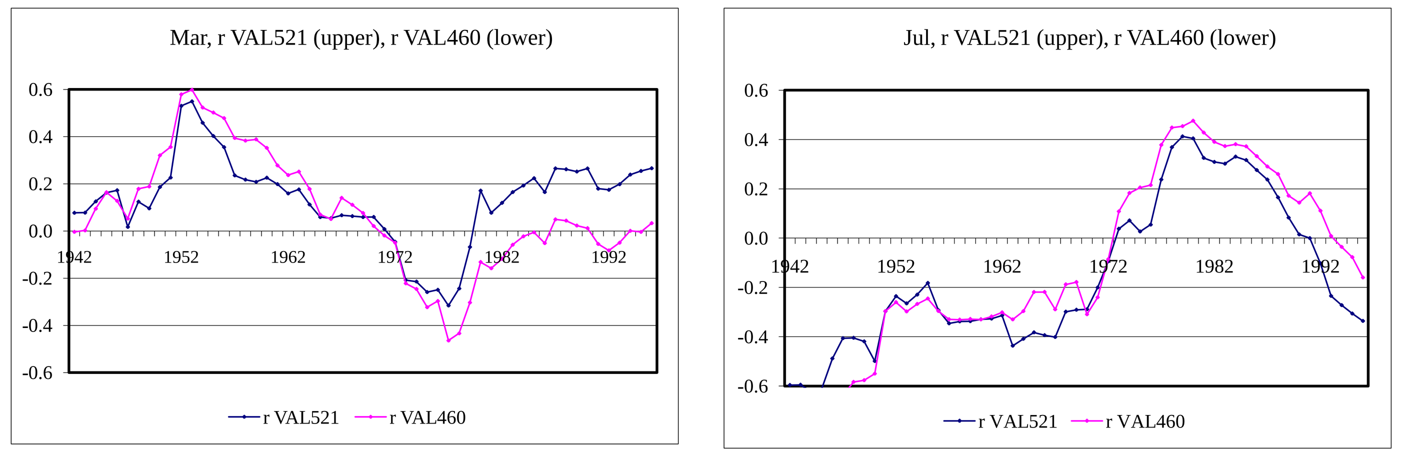

Figure 6. Trends of Pearson's-*r* between 21-years running means of monthly mean temperature and residuals of tree-ring chronologies at VAL in March and July during the period 1940-1996. The blue line shows the upper site, the magenta line is the lower site.

Conclusions

• In montane environments such as the Tuscan Apennine Alps, silver fir (*Abies alba* Mill.) grows in a narrow, discontinuous belt near treeline. At these sites silver fir are susceptible to climate alterations. Although climate models project regional trends of increasing temperatures, there may be considerable variation at the local level. Understanding how climate variability is manifest at local level is critical for biodiversity and nature conservation, as well as forest management. Although mean monthly temperatures have increased by ~2.5°C in Tuscany over the 20th Century, detailed climate records from four montane study sites across Tuscany demonstrate substantial local variability even across short distance and similar elevations.

• Dendrochronological analyses revealed that tree growth at three of the sites is significantly correlated with temperature. The fourth site (ABE) shows only marginal correlation at the upper elevation site. The growth of silver fir in these forests is correlated with February and August mean temperatures. However, these correlations mask considerable temporal variability in strength and sign of tree-ring/climate relationships. The relationship between growth of silver fir and local temperatures is nonstationary over the 20th Century. These patterns demonstrate remarkable variability in the responsiveness of silver fir to climate and raise important questions about reconstructing past temperatures in Europe using tree-rings, as well as about the ecophysiology of silver fir.