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Stable isotope ratios in late wood of *Picea abies* from Engadine

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Introduction

Trees supply terrestrial records from pre-industrial period that are invaluable for climate change studies: to fully exploit the potential of tree-rings as archives of paleoclimate data, several tree-ring parameters should be examined in combination. In this on going project we aim to compare fluctuations of $\delta^{13}C$ and $\delta^{18}O$ in tree-rings, with tree-ring width and maximum density. A first set of results concerning the $\delta^{13}C$ isotopic ratios is presented here.

In this study, $\delta^{13}C$ variations in late wood cellulose of *Picea abies* Mill., growing at the upper timberline were calibrated with meteorological data. Two time windows of 50 years, covering periods of climatic interest were investigated, namely, the end of the 20th century (1946-2000 AD) as a warm period, and the beginning of the 19th century (1800-1850 AD) covering the Dalton minimum.

This research is part of a program investigating palaeoecological natural archives with annual resolution (lake varves, ice cores and tree rings) from the same geographic area (Central Alps) (NCCR Climate, project VITA).

Methods

Samples were taken in the Central Alps, Engadine Valley, Switzerland, at 1900 m a.s.l. Bedrock is acidic (gneiss) and soil type podzsol, soil drainage was good, trees were growing at middle slope, with SW aspect, on a convex Topography. Sampled *Picea abies* trees grow in an open mixed conifer community with *Larix decidua* and *Pinus cembra* (40% cover). Forest understorey was dominated by *Calamagrostis villosa*, *Vaccinium myrtillus*, *Rhododendron ferrugineum* (80% herb layer, 10% shrub layer). Four to six cores from *Picea abies* (L.) Karsten dominant trees were taken. At the same time two cores were taken from 40 sub-dominant and suppressed spruce trees to develop a reliable chronology. Two cores from four selected dominant trees were used for isotopic analysis. The late wood and early wood from each ring was separated with a razor blade under a binocular, the boundary late/early wood was clearly visible making accurate separation possible.

The late wood of two cores from the four selected trees was pooled for each year to further analysis (Treydte, Schleser et al. 2001). Pooled late wood samples were then milled. Pooling and homogenizing the wood has shown to give a reliable mean isotope curve.

Cellulose was extracted from the wood through dissolution of the extractives with toluene and ethanol in a soxhlet apparatus, followed by lignin and hemicellulose extraction (with

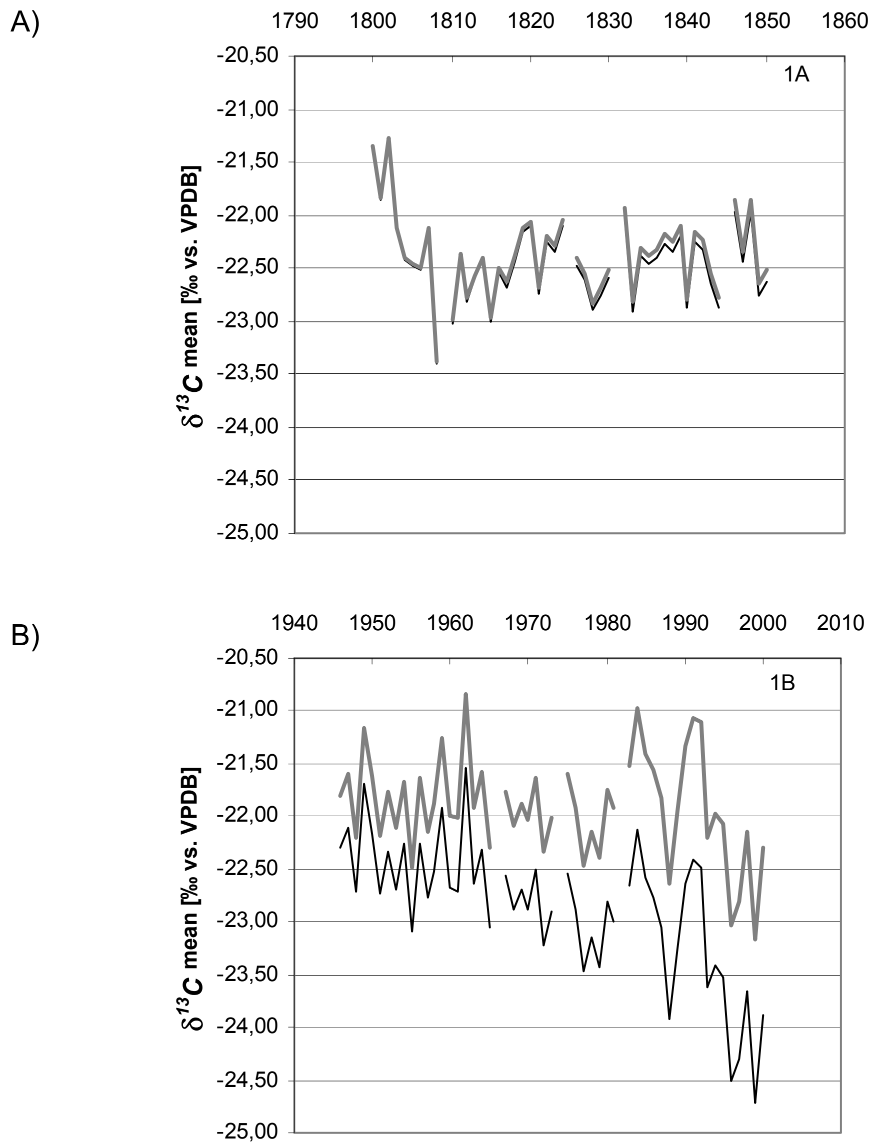


Figure 1: δ^{13}C mean [‰ vs. VPDB] in the two periods analysed (A: 1800-1850 AD; B: 1946-2000 AD); measured values in black, corrected values in grey.

$NaClO_2$, acetic acid solution, and NaOH, respectively) and final cleaning of the α-cellulose in deionised water (Green 1963; Brenninkmeijer 1983). Isotopes were measured with a IRMS at the Physical Insitute, Bern. Measured isotope data expressed as δ^{13}C vs PDB (‰) were detrended using residuals from a 5 –year Kernel filter to pronounce very high frequency variations.

Mean monthly homogenised temperature anomalies, homogenised precipitation, sunny hours and relative humidity were available from the nearby station of Davos for the years 1946-2000 AD. Mean monthly temperatures and precipitation dating back to 1800 AD were available from a meteorological station in Milan. Residuals of meteorological data, after filtering by a 5-year Kernel filter, were correlated with standardized isotopic variations to enhance the short term signal.

Results

The content of $\delta^{13}C$ in cellulose is influenced by the progressive decrease of atmospheric $\delta^{13}C$ due to the emission of CO_2 of plant fossil origin since the beginning of industrialisation. This long term effect has to be considered when investigating the relationship between meteorological data and tree ring $\delta^{13}C$. Ice core $\delta^{13}C$ values from Cape Grim were used for corrections of the tree ring isotopes (Francey, Allison et al. 1999) (Figure 1A, and 1B). In the text we refer from now to corrected values.

The records of $\delta^{13}C$ in the tree ring cellulose for the 1800-1850 AD interval (Figure 1A) show a strong decreasing trend in the first decade of the 19th century (1800-1808 AD) with values ranging from –21.84‰ to –23.39‰. In contrast, from 1810 to 1850 AD, the isotopic ratios range only from -22.99‰ to -21.9‰. The mean value for the whole 50 year period is –22.37‰.

The whole record for the 1946-2000 AD period shows a decreasing trend, the mean of this 50 years interval being -21.90‰. In the first 30 years of the 20th century the isotopic records range between -20.84‰ and –22.49‰, but in the last 20 years of the century a minimum of -23.16‰ is reached.

Correlation coefficients between isotopic ratios and monthly values of temperature, precipitation, sunny hours and relative humidity were calculated. Table 1 shows the correlation to the summer season. Highest correlations were recorded for the combination of the months July and August for temperature; precipitation, sunny hours and relative humidity (see Figure 2A and 2B for temperature). Precipitation has a higher negative correlation when the whole growing season is considered (June, July and August).

*Table 1: Correlation coefficients between corrected $\delta^{13}C$ and residuals of meteorological data for summer months (after standardization) for the two time periods analysed; (**=p<0.01; *=p<0.05).*

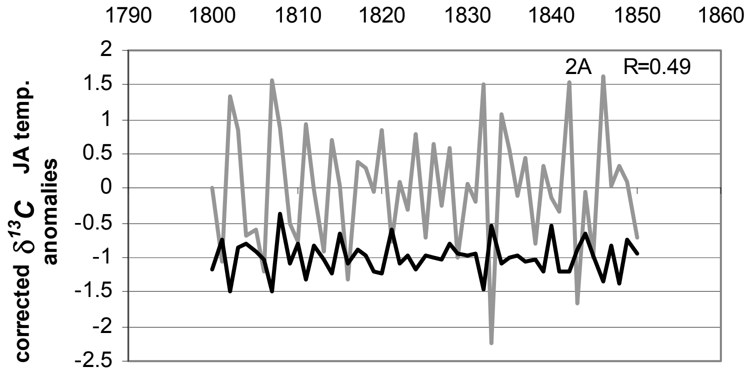
	JJA	**JJ**	**JA**
1946-2000 AD, Davos			
PRECIPITATION TOTALS	-0.30*	-0.19	-0.21
TEMPERATURE ANOMALIES	0.27*	0.13	0.41**
SUNNY HOURS	0.38**	0.36**	0.46**
RELATIVE HUMIDITY	-0.34*	-0.40**	-0.37**
1800-1850 AD, Milan			
PRECIPITATION TOTALS	-0.16	-0.34*	-0.16
TEMPERATURE ANOMALIES	0.34*	0.29*	0.49**

Discussion and conclusions

Accurate calibration of isotopic signal with reliable meteorological data in different species and in the most diverse ecological settings are necessary. Currently only one study is available for the alpine regions (Treydte, Schleser et al. 2001).

The $\delta^{13}C$ late wood record in the two time windows shows a marked decrease, with a difference between the mean values of the two periods of 0.78‰. A longer continuous record would be necessary to assess the relevance of such a decreasing trend and to investigate its possible relations with the recorded global warming for the last century.

A)



B)

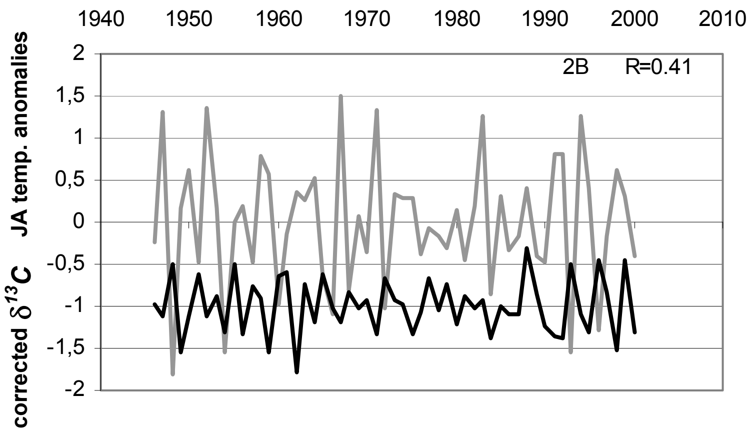


Figure 2: Variations of residuals of July-August temperature anomalies (grey) and $\delta^{13}C$ standardized values (black); (A: 1800-1850 AD; B: 1946-2000 AD).

Isotopic variations in late wood cellulose were calibrated with meteorological parameters. The number of sunny hours during the months of July and August showed to be the most relevant parameter to predict the variations in the cellulose isotopic record in the 20th century window (r=0.46). This parameter integrates tree growing conditions during the late growing season in which late wood is produced. For the 19th century window records of sunny hours were not available, but temperature seems to be even a stronger predictor (R=0.49). A stronger correlation with temperature for the years 1800-1850 AD suggests the climatic signal in the more recent isotopic records being dampened by the effect of the increase in atmospheric CO_2 concentration resulting from fossil fuel burning, deforestation and expansion of agriculture. If this is the case, further corrections should be considered to take into account the plant responses to changed growing conditions (Treydte, Schleser et al. 2001, Treydte 2003).

Comparisons with other tree-ring parameters measured on the same samples should yield additional information to evaluate the potential of isotope variations for climate reconstruction.

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