

## The European Isotope Network ISONET: First Results

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### Introduction

Within the EU-Project ISONET (co-ordinator: G. Schleser, <http://www.isonet-online.de>), 16 partner institutions collaborate to develop the first large-scale network of stable isotopes (C, O and H), integrating 25 European tree sites reaching from the Iberian Peninsula and southern Italy to Fennoscandia. Key species are oak and pine. The sampling design considers not only ecologically “extreme” sites, with a single climate factor predominantly determining tree growth, as required for ring width and wood density analyses (Bräuning and Mantwill 2005, Briffa et al. 2001, 2002, Frank and Esper 2005a, b), but also temperate regions with diffuse climate signals recorded in the ‘traditional’ tree ring parameters. This may enable expanding climatic reconstructions into regions not yet well covered.

In this project we aim to estimate temperature, humidity and precipitation variations with annual resolution, to reconstruct local to European scale climate variability over the last 400 years. Climate variability is addressed on three timescales, namely decade-century, inter-annual and intra-annual. This strategy allows understanding of both, high frequency (high resolution exploration of seasonality signals, and extreme events) and longer-term trends (source water/air mass dominance, baseline variability) in site specific and synoptic climate across Europe. Here we present results from initial network analyses considering first data of

carbon ( $\delta^{13}\text{C}$ ) and oxygen ( $\delta^{18}\text{O}$ ) isotopes, to evaluate (a) common patterns in these networks and (b) their potential for detailed climate reconstruction beyond the information commonly achieved from ring width and density analyses.

### **Material and Methods**

Oxygen isotopes were measured at 18 sites, and carbon isotope analyses at 21 sites (several data sets provided independent from ISONET), ranging from the Iberian Peninsula and southern Italy up to Fennoscandia, as shown in figure 1.

Ring widths were measured using a semi-automated RinnTech system with a resolution of 0.01 mm and cross dated following standard procedures (Fritts 1976). 4 trees per site (2 cores per tree) were selected for isotope analysis. Criteria for sample selection were low numbers of missing rings and regular ring boundaries. Tree rings were then separated year-by-year using sharp knives or scalpels (for oak only late-wood was considered). For the majority of sites tree-rings grown in the same year were pooled prior to cellulose extraction to facilitate the development of this large network (Borella et al. 1998, Leavitt and Long 1984, Treydte et al. 2001). Cellulose was extracted following standard procedures (overview in McCarroll and Loader 2004) and burned to  $\text{CO}_2$  or pyrolysed to  $\text{CO}$ , respectively, before mass spectrometer analysis (McCarroll and Loader 2004).  $\delta^{18}\text{O}$  values are expressed as deviations from the VSMOW and  $\delta^{13}\text{C}$  values as deviations from the VPDB standard (Craig 1957).

Carbon isotope records were corrected for the decrease of atmospheric  $\delta^{13}\text{C}$  values due to fossil fuel burning since the beginning of industrialisation AD 1850 (Friedli et al. 1986, Francey et al. 1999).

### **Results and Discussion**

In a first step, individual site chronologies of all records were calculated over the common period of AD 1913-1994.  $\delta^{18}\text{O}$  means mirror the patterns of  $\delta^{18}\text{O}$  values in precipitation, recorded by European GNIP-stations ("Global Network of Isotopes in Precipitation", IAEA), with distinct gradients from lower to higher latitudes, oceanic to continental regions, and low to high elevation (Fig. 1). These patterns are related to evaporation and condensation effects taking place as air masses move from oceanic source regions to higher latitudes, over continental land or from low lands to mountainous regions (Cole et al. 1999, Jouzel et al. 2000, Siegenthaler and Oeschger 1980, Rozanski et al. 1993). Corresponding mean values of the  $\delta^{13}\text{C}$  chronologies reflect local water supply due to the physiological response and fractionation of trees under water stress and therefore are related to the regional atmospheric moisture distribution (Saurer et al. 1997b, Treydte et al. 2001) (Fig. 1).

Cluster and Principal Component Analyses (PCA) suggest that both  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  site chronologies show systematic spatial relationships independent of species, although the inter-site correlations are higher for  $\delta^{18}\text{O}$  than for  $\delta^{13}\text{C}$ . Clusters are identified in western central, eastern, and southern Europe. The "network extremes", namely both Mediterranean sites in southern Spain and Italy and the Finnish site do not fit in any clusters, pointing to specific climate and/or site conditions.

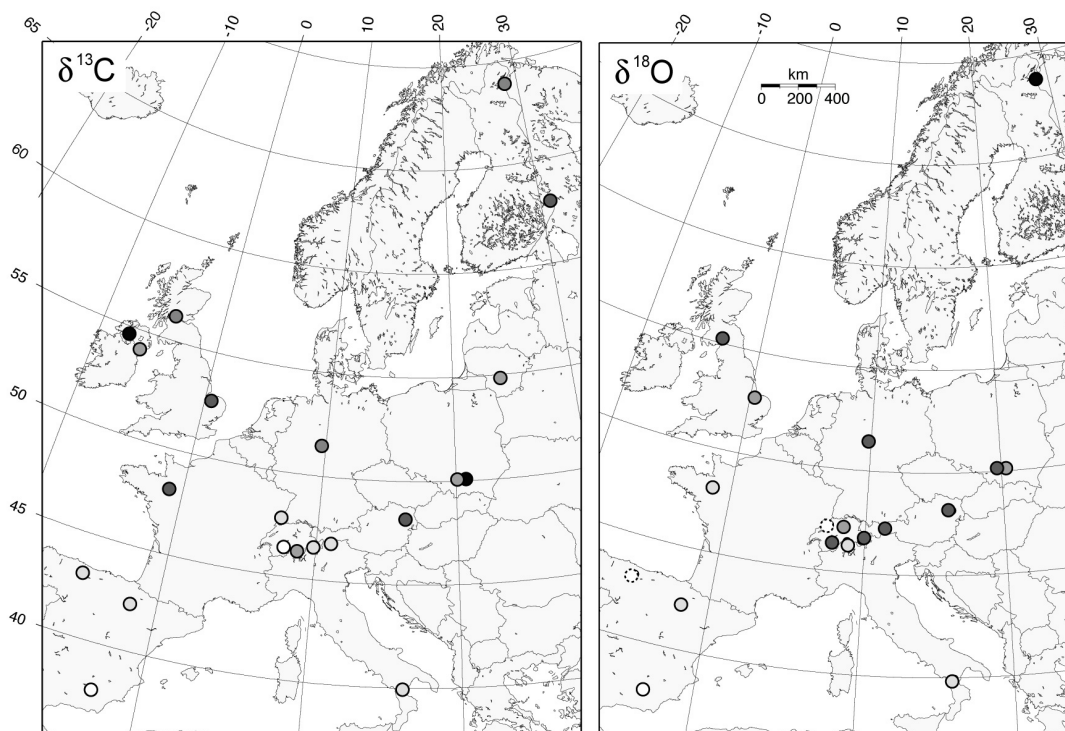


Figure 1: Sites used for preliminary network analysis (left:  $\delta^{13}\text{C}$ , right:  $\delta^{18}\text{O}$ ). Light colours: high mean isotope values, dark colours: low mean isotope values, dotted signature: missing cellulose values for the common period, therefore excluded for comparison of mean values, but used for time series analysis.

Most of the  $\delta^{18}\text{O}$  sites show positive loadings on the first principal component (PC1) (again except for the above mentioned sites), pointing to a common signal over the network (21% explained variance at PC1). In comparison, coherence within the  $\delta^{13}\text{C}$  network is lower, likely resulting from differences in local ecological conditions, which have a greater influence on  $\delta^{13}\text{C}$  than on  $\delta^{18}\text{O}$  patterns (Saurer et al. 1997a, Treydte 2003). Both, PCA and cluster analysis prove the quality particularly of the  $\delta^{18}\text{O}$  network through clear common signals, but also point to potential regionalisation of European climate reconstruction.

Parameter-specific analysis of low-frequency trends, using 200-year splines, suggests heterogeneous long-term behaviour in the oxygen records. In contrast,  $\delta^{13}\text{C}$  long-term trends are rather common over the network pointing to the dominant impact of decreasing atmospheric  $\delta^{13}\text{C}$  values induced by fossil fuel burning since industrialisation (Friedli et al. 1986, Francey et al. 1999). Correcting the records for this effect leads to heterogeneous long-term behaviour similar to the oxygen measurements. Differences could either be due to regionally differing low-frequency climatic trends over the study region, individual age-related long-term biases in the records, variable physiological response (e.g. reduction of stomatal conductance) to increasing  $\text{CO}_2$  depending on differing site conditions, or currently unexplainable noise (Treydte 2003, Treydte et al. 2005). However, this finding has to be tested in the future using all records covering the full time span of 200-400 years.

After high-pass filtering from 200-year-splines, the oxygen records in particular reveal significant variance in the inter-decadal frequency domain. This signal seems to be common over the whole network.

The oxygen isotope network was used for initial climate calibration. Based on calculations with a 100-year (1901-2000) monthly European temperature and precipitation 0.5° gridded data set (New et al. 2002), months of significant correlation could be identified.

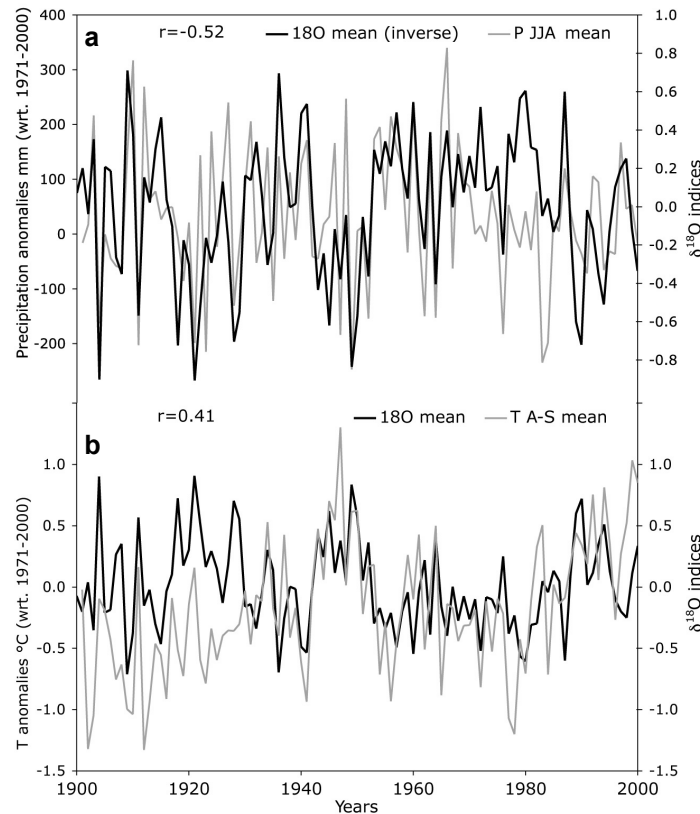


Figure 2: Comparisons between precipitation (a), temperatures (b) and a mean (European)  $\delta^{18}\text{O}$  chronology for the 20<sup>th</sup> century (detrended from 200-year splines); The isotope chronology was developed by averaging  $\delta^{18}\text{O}$  measurements from all available sites, the climate records by averaging all corresponding grid point data. P JJA mean is the mean summer precipitation from June to August; T A-S are the mean temperatures from April to September, both expressed as anomalies with respect to their 1971-2000 means.

At the majority of sites, tree ring  $\delta^{18}\text{O}$  correlates positively with temperature and negatively with precipitation variations during the summer months. Averaging the  $\delta^{18}\text{O}$  records of all sites and correlating them with similarly averaged meteorological data, leads to highly significant relationships for June to August precipitation (-0.52) and April to September temperature (0.41), indicating the potential for a “European” climate reconstruction. It should be noted, that in some cases the meteorological grid points do not ideally represent local site conditions. This holds particularly for precipitation conditions at high elevation sites, e.g. in Italy. Hence, using local meteorological station instead of grid point data could likely enhance the precipitation signal.

The rather coarse data treatment of averaging all sites and hence ignoring spatial details within the network provides already surprisingly good results. Obviously precipitation

variability is mirrored particularly in the short-term (year-to-year) domain (Fig. 2a), whereas temperature variability is fingerprinted particularly in the decadal scale domain (Fig. 2b). Differing temperature and isotope records in the early period (Fig. 2b) could be explained on the one hand through a too stiff de-trending of the isotope records, on the other hand through decreasing data replication in the instrumental records (Büntgen et al. 2005, this volume). Initial comparisons of the mean carbon and oxygen isotope chronologies averaged over the whole network (Fig. 3a) indicate significant correlation between these parameters (0.53 for the 20<sup>th</sup> century). This relationship seems to appear mainly between high-frequency variations, whereas on decadal scales some differences exist. Correlations between the first principal components of the carbon and oxygen data improve this relationship to 0.58.

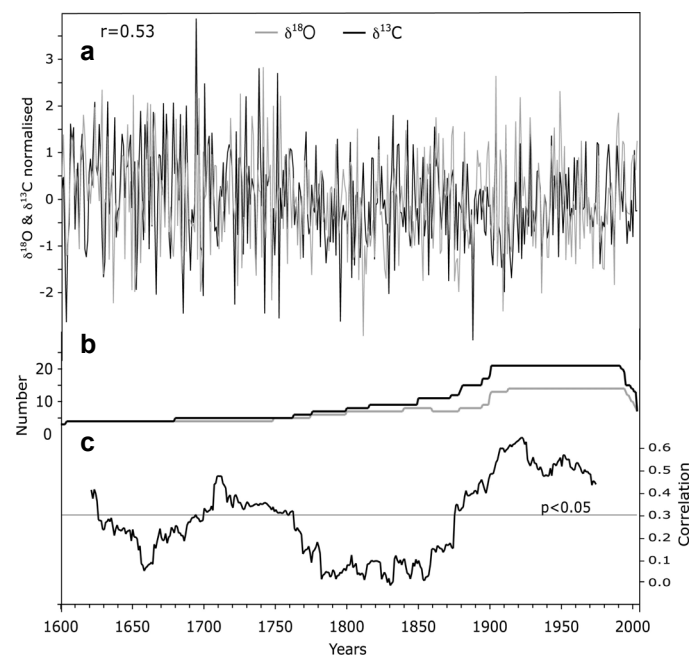


Figure 3: Relationship between the “European”  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  chronologies; Site data are de-trended using 200-year splines (a). The records correlate at 0.53. (b) Replication of the chronologies, and (c) moving correlation using 30-year time windows.

Moving correlations over a 30-year time window (Fig. 3c) indicate strongest relationships in the 20<sup>th</sup> century, being the period with highest replication (Fig. 3b). The changing sign of the correlation coefficient could indicate some change in the climate system (yet to be explored). High-frequency similarity between carbon and oxygen data is explained through variations in stomatal conductance, influencing the behaviour of both isotopes, due to the combined effect of varying temperature and precipitation conditions, which themselves are inter-correlated. Low stomatal conductance during dry/warm weather conditions causes high  $\delta^{13}\text{C}$  values through weak discrimination against  $^{13}\text{C}$ . Nevertheless transpiration increases compared to cool/wet conditions, resulting in higher leaf water enrichment and thus in higher  $\delta^{18}\text{O}$  values (Anderson et al. 1998, 2002, Farquhar and Lloyd 1993, Leuenberger et al. 1998, Masson-Delmotte et al. 2005, Rafalli-Delerce et al. 2004, Roden et al. 2000, Treydte 2003, Treydte et al. 2004). Hence, both parameters should be mainly driven by summer moisture conditions.

## Conclusion and Outlook

Preliminary tree ring  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  network analyses integrating data from about 20 European sites clearly demonstrate the potential for detailed European climate reconstructions over the last 400 years. Isotope datasets from temperate sites in Central Europe contain species-independent common signals, which enable to spatially extend climate reconstruction from tree rings which at present are mainly limited to “extreme” sites. Common signal strength on annual to multi-decadal timescales is higher in the oxygen isotope than in the carbon isotope network, pointing to a stronger external forcing. Nevertheless, the comparison of “European”  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  chronologies after averaging all sites indicates significant similarities on annual to decadal scales. We hypothesise that both parameters are mainly driven through summer moisture availability. This is important because currently detailed tree-ring reconstructions of precipitation are lacking for temperate regions. Centennial scale variation is, however, not yet understood in  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  data. Besides the incompleteness of the current data-sets, regionally differing synoptic conditions, age-related biases, and varying plant physiological reactions on changing atmospheric  $\text{CO}_2$  concentrations could account for heterogeneities in the long-term behaviour between sites. Further investigations will be based on the use of complete and extended isotope datasets from all sites, covering the full period of 400 years where possible. Detailed wavelength analyses by separating the datasets into different timescales (high frequency, decadal, secular) will be employed to analyse the climate signal in tree ring data and to differentiate potential age- and site-related and anthropogenic noise from climate signals. Consideration of additional meteorological data such as vapour pressure, sunny hours, cloudiness, and particularly drought indices will be utilized to test the environmental information in the isotope records. Together with large-scale surface pressure data sets, such as NAO, and comparisons with new European temperature reconstructions (e.g. Luterbacher et al. 2004), detailed knowledge about European climate variation over the past few centuries will be derived.

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