

P 1.3

Drought effects and PDSI reconstruction from Southern and Central European trees (DE-TREE)

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1. Three research questions of the project

- What are the effects of water availability on tree growth and how can we optimally utilize ring width and isotopic data to reconstruct changes in the water cycle from widespread (non-boundary/treeline) forests in southern and central Europe?
- What long-term changes in drought and pluvial episodes (e.g., via the Palmer Drought Severity Index, PDSI) occurred in Europe, and how do PDSI and precipitation variance spectra appear over multi-centennial timescales?
- Can regionally explicit moisture-regime changes be reconstructed in Europe, and can these variations be related with long-term climate model output?

2. Research Summary

Most efforts to reconstruct regional to large-scale climate variability have focused on temperature. This tendency, driven to quantify natural and anthropogenic radiative forcing changes, neglects the arguably much greater importance of water availability, and its short to long-term variations, to society and ecosystem functioning. We thus seek to reconstruct drought variability and impacts from widespread European tree species, and compare empirically based estimates with long-term climate model simulations and intra-seasonal growth data.

Within De-Tree analyses of tree-ring width and stable isotope data from widespread forests in southern and central Europe and subsequent calibration of these proxy data against gridded and long-term instrumental station records are scheduled. We will assess age-related biases in tree-ring isotopes (Treydte et al., 2006), explore possible changes in transpiration related to the ~35% increase in atmospheric CO₂ over the past 150 years, and combine stable isotope with traditional tree-ring width data (Treydte et al., 2007) to develop multi-parameter supported climate reconstructions.

De-Tree includes an analysis of drought fingerprints in existing and newly developed data, and estimation of PDSI signals both in extremes and for multi-decadal to centennial scale variations (Cook et al., 2004). Particularly sensitive sites and species will be combined with low elevation archaeological/relict data to reconstruct PDSI over the past millennium (Esper et al., 2007) and to associate these histories with climate models using time-slice experiments (Trouet et al., 2008). Changes in boundary conditions and possible shifts in source water will be explored by analyses of isotopic signatures in existing tree-ring and precipitation data, and changes in water use efficiency assessed via annual timeseries of carbon isotope discrimination from broadly distributed locations throughout Europe (Treydte et al., 2007). Expected output includes a better quantification of the long-term changes in the hydrological cycle, a long-term assessment of hydroclimatic impacts on aboveground woody biomass, and initial evaluations of vegetative feedbacks on the European climate.

3. Data and methods

To answer the above research questions, we will shift foci and methods from those developed and successfully implemented during the previous two phases of NCCR-Climat. Rather than targeting extreme treeline locations, compilations of existing and development of new data will target forested areas representative for the European continent. This will allow changes in continental-scale productivity and related water use to be assessed. For one selected location in central Europe (e.g., Germany or Switzerland) we will develop an annually resolved isotope-based timeseries and for another location in the Mediterranean (e.g., Spain or Italy) we will develop a long-term tree-ring width series. The species and the exact sites will be selected based upon pre-investigations to maximize chronology length and

sensitivity to changes in the hydrological cycle. *Pinus spp* in the Mediterranean and both hardwood (*Quercus spp.* or *Fagus sylvatica.*) and conifers for central Europe are under primary consideration. The newly developed records will be compared and combined with existing tree-ring timeseries that contain some precipitation signal. As particularly the ring width data from central Europe often contain weaker climatic signals (Friedrichs et al., 2008), we seek to integrate larger multi-species datasets from both living stands and historic material to cope with this shortcoming, and develop longer-term records indicative of changes in the hydrological cycle on timescales from years to centuries.

Novel methods of tree-ring detrending – including basal area increments – carbon data correction, reconstruction error estimation, and empirical data versus model comparison will be explored. Also new to De-tree will be the possibility to link, for the first time, intra-annual responses of trees to climate (e.g., growing season length, periods of cellular activity, wood anatomical features) with signals in long-term proxy based reconstructions. We will develop and improve upon various methodological aspects of palaeoclimatic reconstruction, better quantify possible age-related trends (Esper et al., 2008) in isotope data, and hence test their suitability for unobstructed reconstruction of low-frequency climatic variations. Pre-investigations have shown that the drought indices such as the PDSI (van der Schrier et al., 2006) may capture a significant amount of the year-to-year variability in broadly distributed tree species, and may thus offer the possibility to develop regional (Esper et al., 2007) and gridded PDSI reconstructions (Cook et al., 2004) that do not require stationary assumptions of climatic teleconnections defined during the calibration period.

Particular attention will be paid to relationships inferred and calibrated during the instrumental period to (i) assess possible inconsistencies and biases in early instrumental station data that are relevant to test the temporal stability of transferred reconstructions (Frank et al., 2007a; Böhm et al., 2008), (ii) define the amplitude of reconstructed variations (Esper et al., 2005), and (iii) determine possible instabilities or long-term changes in the sensitivity of biological systems to climatic change and extremes (Rutishauser et al., 2008; Büntgen et al., 2008). The spectral properties of proxy and instrumental dataset will be considered (Osborn and Briffa, 2004) to determine the most suitable reconstruction targets and techniques (Frank et al. 2007b; Esper and Frank, 2008).

These and methodological uncertainties will be considered to set more realistic and properly defined error estimates (Esper et al., 2007) that will allow De-Tree to contribute well-verified regional reconstructions of longer-term drought variability, and will aid in the multi-proxy compilations and the overall objectives scheduled for the third NCCR Climate phase. Proxy-based reconstructions will be associated with regional output derived from global climate models using proxy-surrogate-techniques (Graham et al., 2007) to assess the spatial coherence of reconstructed drought patterns and further knowledge of the association of atmospheric high- and low-frequency climate modes (Raible 2007).

4. Milestones and deliverables

After 18 months:

- Composition of existing drought-sensitive ring width data of widespread European tree species;
- Documentation of local and regional precipitation and drought reconstructions including assessments of variance changes and spectra;

After 36 months:

- Development of one long-term, PDSI sensitive ring width datasets from the Mediterranean, and one long-term, PDSI or relative humidity sensitive stable isotope dataset from Central Europe;
- Regional drought reconstructions from southern and central Europe integrating existing and newly developed data, accompanied by well-constrained reconstruction error estimations.

5. Contribution to the WP1 and collaboration with other NCCR projects and 3rd parties

The expertise developed by De-Tree members in reconstructing past climate variability will form a critical part in linking changes in the past with those observed by modern

instrumental networks and projected via simulations, within the NCCR-framework. Collaborative efforts include: (i) Joint analyses of quantile regression methodology (P1.2); (ii) Contribute long-term drought records to spatially explicit precipitation reconstruction (P1.2); (iii) Comparison of reconstructed decadal scale changes in the regional hydrological cycle with CCSM3 time-slice experiments and 500-year simulations (P1.1); (iv) Associate proxy-based reconstructions with CCSM3 output using proxy-surrogate-techniques (P1.1); (v) Association of the inter-annual drought reconstructions with the intra-annual monitoring of forest growth from the Swiss Canopy Crane and helicopter-based forest sites (P3.3). De-Tree is well placed to contribute to the European Community projects “Millennium” and “CARBO-extremes”, representing larger coalitions of the 6th and 7th framework programmes, respectively. Results will be relevant to local and regional organizations and authorities, and to scientific programs and databases dealing with climate variability, impacts, and global change issues. Examples include: (i) Past Global Changes Program (PAGES), Bern, Switzerland; (ii) National Geophysical Data Center (NOAA) and the International Tree-ring Databank (ITRDB), Boulder, Colorado; and (iii) The Intergovernmental Panel on Climate Change (IPCC), WMO and UNEP, Geneva, Switzerland. Long-term reconstructions will be of importance to large-scale proxy data compilation, the assessment of inter-regional drought variations, and likely for attribution studies.

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