European tree-ring data and the Medieval Climate Anomaly

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European tree-ring chronologies reveal that temperatures during the Medieval Climate Anomaly (MCA) were likely as warm as during the 20th century, that earlier hydroclimatic changes have at times exceeded recent variations, and that evidence for a clear spatiotemporal pattern of the MCA remains puzzling.

Europe possesses a dense network of long instrumental station measurements, and with Scandinavia and the Alps, harbors at least two of the world's hotspots of dendroclimatic research that provide an exceptional pool of archeological wood material. Annually resolved millennium-long tree-ring chronologies that enhance our understanding of the Medieval Climate Anomaly (MCA, ca. 900-1400 AD), exist for different parts of Europe and northern Africa. Individual records that combine an adequate number of recent and historical samples can reflect high- to low-frequency variations in either warm season temperature or precipitation.

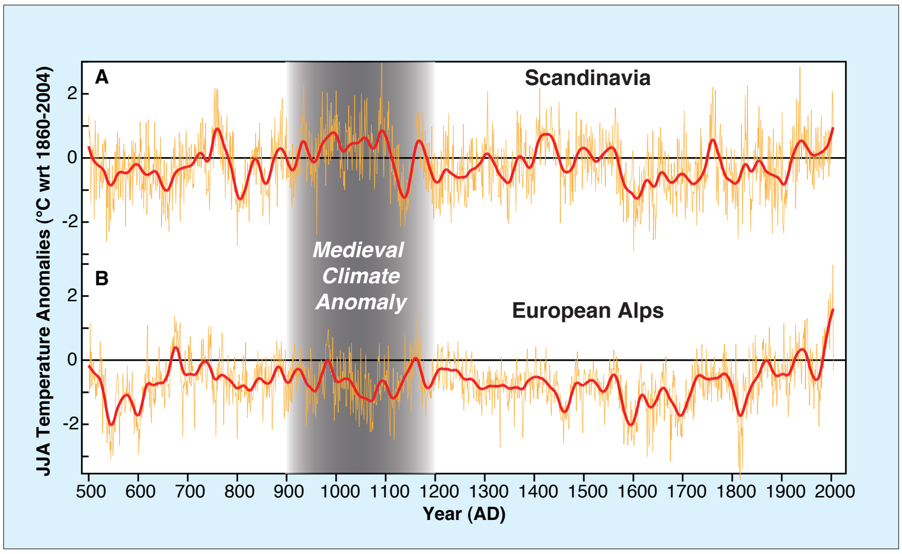

*Figure 1: Annually resolved and 40-year low-pass filtered temperature reconstructions averaged over (**A**) Scandinavia and (**B**) the Alps. Five tree ring-based warm season temperature reconstructions from Scandinavia (Briffa et al., 1992; Gouirand et al., 2008; Grudd et al., 2002; Grudd, 2008; Helama et al., 2009b) were re-scaled against June-August (JJA) temperatures (1860-2004 AD), averaged and smoothed. Their individual start and end dates range from 500-802 and from 1970-2004, respectively. Four tree ring-based warm season temperature reconstructions from the Alps (Büntgen et al., 2006, 2009, 2011; Corona et al., 2010) were re-scaled against JJA temperatures (1860-2004 AD), averaged and smoothed. Their individual start and end dates range from 500-1000 and from 2000-2004, respectively. Note that the initial reconstructions are not independent in terms of the data used and methods applied.*

Reconstructions

Millennium-long tree ring-based temperature reconstructions exist in northern Scandinavia (e.g., Briffa et al., 1992; Grudd et al., 2002; Grudd, 2008; Gouirand et al., 2008; Helama et al., 2009b) and the Alpine arc (e.g., Büntgen et al., 2005, 2006, 2009; Corona et al., 2010; Nicolussi et al., 2009). The Scandinavian composite records are based on living conifers, which grew during the past few centuries, and utilize dry-dead and sub-fossil material further back in time (see Linderholm et al., 2010 for a review). The Alpine temperature reconstructions are mainly based on high-elevation living conifers and historical construction timber. Slightly shorter temperature reconstructions that reach back into the 12th and 13th centuries are available from the Romanian Carpathians (Popa and Kern, 2009) and the Spanish Pyrenees (Büntgen et al., 2008). Both records show distinct summer temperature variations that are comparable to those obtained from the Alps. Dendrochronological studies in southern France (Serre, 1978), Albania (Seim et al., 2010) and Bulgaria (Panayotov et al., 2010) also revealed millennium-long ring width chronologies, but they only contain a mixed and overall lower climate signal (e.g., Büntgen et al., 2010a).

Northern and central European sites may reflect different patterns of temperature change (Büntgen et al., 2010b). Scandinavian summer temperatures were roughly below the 1860-2004 AD average from ca. 800-900, 1100-1400, 1570-1750, and from 1780-1920 AD (Fig. 1a). Summer warmth centered on the 760s, between ca. 980 and 1100 AD, and again in the 1410-1420s was comparable to, or even higher than, conditions during the 1930s and after ca. 1980. The timing of Scandinavian medieval warmth may have coincided with the establishment of Norse colonies in the cold and harsh environments of Iceland and Greenland (Patterson et al., 2010). In contrast, Alpine summer temperature depressions were estimated during the Little Ice Age (LIA) from the mid 15th century to ca. 1820 AD and coinciding with the Oort Solar Minima ca. 1050-1120 AD. Alpine summer temperatures during the late 20th century were unprecedented over the past 1500 years (Fig. 1b). Earlier warm periods occurred in the 990s and between ca. 1150-1250 AD and may have coincided with a rapid demographic and economic, as well as cultural and political rise of medieval Europe (McCormick, 2001).

While a few evenly distributed and highly replicated composite tree-ring chronologies (of distinct temperature sensitivity) are sufficient to capture the spatial character of European summer temperature variability (Büntgen et al., 2010b), many more records are necessary to provide a comparable meaningful picture of the continent's hydroclimatic variability. It should also be noted that most of the local-to-regional-scale hydroclimatic records best reflect drought conditions, such as soil moisture availability (Büntgen et al., 2010b), whose sensitivity is generally restricted to the early vegetation period of intense cell formation. Millennium-long ring width-based reconstructions from southern Finland (Helama et al., 2009a), south-central England (Wilson et al., unpublished data), central Europe (Büntgen et al., 2011), and the southern Mediterranean Maghreb (Esper et al., 2007; Touchan et al., 2010) preserve high- to low-frequency precipitation/drought variability (Fig. 2). Data also contain a pronounced level of synoptic-scale coherency amongst the same latitudinal belts. The two northernmost records agree well and show a drier

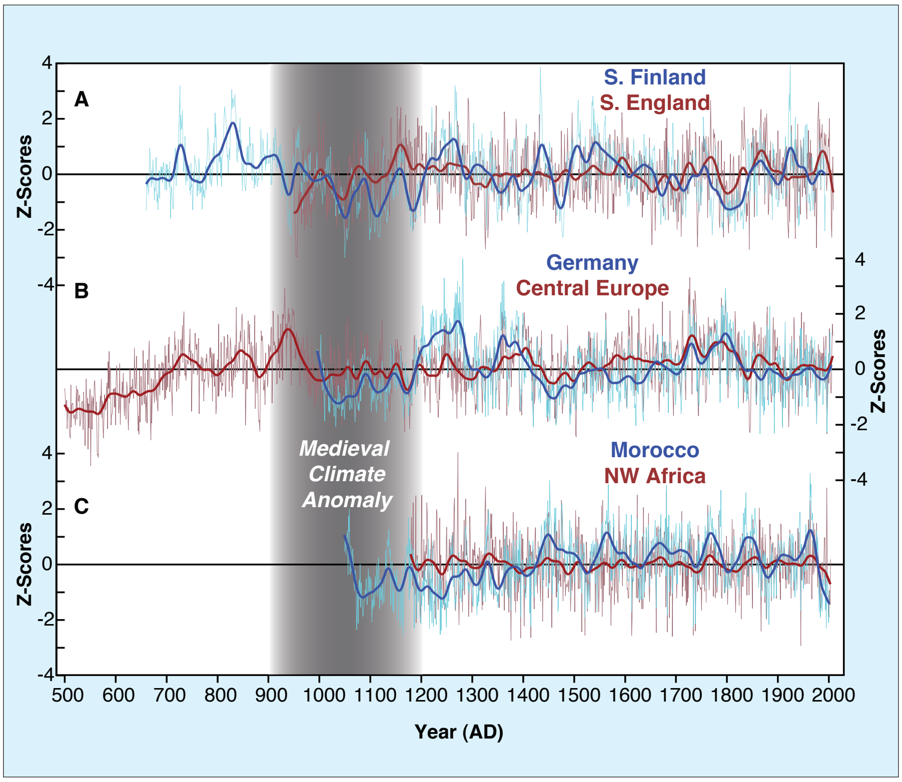

*Figure 2: Annually resolved and 40-year low-pass filtered regional-scale hydroclimatic reconstructions from (**A**) southern Finland (blue; Helama et al., 2009a) and south-central England (red; Wilson et al., unpublished data), (**B**) central Germany (blue; Büntgen et al., 2010) and central Europe (red; Büntgen et al., 2011), and (**C**) Morocco (blue; Esper et al., 2007) and northwest Africa (red; Touchan et al., 2010). Data were normalized over their individual length.*

MCA, a wetter LIA and average 20th century conditions compared to the individual record length (Fig. 2a). The central European records illustrate a similar picture with slightly higher amplitude between a drier MCA and a wetter LIA (Fig. 2b). The two records from the southern Mediterranean show decadal-scale hydroclimatic variations (Fig. 2c), but convincing indication for a longer-term contrast between an overall dry MCA, a wet LIA and an abrupt recent drought is largely derived from the study by Esper et al. (2007). It must be noted that the reconstructed northwest African drought fluctuations are based on a compilation of 39 site chronologies (Touchan et al., 2010), which are somewhat restricted in potentially preserving lower frequency information, and therefore partly deviate from the low-frequency signal displayed by Esper et al. (2007).

Evidence for a generally drier climate from ca. 1000-1200 AD is expressed in all compilations. Overall, wetter summers are found during the 13th and 14th centuries, in parallel to the global onset of the LIA, and may have added to the widespread famine in northern/central Europe in that period (e.g., Kershaw, 1973). Additionally, they may have also played a contributing role in the second plague pandemic, the Black Death (Büntgen et al., 2010c, 2011; Kausrud et al., 2010). Furthermore, the 14th century is associated with the abrupt abandonment of Greenland settlements (Patterson et al., 2010). Caution is however advised, as socio-cultural and epidemiological stressors must be carefully considered when linking climate variability to human history (de Menocal, 2001; O'Sullivan, 2008).

Perspective

The above paleoclimatic evidence emphasizes the need to better understand the timing and amplitude of the European MCA, as well as the associated spatial characteristic. Placing the MCA in a longer-term context and increasing the number of high-resolution proxy records will thus gain in importance. In this regard, it appears interesting that several multi-millennial-long chronologies of annually resolved ring width measurements have been developed for different parts of Europe. These compilations represent a unique dating tool, not only for archeological artefacts and historical construction wood, but also for antique artwork, instruments and furniture (see Haneca et al., 2009 for a review). Continuous chronologies of the past millennium are available for most countries of central and northern Europe. Oak composites of 2000 years exist for different sub-regions in England, Ireland, Denmark, Germany, Poland and France. Additional deciduous species including beech, ash and alder, as well as conifers (i.e., fir, spruce and pine) yield millennium-long chronologies for Germany, Austria, Switzerland, France and the Czech Republic. Their sample size comprises hundreds and thousands of series in Roman, Medieval, and Modern times, but dramatically drops during the so-called transition periods of increasing and continuing political turmoil. The paleoclimatic value of such compilations was recently demonstrated by introducing a random sampling strategy to update archeological chronologies into the 21st century while avoiding statistical over-fitting during the calibration (Tegel et al., 2010).

The annual-precise felling dates of historical wood can provide additional insight into socio-economic dynamics of past civilizations when carefully analyzing the dendrochronological records and utilizing dates of timber harvest as a surrogate for construction activity.

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References

Büntgen, U., et al., 2011: 2500 years of European climate variability and human susceptibility, *Science*, **331**: 578-582.

Corona, C., Guiot, J., Edouard, J.L., Chalié, F., Büntgen, U., Nola, P. and Urbinati, C., 2010: Millennium-long summer temperature variations in the European Alps as reconstructed from tree rings, *Climate of the Past*, **6**: 379-400.

Esper, J., Frank, D.C., Büntgen, U., Verstege, A., Luterbacher, J. and Xoplaki, E., 2007: Long-term drought severity variations in Morocco, *Geophysical Research Letters*, **34**, doi: 10.1029/2007GL030844.

Kausrud, K.L., et al., 2010: Modeling the epidemiological history of plague in Central Asia: paleoclimatic forcing on a disease system over the past millennium, *BMC Biology*, **8**, doi: 10.1186/1741-7007-8-112.

Tegel, W., Vanmoerkerke, J. and Büntgen, U., 2010: Updating historical tree-ring records for climate reconstruction, *Quaternary Science Reviews*, **29**: 1957-1959.

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