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A 600 year-long drought index for central Anatolia

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Abstract

We have used sediments from Nar lake in central Turkey to reconstruct climatic variability over timescales longer than can be obtained from direct meteorological observations. Because the sediments of this lake are annually layered and precisely dated, it has been possible to calibrate sedimentary climate proxies against meteorological records to derive a drought index; this has then been applied to time periods before instrumental data are available. In this study, $\delta^{18}O$ from Nar lake carbonates have been used to generate a decadal average P/E index for central Anatolia, which highlights major drought events since 1400 AD.

Keywords: Anatolia, lake sediments, varves, calibration, Little Ice Age, oxygen isotopes

Introduction

In the context of a changing global climate, it is important to understand Mediterranean hydro-climatic variability over timescales longer than those that can be obtained from direct monitoring and observations (i.e. >100 years). The long-term frequency, duration and intensity of drought periods are especially significant for rain-fed agriculture, water supply, and other key human needs. Our objective in this study is a reconstruction of hydro-climatic conditions for the last 600 years for central Anatolia, one of the driest regions of Turkey and consequently especially sensitive to hydro-climatic variations. We have used the oxygen isotope composition ($\delta^{18}O$) of individual carbonate layers from Nar Gölü, a small volcanic lake whose sediments are annually laminated, or varved. Analysis of historical meteorological data suggests that climatic trends at this

site are likely to be representative of the central Anatolian climate region (Türkeş *et al*. 2009) (Figure 1).

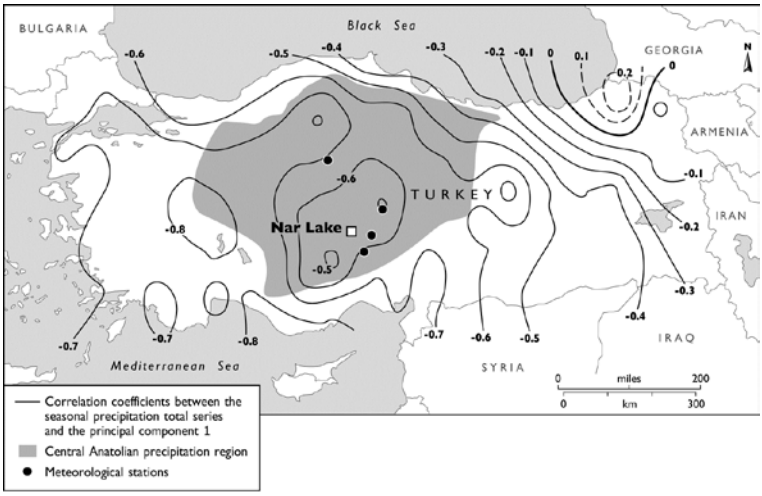

Figure 1. Spatial correlations in winter precipitation for Turkey 1953-2002 (see Türkeş *et al.* 2009 for detailed explanation. PC1 explains 46.5% of variance)

Central and western Anatolia shows good coherency in the pattern of precipitation (Pearson's correlation coefficients r ≥0.5). The Central Anatolian precipitation region is shown along with the location of the Nar lake study site and meteorological stations used for P/E index calibration.

Materials and methods

We have calibrated $\delta^{18}O$ of carbonates from individual Nar lake varves against temperature, precipitation, etc. for four central Anatolian meteorological stations for the last ~70 years (Ankara, Nevşehir, Derinkuyu, Niğde) to derive a regional drought index; viz. Precipitation/Evaporation (or P/E). Because of the multi-year residence time of the Nar lake water, sedimentary proxy data represent an 8-year average of lake water balance (Jones *et al.* 2005). They therefore allow past droughts of decadal or longer duration to be identified, but year-to-year weather variations are less clear.

We have used 1940-1976 as the reference period for this "calibration in time" approach. After 1980, shifts in the lake system, marked by a change in carbonate mineralogy between aragonite and calcite, altered isotopic balance in the lake, and complicate any linear calibration. For the calibration period there is an R^2 correlation of 0.76 between $\delta^{18}O$ in lake sediments and the 8-year running mean index for P/E. We have confirmed this relationship by annual

monitoring of Nar lake since 1998, a time period which has included a fall in lake level, increase in salinity and rise in $\delta^{18}O$ (Dean *et al.* in press).

Results

Our P/E calibration has been applied to $\delta^{18}O$ on individual carbonate laminae from long lake sediment cores from Nar lake (Figure 2). Although this Late Holocene record extends back to ~300 AD, we focus here on drought events during the Little Ice Age and modern times (1400-1980 AD), for which the lake carbonate mineralogy is mono-specific (i.e. aragonite) and we are confident of the linear relationship between $\delta^{18}O$ and climate.

Overall, the Little Ice Age in Anatolia was a period of relatively dry climate, compared to the preceding Medieval times and to the late 20th century. Within it, there were extended phases of drier than average climate during the 15th century (1410-1495 AD), in the 19th century (1810-1900 AD), and also in the mid-20th century (1920-1965 AD), including a number of important drought years during the 1930s. The 16th and 17th centuries were notable for the lack of major dry events, an exception being a severe drought at the end of the 16th century which is registered in Anatolian tree ring widths (Kuniholm 1990; Touchan *et al.*, 2007) as well as in the Nar isotope record (Roberts *et al.* 2012). The historical links between this late 16th-century drought and the Ottoman Celâli rebellion have been studied in detail by White (2011, chapters 6 and 7).

There is no clear relationship between the time interval between droughts and drought severity. Some dry phases included multiple events, for example, there were drought peaks in the 1850s, late 1860s-1870s (which led to the death of 81% of cattle, 97% of sheep, and almost 40% of the human population in Ankara province; Kuniholm 1990) and again in the late 1880s.

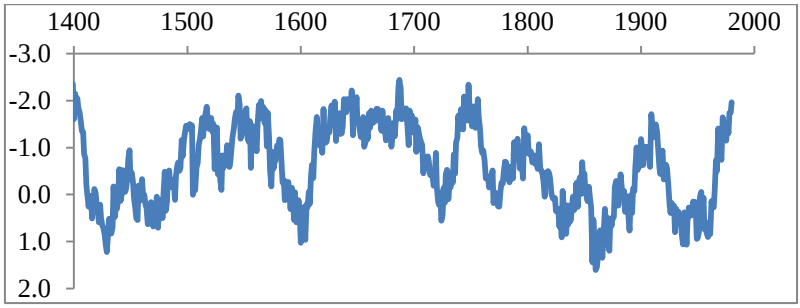

Figure 2. Oxygen isotope values for individual carbonate laminae from Nar Lake cores (1400-1980 AD). Data taken from Jones *et al.* (2006). More positive isotopes indicate dry climatic conditions, more negative values indicate a wetter climate.

Discussion

Because of their annual chronology, it is possible with lake varves (in a similar way to tree rings) to calibrate climate proxies against meteorological records to derive a drought index which can be applied to time periods before instrumental data become available. In this study, $\delta^{18}O$ from lake carbonates have been used to generate a decadal average P/E index for central Anatolia, which highlights major drought events since 1400 AD. This provides a long-term context for understanding future hydro-climatic changes in the eastern Mediterranean region.

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