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Climate on the southern Black Sea coast during the Holocene: implications from the Sofular Cave record

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ABSTRACT

We present the updated Holocene section of the Sofular Cave record from the southern Black Sea coast (northern Turkey); an area with considerably different present-day climate compared to that of the neighboring Eastern Mediterranean region. Stalagmite $\delta^{13}C$, growth rates and initial ($^{234}U/^{238}U$) ratios provide information about hydrological changes above the cave; and prove to be more useful than $\delta^{18}O$ for deciphering Holocene climatic variations. Between ~9.6 and 5.4 ka BP (despite a pause from ~8.4 to 7.8 ka BP), the Sofular record indicates a remarkable increase in rainfall amount and intensity, in line with other paleoclimate studies in the Eastern Mediterranean. During that period, enhanced summertime insolation either produced much stronger storms in the following fall and winter through high sea surface temperatures, or it invoked a regional summer monsoon circulation and rainfall. We suggest that one or both of these climatic mechanisms led to a coupling of the Black Sea and the Mediterranean rainfall regimes at that time, which can explain the observed proxy signals. However, there are discrepancies among the Eastern Mediterranean records in terms of the timing of this wet period; implying that changes were probably not always occurring through the same mechanism. Nevertheless, the Sofular Cave record does provide hints and bring about new questions about the connection between regional and large scale climates, highlighting the need for a more extensive network of high quality paleoclimate records to better understand Holocene climate.

1. Introduction

Climatic variations on the longer, glacial/interglacial and millennial time scales are known to be very large in both amplitude and areal extent. In contrast, Holocene climatic fluctuations have been much smaller in amplitude and were often spatially incoherent (Wanner et al., 2008). Therefore, construction of regional climate records of either temperature or precipitation is now regarded as a key-objective of current and future paleoclimate research (PAGES, 2009). Such records are crucial for our understanding of the nature of these regional, low-amplitude climate changes that took place during the Holocene. An area with insufficient spatial coverage of well-dated and highly resolved paleoclimate records is Turkey. To date, several records, most of which were derived from lake sediments (e.g., Roberts et al., 2008 and references therein), deliver information on Holocene climate variability in central and southern parts of the country (Fig. 1a), whereas no information exists for the entire Black Sea coast of Turkey. This area, however, has noticeably different climate characteristics compared to the rest of Turkey (Figs. 1b and 2; Türkeş, 1996), best expressed with its lack of summer aridity and much weaker relationship of winter precipitation variability with the North Atlantic Oscillation (Türkeş and Erlat, 2003). Thus, the question is as to whether the climate and the environment at the southern Black Sea coast have been coupled with larger-scale

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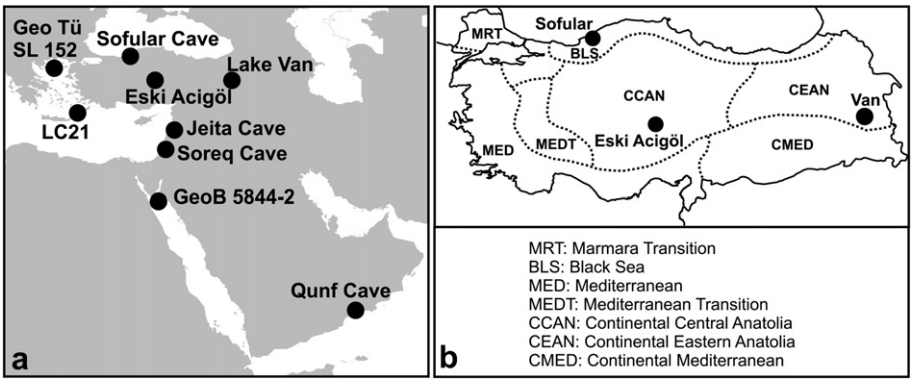

Fig. 1. Location map. a) Geographical locations of paleoclimate records plotted in Figs. 9 and 10. b) Climate zones in Turkey defined mainly by seasonality of rainfall (Türkeş, 1996).

climate patterns in Turkey and the neighboring regions in the Eastern Mediterranean during the Holocene. To answer this fundamental question, we present a precisely dated and highly resolved stalagmite record from Sofular Cave at the Black Sea coast that covers the entire Holocene.

One of the outstanding issues concerning Holocene climate in the Eastern Mediterranean region is the changes in the amount and – possibly – the seasonality of rainfall before the mid-Holocene, especially during the sapropel deposition period between ~ 9–6 ka BP (Rohling et al., 2009a). While a marked moisture increase

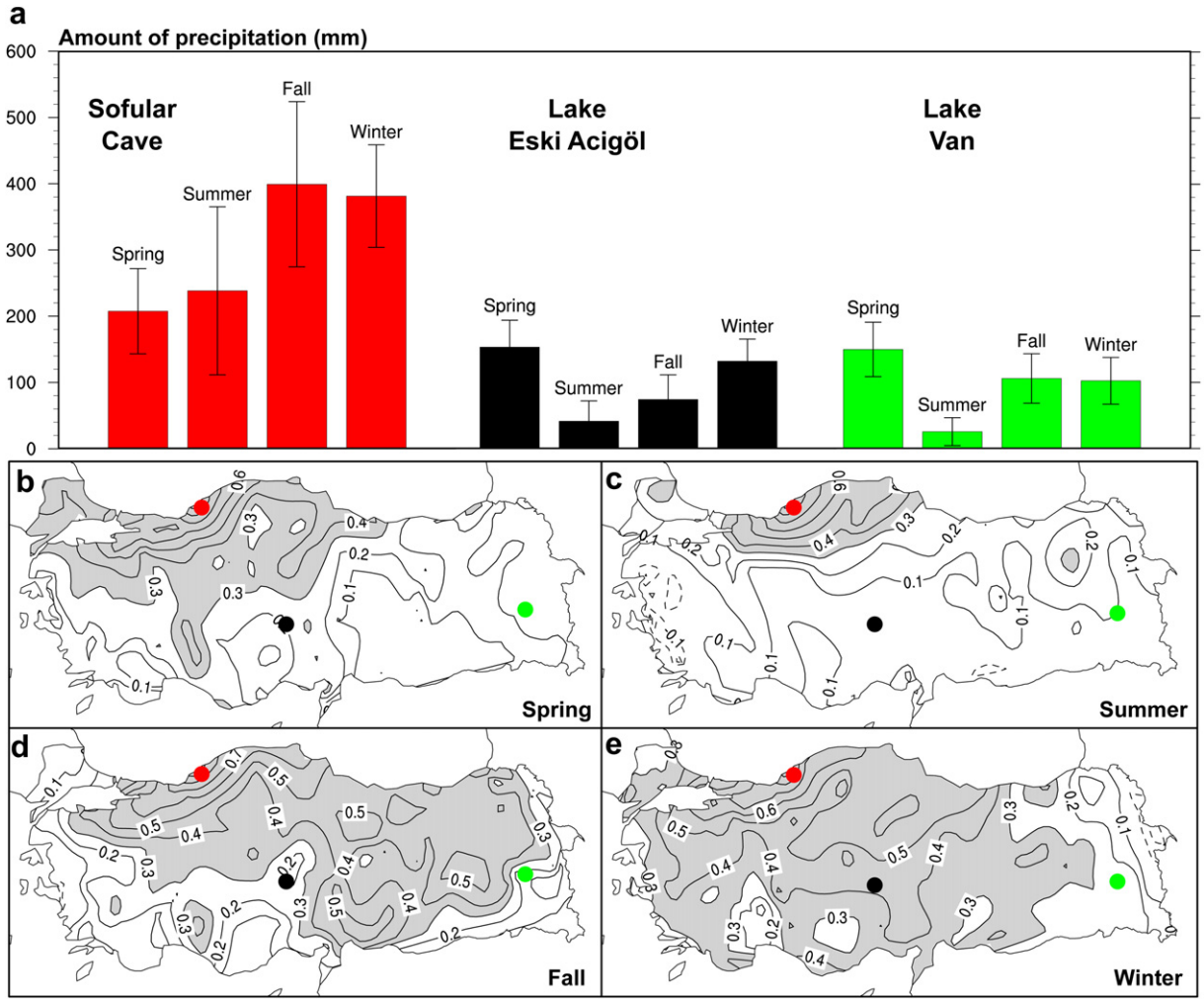

Fig. 2. Climate characteristics at and around Sofular Cave. a) Seasonal precipitation amounts at sites Sofular Cave, Lake Eski Acigöl and Lake Van. Also shown over each seasonal precipitation value is its standard deviation. b, c, d, e) Correlation coefficients of Sofular's seasonal precipitation time series with those of the other meteorological stations in Turkey for spring (MAM), summer (JJA), fall (SON) and winter (DJF). Gray shaded areas mark the statistically significant (95% according to Student's *t*-test) correlations. Full contours represent positive correlations, whereas the dotted contours denote negative correlations. Locations of Sofular Cave, Lake Eski Acigöl and Lake Van are marked by dots with the relevant colors. Station data were obtained from the State Meteorological Service of Turkey and previously quality controlled by Göktürk et al. (2008). The closest meteorological stations to Sofular Cave, Lake Eski Acigöl and Lake Van are Zonguldak, Nevsehir and Van (respectively). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)