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Enhanced humidity in coastal Libya during MIS 3

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Although it is generally accepted that at specific times in the past central North Africa has experienced significantly enhanced humidity the lack of well-dated and continuous time series of precipitation from the region seriously hinders development of a physical understanding of what causes these changes. We present new data from a stalagmite (SC-1) recovered from coastal northeastern Libya which sheds new light on the timing, origin and spatio-temporal variability of rainfall changes in the region during MIS3.

Growth rate in SC-1, controlled by $>$50 U-Th disequilibrium datings, indicates three phases of rapid growth during MIS3 respectively spanning 67-62 ka, 54-50 ka and 37-34 ka. The implication of relatively humid conditions at these times is emphasised by the Susah Cave is dry today and there is no evidence of recent or contemporary growth anywhere within the cave. Not only does the entire period of growth during MIS 3 lie within a period of high northern hemisphere insolation spanning 67-30 ka, the first and third periods coincides with increasing northern insolation due to precessional forcing and the second coincides with increasing northern insolation due to obliquity. Consistent with previous suggestions, there is therefore a close link between humidity in central North Africa and northern hemisphere warming.

However, the SC-1 growth rate record clearly places humid periods under rising northern insolation conditions and they pre-date orbital maxima by $\sim$3ka. This contrasts with expectations drawn from analysis of Mediterranean Sapropel S1 (10-6ka), which has been shown to lag maximum precession by $\sim$3ka. This observed lag is exploited as the basis of cyclostratigraphic analysis of older sapropels, which assume that this 3ka lag is a stable feature of the regional climate system.

The 6ka difference between the growth of SC-1 and the assumed timing of Mediterranean freshening (and therefore indirectly movement of the African monsoon) requires either that 1) the lag of sapropels to northern insolation is *not* stable through time or 2) that coastal humidity maxima do *not* coincide with displacement of the African monsoon. Both interpretations have implications for our understanding of the physical mechanisms underlying these changes.

We also present a mm-resolution stable isotope record for SC-1. $\delta^{18}O_{calcite}$ values vary between -3.5 and -5.5‰ and mostly fall between the values for modern Mediterranean-sourced (-4.1%¸) and Atlantic-sourced (-6.7%¸) precipitation in Tunisia. Even assuming a degree of re-evaporation of precipitated water within the epikarst zone, these values are far more enriched than would be expected for African monsoon rainfall (which is anticipated to be of the order of -10%¸). It is highly likely that the observed $\delta^{18}O_{calcite}$ variability in SC-1 reflects variable admixture of Atlantic-sourced moisture into the rainfall, emphasising the role of westerly winds in driving regional humidity in coastal North Africa. The SC-1 $\delta^{18}O$ record shows a marked similarity to the NGRIP ice core $\delta^{18}O$ record. Isotopically light periods in SC-1 corresponding to relatively warm periods in NGRIP, implying a teleconnection between these regions. Although additional records will be necessary to confirm these patterns, the SC-1 record thus provides a coherent picture of rainfall in coastal North Africa being tied to temperature in the northern polar regions both of orbital and sub-orbital timescales and being controlled by the magnitude of moisture supply from the Atlantic via changes in the strength of westerly winds.