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Climate variability of the Asian monsoon and Westerlies as seen through speleothem records

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Here we present high-resolution and precisely dated speleothem stable oxygen and carbon isotope ($\delta^{18}O$ and $\delta^{13}C$) and trace element records of hydroclimate variability from regions under the strong influence of East Asian Monsoon (EAM), Indian Summer Monsoon (ISM), and Westerlies climate systems. The EAM speleothem $\delta^{18}O$ record from Eastern China covers the complete U/Th dating range from 640 ka to present and demonstrates that insolation changes associated with the Earth's precession variances not only drives the EAM variability on orbital scales, but also acts as the dominant pacemaker of recurring millennial-scale climate variations, including the last 7 ice age terminations. This record highlights that the major glacial terminations coincided with rising boreal summer insolation and span either 4 or 5 precession cycles, suggesting that the "100 ka" glacial cycle actually consists of discreet numbers of precession cycles.

Our new speleothem $\delta^{18}O$ record from Northern India reconstructs the ISM variability over the past 280 thousand years (ka). The correlation between ISM and EAM records on orbital timescale suggest that both Asian Monsoon (AM) subsystems exhibit a coupled response to changes in boreal summer insolation without significant temporal lags. Comparisons of the AM records with both Antarctic and Greenland ice core records over the last glacial period do not clearly suggest a dominant role of Southern Hemisphere climate processes in regulating the ISM variability on millennial-orbital timescales.

The apparent similarity regarding gradual trends observed between Antarctic temperature and AM $\delta^{18}O$ records may not suggest a direct causal link of one to the other. Alternatively, it maybe most likely a manifestation of a common response to a same forcing, likely the oceanic reorganization, such as sea surface temperature and ocean circulation variations triggered by abrupt changes in the Atlantic meridional overturning circulation.

Our speleothem records from Central Asia characterize the climate variability in the Westerlies region over the past 500 ka. The supra-regional hydroclimate variation inferred from the $\delta^{18}O$ record reveals a precession rhythm punctuated by millennial-length climate events that closely correlate with the AM variability, supporting the recent view that the climate changes are fully coupled between the Westerly Central Asia and the Monsoon Asia on a wide range of timescales. In contrast, the local patterns of hydroclimatic variations on multiple timescales inferred from speleothem $\delta^{13}C$ and trace element records are rather complex. Particularly, the local Holocene hydroclimate variations demonstrate a lag of several ka to the supra-regional climate variability. These observations explain the apparent out-of-phase Holocene hydroclimate variability between Central Asia and Monsoon Asia.