# Multi-Proxy Speleothem Evidence for Southeast Asian Hydroclimate Variability since 38 ka

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Speleothem oxygen isotope ($\delta^{18}O$) records are one of the most widely utilized proxies for tropical hydroclimate and monsoon variability. While speleothem $\delta^{18}O$ records from China have provided unparalleled evidence for large-amplitude Asian monsoon (AM) variability on orbital and millennial timescales, their paleoclimatic interpretation remains controversial, due to complex controls on precipitation $\delta^{18}O$ values. Furthermore, a lack of records in key regions, such as Mainland Southeast Asia, hamper our ability to investigate the dynamics underlying spatial and temporal precipitation variability across the broad AM region. To address these issues, we have developed a multi-proxy speleothem record from Tham Doun Mai (TM) cave in Northern Laos. We combine high-resolution $\delta^{18}O$ measurements, which we interpret as a large-scale AM proxy, with additional proxies that are more sensitive to variations in local hydrology, including crystal fabrics, $\delta^{13}C$, Mg/Ca, Sr/Ca, $^{14}C$, and $(^{234}U/^{238}U)_{initial}$. We utilize a combination of proxies and geochemical models to constrain the underlying mechanisms of proxy variability and develop a robust paleoclimate reconstruction.

The TM $\delta^{18}O$ record is remarkably similar to others from the AM region, suggesting that upstream rainout over the Indian Ocean and Indian Monsoon region exerts a primary control on AM speleothem $\delta^{18}O$. The most positive $\delta^{18}O$ values, interpreted as weakest AM strength, occur during Heinrich stadial 1, concurrent with the driest conditions locally as suggested by the additional proxies. Conversely, the multi-proxy evidence suggests relatively dry conditions during the early Holocene summer insolation maxima, despite the low $\delta^{18}O$ values, indicating a strong AM at that time. Our results suggest that the wettest Holocene conditions occurred around 6 ka, consistent with other non-speleothem proxy evidence from the AM region.