



Regime shifts in Holocene Asian monsoon dynamics inferred from speleothems: Potential impacts on cultural change and migratory patterns

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The Asian monsoon system has been recognized as an important potential tipping element in Earth's climate. A global warming-driven change in monsoonal circulation, potentially towards a drier and more irregular regime, would profoundly affect up to 60% of the global human population. Hence, to improve our understanding of this major climate system, it is mandatory to investigate evidence for nonlinear transitions in past monsoonal dynamics and the underlying mechanisms that are contained in the available palaeoclimatic record. For this purpose, speleothems are among the best available high-resolution archives of Asian palaeomonsoonal variability during the Holocene and well beyond.

In this work, we apply recurrence networks, a recently developed technique for nonlinear time series analysis of palaeoclimate data (Donges et al., PNAS 108, 20422-20427, 2011), for detecting episodes with pronounced changes in Asian monsoon dynamics during the last 10 ka in oxygen isotope records from spatially distributed cave deposits covering the different branches of the Asian monsoon system. Our methodology includes multiple archives, explicit consideration of dating uncertainties with the COPRA approach and rigorous significance testing to ensure the robust detection of continental-scale changes in monsoonal dynamics.

We identify several periods characterised by nonlinear changes in Asian monsoon dynamics (e.g., \sim 0.5, 2.2-2.8, 3.6-4.1, 5.4-5.7, and 8.0-8.5 ka before present [BP]), the timing of which suggests a connection to extra-tropical Bond events and rapid climate change (RCC) episodes during the Holocene. Interestingly, we furthermore detect an epoch of significantly increased regularity of monsoonal variations around 7.3 ka BP, a timing that is consistent with the typical 1.0-1.5 ka periodicity of Bond events but has been rarely reported in the literature so far. Furthermore, we find that the detected epochs of nonlinear regime shifts in Asian monsoon dynamics partly coincide with known major periods of migration, pronounced cultural changes, and the collapse of ancient human societies from the archaeological record. These findings point to a possible causal mechanism, which indicates that also future changes in monsoonal dynamics could significantly contribute to potentially severe socio-economic impacts of climate change in the Asian monsoon domain.