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# Rainfall seasonality changes in northern India across the 4.2 ka event

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Despite intensive research efforts by archaeologists, geomorphologists, and palaeoclimatologists, the climatic and environmental changes accompanying the societal changes in the wider Indus/Thar region c. 4000 years ago remain puzzling. In particular, rainfall seasonality might be an important determinant for societal well-being. A major hurdle to a more detailed understanding of climate-human interaction is the relative scarcity of well-dated and highly resolved proxy records.

We present a multi-proxy record from aragonitic stalagmite DHAR-1 collected in Dharamjali Cave, Uttarakhand, India, that spans c. 1600 years between c. 4.25 and 2.6 ka BP. The stalagmite has been dated with 13 U/Th dates with average uncertainties of <18 years (2σ). In addition to c. 1600 oxygen and carbon isotope samples, element ratios (X/Ca) were measured using high resolution μXRF and laser ablation ICPMS at 25 μm resolution.

The DHAR-1 record represents the most precisely dated speleothem record to date from northern India, covering the mid-Holocene 4.2 ka BP event and the millennium thereafter. The attained sub-decadal to seasonal resolution allows robust assessment of both regional and local hydrological changes, and changes in amount and temporal distribution of summer and winter rainfall.

The speleothem record reveals decadal-scale trends that can be related to changes in seasonality. The $\delta^{18}O$ record reveals a 220-year period of weakened ISM from 4.2 to 3.98 ka BP. A contemporaneous increase in $\delta^{13}C$, and decrease in U/Ca, Ba/Ca, and Sr/Ca point to increased prior aragonite precipitation (PAP) resulting from increased aridity above the cave extending throughout the dry season. The ISM intensified after c. 3.7 ka BP while dry seasons remained dry, with a resultant increase in seasonality. Lower PAP after c. 3.4 ka BP can be interpreted as sign of reduced rainfall seasonality.

We compare the results with available records from the wider region, and discuss potential implications of the suggested changes in seasonality for agriculture-based societies.