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Calibrating multiple isotopic proxies in a modern aragonite speleothem from Northeast India

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Uranium, strontium and calcium isotope ratios in calcite speleothems are used as proxies for water-soil-rock interactions and prior calcite precipitation, and thus provide information about effective rainfall amount variations, primarily in semi-arid or highly seasonal regions. However, less is known about how these proxies function in humid regions and in aragonite speleothems. MAW-0201 is an annually laminated aragonite stalagmite that grew from 1960-2012 in Mawmluh Cave, Meghalaya, India, which is the rainiest place on Earth. In this study, we use meteorological data to calibrate $(^{234}U/^{238}U)_i$, $^{87}Sr/^{86}Sr$ and $\delta^{44/40}Ca$ in MAW-0201 to determine how these proxies reflect effective rainfall amount in both the monsoon and dry seasons. Rainfall here is extremely seasonal due to the Indian Summer Monsoon (ISM), which brings several meters of rain to the region each summer, but with inter-annual variability in total rainfall. Mawmluh dripwater and speleothem $\delta^{18}O$ reflects moisture source and transport, rather than rainfall amount. From 1980 to 1990, we observe large changes in all isotope systems and many trace elements. Variations in Mg/Ca and U/Ca in MAW-0201 show seasonal and multi-annual variability with local minima at 1985. Sr/Ca varies on the sub-seasonal to seasonal scale with an overall negative slope which steepens at 1990. The soil colloid tracers Zn/Ca and Al/Ca, which intermittently appear in the record, increase after 1990. For the entire record, $(^{234}U/^{238}U)_i$ is less than 1, remaining at ~0.89 from 1960-1985, and then exhibiting a linear increase from 0.890 ± 0.002 to a peak of 0.941 ± 0.002 in 2000. After 2000, $(^{234}U/^{238}U)_i$ decreases to 0.926 $\pm$ 0.003 by 2012. Preliminary $^{87}Sr/^{86}Sr$ spanning 1984-2009 and $\delta^{44/40}Ca$ from 1969-1984 suggest potentially significant changes beginning around 1984-1986. We hypothesize three mechanisms that would be consistent with the synchronous changes observed in all proxies in the interval from 1980 to 1990: 1) a change in flow path, 2) a decrease in annual rainfall, or 3) an increase in dry season rainfall. Hypothesis 1 is supported by the increase in $(^{234}U/^{238}U)_i$, which may reflect weathering of fresh host rock along a new flow path. The increase in Zn/Ca and Al/Ca may suggest a new path that allows soil to wash deeper into the cave more frequently. Hypothesis 2 is supported by increasing Mg/Ca, U/Ca and $\delta^{44/40}Ca$, prior calcite precipitation proxies that suggest decreasing rainfall. Fewer large rainfall events could prevent soil colloids from being washed out, leaving more to reach the cave with monsoon rains. The opposite interpretation of Zn/Ca and Al/Ca supports hypothesis 3, suggesting more dry season rainfall flushes soil colloids into the cave during the higher growth season. In this scenario, high $(^{234}U/^{238}U)_i$in dry season soil waters reach the cave more frequently. We couple geochemical models with meteorological data and assessments of past land use in order to evaluate these three hypotheses. Ultimately, our goal is to recommend the most appropriate suite of proxies to reconstruct both wet and dry season rainfall in this region in order to understand past ISM variability.