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Hydroclimate reconstruction: testing theoretical geochemical models on a global speleothem database

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Speleothems are calcium carbonate precipitations found in caves and are a powerful paleoclimate archive in particular for changes in hydroclimate. They are globally distributed, provide absolute age control going back to 500,000 years through radiometric methods, and up to seasonal resolution climate information through multiple proxies.

During prolonged drought periods, reduced infiltration causes longer water residence times and rock-water interactions that increases the concentration of sparingly soluble elements (Mg, Sr). Prolonged droughts also create more air pockets in the host rock, promoting degassing and further driving the solution toward calcium carbonate precipitation before the fluid reaches the stalagmite. This process is referred to as Prior Carbonate Precipitation (PCarbP) and provides a powerful hydroclimate tool when recorded in multiple hydroclimate proxies such as Mg/Ca, Sr/Ca and carbon isotopes.

Previous studies developed theoretical frameworks for the PCarbP process providing a well-defined slope range of Sr/Ca vs. Mg/Ca that can be easily derived from stalagmite trace element data. Crucially, this slope range is driven only by trace element partition coefficients and not by unknown drip water composition.

Here, we use data from the SISALv3 global speleothem database [1]. There are 57 stalagmite datasets (entities) from 43 sites that have the required proxy measurements. By keeping in mind comparisons with previous studies, we detail statistical choices for accurate slope calculations, facilitating the future use by the speleothem community. We identify drought periods based on previously published PCarbP theoretical frameworks and discuss the extent to which speleothem -trace element data align with theory.

The ultimate goal is to create a global database using robustly verified proxy mechanisms for hydroclimate interpretations. Since the database will be independent of water-isotope proxies, it will provide a local metric that is independent of atmospheric circulation patterns. This is useful for isotope-enabled and non-isotope-enabled data-model comparisons. The database will also enable the development of more quantitative rainfall reconstructions using oxygen isotopes and novel proxies such as calcium isotopes by constraining the impact of PCarbP on these proxies.

[1] Kaushal, Nikita, et al. "SISALv3: a global speleothem stable isotope and trace element database." *Earth system science data* (2024).