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Embracing the karst hydrological control on speleothem oxygen isotope variability

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The influence of karst hydrology or 'flowpaths' on speleothem oxygen isotopic ($\delta^{18}O$) values has been simulated using karst forward models. Cave monitoring studies have also shown that variability in dripwater $\delta^{18}O$ can be directly related to whether flowpaths are dominated by preferential/quick flow or diffuse/slow flow which challenges the paradigm of speleothems as archives of past variability in mean rainfall $\delta^{18}O$. Yet it is not known how common this flowpath effect is and whether it should be considered in the interpretation of speleothem $\delta^{18}O$ records. Recently, Treble et al. (2022) analysed two global databases: SISAL v2 (Comas-Bru et al., 2020) and an extended compilation of dripwater from Baker et al. (2019). It was demonstrated that within-cave variability in mean $\delta^{18}O$ values were common worldwide in both datasets. An analysis of cave meta-data demonstrated that the flowpath effect is unrelated to climate, cave depth or lithology; further supporting the ubiquitous nature of flowpaths, i.e., there is (1) a mixture of preferential and diffuse flow for all karstified carbonate rocks due to its triple-porosity nature (primary=matrix, secondary=fracture, tertiary=pipes and conduit); and (2) differences in soil/epikarst water storage and drainage characteristics.

We demonstrate how a mechanistic understanding of flowpaths can lead to a more robust interpretation using a case study that is also relevant for managing water resources in the Mediterranean-type climate of south-west Australia. Using seven modern stalagmite records from four caves, plus dripwater data, we demonstrate that the cave $\delta^{18}O$ record shows a common response to a sustained decrease in rainfall that impacted the region in the 1970s, characterised by a rise or 'uptick' in $\delta^{18}O$ (Priestley et al., 2022). Mean annual rainfall $\delta^{18}O$ values over the same period were quantified using observed and modelled data to have varied by −0.4 to +0.1 ‰ whereas the speleothem uptick is +1.5 ‰. The much larger magnitude of the uptick is consistent with a reduction in the preferential-flow component to these caves driven by reduced rainfall recharge. Preferential flow is an important contribution to groundwater. The 'uptick' or reduction in preferential flow implies that rainfall recharge to groundwater across the study region may no longer be reliably occurring. The longer paleo-record for south-west Australia confirms that no replicated upticks are seen in the last 800 years in stalagmites from the region and highlights the impact of climate change to water security in a region heavily dependent on groundwater.

Comas-Bru, L. et al. SISALv2 (2020). A comprehensive speleothem isotope database with multiple age-depth models. Earth Syst. Sci. Data 12, 2579–2606 (2020).

Priestley, S., et al. (2022). Caves provide early warning of unprecedented decrease in rainfall recharge of groundwater. Research Square. doi:https://doi.org/10.21203/rs.3.rs-1556439/v1

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