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Spatio-temporal gradients in δ^{18}O among Northern hemisphere Holocene speleothems; deciphering temperature, aridity and moisture transport effects

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In contrast with speleothems from low-latitude sites that may be influenced strongly by monsoon-related and/or strong precession-driven ITCZ-related δ^{18}O signals, the interpretation of oxygen isotope variability in mid-latitude temperate zone Holocene speleothems from the northern hemisphere in terms of palaeoclimate is often equivocal, reflecting their relatively poor signal to noise ratio and the absence of a single strong climate variable that controls δ^{18}O. In particular, the interpretation of single δ^{18}O time-series in isolation is fraught with difficulties because local site-specific effects (e.g. kinetic fractionation) and seasonal biases (e.g. preferential infiltration of meteoric water during the wet season) may be superimposed on regional-scale climate-related influences. Often the magnitude, or indeed the sign of δ^{18}O change as a function of key climate variables such as mean annual air temperature or rainfall amount is not obvious. While some records discussed here include unequivocal Younger Dryas signals that can provide useful calibration points between carbonate δ^{18}O and climate variables, most temperate zone European Holocene records lack such obvious calibration points. A more generally applicable approach therefore, may be to devise an interpretative framework in which the spatial gradients in meteoric water δ^{18}O, inferred from multiple speleothem records are considered together. Present-day spatial gradients in the δ^{18}O of meteoric water as a function of latitude, altitude, mean annual temperature and rainfall amount are accessible for large regions of the globe from the GNIP database. Importantly, these are characterised by smooth spatial trends. Crucially, as more speleothem O isotope records are published, the spatial density of Holocene speleothem δ^{18}O records is now approaching that of the GNIP network in some regions (e.g. Europe). This in turn permits calculation of theoretical present-day carbonate δ^{18}O gradient maps, taking into account a site's weighted mean meteoric δ^{18}O value and its mean annual air temperature. Interpolations based on this database provide a theoretical carbonate δ^{18}O gradient template from which it is possible to recognise anomalous behaviour in speleothem δ^{18}O gradients in the recent past that must reflect site-specific effects and/or seasonal biases. This approach necessarily requires some temporal averaging of the data, resulting in reduced temporal resolution, but is likely to provide more robust interpretations than those based on data from single sites considered in isolation, especially when key variables (e.g. mean annual air temperature) are checked against estimates from completely independent palaeoclimate proxies such as those provided by the European pollen database. Inferences about past gradients in carbonate δ^{18}O can also be checked against other carbonate δ^{18}O proxy records (e.g. tufa and lake carbonates) to improve the reliability of speleothem-based palaeoclimate interpretations and to isolate local effects from smooth regional scale trends.