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1 Fidelity of isotope climate proxies in a modern speleothem from St. Michaels Cave, Gibraltar: prospects for climate hindcasting

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Gibraltar occupies a unique position in south Iberia where speleothem cave systems are proximal to continuous instrumental meteorological records maintained for two centuries. An ultra-high resolution study of an active and fast growing speleothem (Gib04a) from New St Michaels Cave, Gibraltar has revealed clear annual variations in ä^{13}C and ä^{18}O that are correlated to fabric and trace element patterns. Annual oscillations in speleothem ä^{13}C appear to be driven by large seasonal changes in cave air pCO_2 which exerts a strong control on the rate of growth and ä^{13}C of dripwater DIC. CO_2 concentrations vary systematically with season and are highest (4000-8000 ppm) between October and April and lowest ($<$1000 ppm) in summer. CO_2 concentrations begin rise sharply within two weeks of the first winter rains and remain high until April when they fall rapidly to summer levels. Timing and isotopic arguments suggest that cave air pCO_2 is not simply a passive response coupled to soil CO_2 availability and transport in groundwater and new data for airflow and simultaneous multi-channel CO_2 measurements taken laterally and vertically through the cave system clearly show the effects of seasonal of buoyancy-driven ventilation and short term (but sometimes

dramatic) effects of synoptic scale events.

A winter peak in cave air CO_2 levels is unusual compared to cave systems studied elsewhere and again shows how important it is to understand all aspects of cave hydrology and ventilation schemes in order to understand isotopic signals encoded in speleothem calcite. The regular oscillations in ä^{13}C observed in Gib04a provide a precise chronology in calendar years counting from the date of sampling in 2004 back to 1948 enabling an inter-annual comparison with the local instrumental record, which includes GNIP data for precipitation isotopes since 1961. The high resolution oxygen isotope record is more complex, with a combination of seasonal change (lowest ä^{18}O in the winter, and generally rising ä^{18}O in the summer) superimposed on longer term (decadal) variations. A winter ä^{18}O signal, corresponding to ä^{13}C minima, provides the best interannual oxygen isotope record least affected by ET processes in the aquifer and summer drying in the cave, and closely tracks changes in isotopic composition of incoming precipitation. The ä^{18}O of winter dripwater calculated from the winter speleothem signal shows a significant interannual correlation with observed winter precipitation and MAT. The year to year isotopic ‘noise’ is clearly related to longer term trends in precipitation amount. The more extreme outliers in the oxygen isotope time series are clearly related to unusually wet years. One of the implications of the monitoring data is that rising δO of summer speleothem growth is a result of evaporation effects in the shallow unsaturated zone, lowered in wet years by more effective flushing of winter precipitation. Ongoing water tracing experiments and drip monitoring are being used to develop a hydrological model but this 50 year calibration provides encouraging evidence that seasonally resolved isotope records from speleothem in semiarid climates provide robust climate proxies of precipitation isotopes, MAT and wet year frequency.