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Modification of the δ^{18}O value of meteoric water to cave drip water and speleothem calcite

Anne Wackerbarth (1), Denis Scholz (2), Jens Fohlmeister (1), and Augusto Mangini (1)

(1) University of Heidelberg, Germany (anne.wackerbarth@iup.uni-heidelberg.de), (2) Universitiy of Mainz, Germany

Stable isotope signals of speleothems have proved to be valuable archives for past climate variability in recent years. They provide the possibility of precise dating using the Th/U-method and allow high resolution isotope analyses. The stable isotope signal of stalagmites strongly depends on the isotopic composition of the drip water which is affected by climate parameters, vegetation parameters and the residence time in the soil and epikarst layer.

To understand how the δ^{18}O value of drip water and stalagmite calcite is influenced by climate parameters, we developed the Drip Water Model, where the input parameters are: temperature, amount of cave infiltration, air humidity, the type of vegetation and the CO_2 content of soil air.

The δ^{18}O value of precipitation is determined in dependency on temperature by a linear data fit. Evapotranspiration modifies both, the isotopic composition and the amount of drip water, since evaporation is accompanied by kinetic fractionation while transpiration is not. Hence, depending on the ratio of evaporation to transpiration the soil water is enriched in heavy oxygen. Evapotranspiration is higher in the warmer months, leading to a larger contribution of winter precipitation to drip water.

The model establishes a weighting function for the δ^{18}O value of a monthly water parcel and determines its contribution to the annual mean composition of speleothem calcite. The Ca^{2+} content decides how much calcite is able to precipitate from the water parcel. The model shows that despite that the CO_2 content of soil air being higher in summer than in winter, the Ca^{2+} content of drip water is lower in summer than in winter when the residence time of the water in the soil and epikarst is in only in the range of few months. This results in even stronger weight of cooler months on the isotopic composition of stalagmites from Atta Cave, Bunker Cave and B7 Cave in Central Europe.

The reversed model enables us to tentatively reconstruct average temperatures of past times from δ^{18}O record from stalagmites. This model takes into account the correlation between the amount of winter precipitation and temperature in Central Europe which is attributed to the North Atlantic Oscillation.

The results show a clear anticorrelation of cave temperature and the δ^{18}O value of speleothem calcite, as observed in samples throughout North and Central Europe.