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Modelling of dead carbon fraction in speleothems: a step towards reliable speleothem ^{14}C-chronologies

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Over the past two decades, speleothems have become one of the most versatile and promising archives for the study of past continental climate. Very precise absolute dating is often possible using the U-Th method, resulting in paleoclimate records of exceptional resolution and accuracy. However, not all speleothems are amenable to this dating method for a variety of reasons (e.g. low U concentrations, high detrital Th etc). This has lead researchers to exclude many otherwise suitable speleothems and cave sites from further investigation. ^{14}C-dating of speleothems has so far not been applicable, due to the “dead carbon” problem. As drip water percolates through the karst, dissolving $CaCO_3$, a variable amount of ^{14}C-dead carbon is added to the solution. This results in a temporally variable and site-specific reservoir effect, ultimately undermining the development of speleothem ^{14}C -chronologies. However, a number of recent studies have shown a clear link between karst hydrology and associated proxies (e.g., Mg/Ca and δ^{13}C) and this “dead carbon fraction” (DCF). We take advantage of this relationship to model DCF and its changes using Mg/Ca, δ^{13}C and ^{14}C data from published speleothem records. Using one record for calibration purposes, we build a transfer function for the DCF in relation to δ^{13}C and Mg/Ca, which we then apply to other ^{14}C records. Initial model results are promising; we are able to reconstruct general long-term average DCF within uncertainties of the calculated DCF from the U-Th chronology. Large shifts in DCF related to hydrology are also often detected. In a second step, we apply the model to a speleothem from southern Poland, which so far could not be dated, due to very low U-concentrations. To construct a ^{14}C chronology, the stalagmite was sampled at 5 mm intervals. $CaCO_3$ powders were graphitized and measured by Accelerator Mass Spectrometry (MICADAS) at ETH Zurich. Additional high-resolution (0.1 mm/sample) ^{14}C measurements were performed on the top 1mm of the stalagmite, using a gas ion source (GIS) on the MICADAS. The resulting DCF-corrected chronology shows that the stalagmite grew over much of the Holocene, and reveals that existing U-Th dates strongly overestimated the real ages and thus are unreliable. In contrast, the new ^{14}C-based chronology, when constrained using trace element ratios and stable isotopes, enables confident reconstruction of broad climatic changes and trends over the Holocene.