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StalAge - A new algorithm especially designed for the construction of speleothem age-depth models

Denis Scholz (1,2) and Dirk Hoffmann (2,3)

(1) Insitute for Geosciences, University of Mainz, Johann-Joachim-Becher-Weg 21, 55128 Mainz, Germany (scholzd@uni-mainz.de), (2) Bristol Isotope Group (BIG), School of Geographical Sciences, University of Bristol, University Road, BS8 1SS Bristol, United Kingdom, (3) CENIEH, Paseo Sierra de Atapuerca s/n, 09002-Burgos, Spain

A standard approach to construct age-depth models for speleothems on the basis of ^{230}Th/U-ages is not available yet. Some studies apply linear interpolation between dated depths; others use least squares polynomial fits. Other authors, in turn, use various kinds of splines or even more sophisticated methods based on the general growth mechanisms of speleothems. A general approach to estimate the *uncertainty* of stalagmite age models has neither been developed yet. Since the exact determination of the timing and duration of climatic events recorded in speleothem calcite depends on the method used to calculate the age model, a general technique for the calculation of both the age model and its uncertainty is urgently needed.

Here we present a new algorithm, especially designed for constructing age-depth models based on speleothem ^{230}Th/U-ages. The algorithm relies on two basic assumptions: (i) the age model must increase monotonically with increasing distance from top of the stalagmite, and (ii) if possible within the associated error bars, the simplest age-depth relationship (i.e., a straight line) is fitted to the age data. Whereas the first assumption simply arises from the absolute constraint of increasing age with increasing distance from top, the second assumption avoids over-interpretation of the age data.

The performance of the algorithm was tested using synthetic speleothem age data. For this purpose, a numerical model simulating (i) speleothem growth, (ii) incorporation and temporal evolution of U-series isotopes and (iii) mass spectrometric analysis was developed. This allows simulation of extreme scenarios, such as stalagmite sections including obvious outliers, age inversions and pronounced detrital contamination, and also to test the performance and robustness of the algorithm under these conditions.

The developed algorithm has distinct advantages in comparison with the existing methods. Firstly, it is very robust. Outliers and age inversions are automatically detected and taken into account for the calculation of the age model and its uncertainty. The uncertainty in such sections is appropriately enlarged and, thus, probably more realistic than that calculated by other methods. Secondly, the inclusion of the monotonicity criterion provides additional information apart from the ^{230}Th/U-ages and the corresponding errors. This results in smaller errors than those calculated by other methods in sections without age inversions.

The algorithm is written in the free statistical software R and will be made available as a free download to the speleothem community.