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A Bayesian framework to model speleothem oxygen isotope data with age uncertainties

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Age-depth models are widely used to build chronologies from proxy records and are most often implemented for speleothems due to age uncertainties and lower resolutions. In this study, we use a variation of the accumulation rate method to perform a pseudo-proxy reconstruction of large-scale variability in monsoon precipitation using synthetic oxygen isotope records from speleothem sites and the isotope-enabled ECHAM/MPI-OM climate model. We present a probabilistic approach to synchronize speleothems by informative priors of oxygen isotope data and individual independent age constraints. This is achieved by co-estimating the regional $\delta^{18}O$ variations through time, where $\delta^{18}O$ variability is modeled using Gaussian processes and a Bayesian model is further used for the individual speleothem chronologies. The method is tested using synthetic speleothem data generated from the last millennium-long climate model simulation and corrupted through realistic noise from speleothems in the Indian Ocean region from the SISALv2 database. Through the creation of a millennium-long reconstruction, we aim to study the atmospheric dynamics from the reconstruction over the Asian region to help us further constrain the drivers, responses to, and changes in the variability of the monsoon. By synchronizing the time series of oxygen-isotope data through the incorporation of accurate and realistic depth-dependent age uncertainties, this modeling approach may lead to advancements in handling speleothem data and climate model simulations for regional to global evaluations of variability and past climate reconstructions.