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Probabilistically constraining proxy age-depth models within a Bayesian hierarchical reconstruction model

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Reconstructions of late-Holocene climate rely heavily upon proxies that are assumed to be accurately dated by layer counting, such as measurement on tree rings, ice cores, and varved lake sediments. Considerable advances may be achievable if time uncertain proxies could be included within these multiproxy reconstructions, and if time uncertainties were recognized and correctly modeled for proxies commonly treated as free of age model errors.

Current approaches to accounting for time uncertainty are generally limited to repeating the reconstruction using each of an ensemble of age models, thereby inflating the final estimated uncertainty – in effect, each possible age model is given equal weighting. Uncertainties can be reduced by exploiting the inferred space–time covariance structure of the climate to re-weight the possible age models. Here we demonstrate how Bayesian Hierarchical climate reconstruction models can be augmented to account for time uncertain proxies. Critically, while a priori all age models are given equal probability of being correct, the probabilities associated with the age models are formally updated within the Bayesian framework, thereby reducing uncertainties. Numerical experiments show that updating the age model probabilities decreases uncertainty in the climate reconstruction, as compared with the current de-facto standard of sampling over all age models, provided there is sufficient information from other data sources in the region of the time-uncertain proxy. This approach can readily be generalized to non-layer counted proxies, such as those derived from marine sediments.

Werner and Tingley, Climate of the Past Discussions (2014)