Geophysical Research Abstracts
Vol. 18, EGU2016-3431, 2016
EGU General Assembly 2016

Representation of layer-counted proxy records as probability densities on error-free time axes

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Time series derived from paleoclimatic proxy records exhibit substantial dating uncertainties in addition to the measurement errors of the proxy values. For radiometrically dated proxy archives, Goswami et al. [1] have recently introduced a framework rooted in Bayesian statistics that successfully propagates the dating uncertainties from the time axis to the proxy axis. The resulting proxy record consists of a sequence of probability densities over the proxy values, conditioned on prescribed age values. One of the major benefits of this approach is that the proxy record is represented on an accurate, error-free time axis. Such unambiguous dating is crucial, for instance, in comparing different proxy records.

This approach, however, is not directly applicable to proxy records with layer-counted chronologies, as for example ice cores, which are typically dated by counting quasi-annually deposited ice layers. Hence the nature of the chronological uncertainty in such records is fundamentally different from that in radiometrically dated ones.

Here, we introduce a modification of the Goswami et al. [1] approach that is specifically designed for layer-counted proxy records, instead of radiometrically dated ones. We apply our method to isotope ratios and dust concentrations in the NGRIP core, using a published 60,000-year chronology [2]. It is shown that the further one goes into the past, the more the layer-counting errors accumulate and lead to growing uncertainties in the probability density sequence for the proxy values that results from the proposed approach. For the older parts of the record, these uncertainties affect more and more a statistically sound estimation of proxy values. This difficulty implies that great care has to be exercised when comparing and in particular aligning specific events among different layer-counted proxy records.

On the other hand, when attempting to derive stochastic dynamical models from the proxy records, one is only interested in the relative changes, i.e. in the increments of the proxy values. In such cases, only the relative (non-cumulative) counting errors matter. For the example of the NGRIP records, we show that a precise estimation of these relative changes is in fact possible.

References:
[1] Goswami et al., Nonlin. Processes Geophys. (2014)
[2] Svensson et al., Clim. Past (2008)