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Towards new mathematical tools for obtaining chronologies in discontinuous archives

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In the last years, a variety of new mathematical approaches has been developed for obtaining reliable chronologies of geological and geomorphological archives based on a limited set of dating horizons. These new approaches work relatively well for continuous archives, but quickly approach their conceptual limits in the presence of discontinuities.

Here, I report first steps towards improving existing mathematical algorithms in their performance regarding unknown discontinuities by integrating complementary information based on variations encoded in other archives. The proposed method is based on the following ingredients: (1) a correlation estimator for arbitrarily spaced time series, (2) a maximization criterion for correlations based on a linear rescaling of the unknown time axis, (3) a procedure allowing an automatic evaluation of minimum-cost paths for performing a sophisticated version of "wiggle-matching", and (4) improving the relative chronologies by adding explicit dates via some additional penalty term.

To this end, I will mainly focus on the methodological details associated with the first two steps. Here, correlations between the data set under study and the "reference" archive are evaluated for running windows along the records utilizing a recently developed non-parametric correlation estimator based on a Gaussian kernel function. Allowing for an arbitrary rescaling of the time axis around the respective window midpoint, maximum correlations arise when the windows represent the same time intervals and the rescaled time axis corrects for different material accumulation rates. For sufficiently high-resolution records, the proposed approach can be extended to account also for possible non-linear co-variations between the two considered archives or proxies.

By identifying sequences of subsequent windows with particularly high correlations, relative chronologies can be obtained. Moreover, gaps in such sequences are indicative of archive discontinuities and allow their identification without further prior assumptions. I will illustrate the performance of the proposed framework by initial results obtained for some numerical examples as well as different terrestrial archives. These examples demonstrate that basic requirements to the proposed algorithm are a sufficiently dense sampling, only weak changes of the material accumulation rates over the considered windows, and moderate observational "noise" allowing for a proper estimation of correlations. From a conceptual perspective, the proposed strategy can be combined with any method for obtaining explicit chronologies replacing step (4) of the proposed algorithm.