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Kernel-based correlation estimation for irregularly sampled time series

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In order to understand the complex interplay of variables that result in climate, paleo records like those from stalagmites, ocean, lake or ice core records present our only opportunity to gain knowledge about the past. Due to the nature of their genesis their time resolution is heterogeneous, nevertheless their inter-comparison is of high importance to gain insights on the interactions in the earth system. Standard cross correlation evaluation requires the time series to have the same, regular, observation times, which can only be achieved by interpolation. This, however, creates artificial memory in the time series, which changes the spectra and correlation functions. In a thorough benchmark test we compare the performance of the standard approach, consisting of linear interpolation followed by a fft-based estimator, to the results from different kernel-based estimators and an estimator based on the Lomb-Scargle periodogram, which do not require the observations to be regularly sampled. In our tests we find a 40% lower RMSE for the lag-1 ACF for the gaussian kernel method vs the linear interpolation scheme, for the CCF the RMSE is lower by 60%. The application of the Lomb-Scargle technique yielded comparable results for the univariate but very poor results for the bivariate case. We find that especially the high-frequency components of the signal, where classical methods show a strong negative bias, are preserved when using the kernel methods. We apply the gaussian kernel estimator and interpolation followed by the standart fft-routine to paleo records from the Asian Monsoon domain. We estimate cross-correlation and persistence time of two speleothem δ18 O records, one from Dandak cave in Southern India and one from Wanxiang cave in North-central China. The correlation between the records in the overlapping section is significant to the 95% level for both methods which could mean that both records are influenced by an overall Asian Monsoon signal. The gaussian kernel results for the AR-1 persistence times of the individual records is close to that of the independent least-squares estimator, where interpolation results in a doubling of the persistence time.
The gaussian kernel estimator is, we find, a reliable, robust technique with significant advantages over other methods and suitable for wider application to paleo-data.