Recurrence networks, age uncertainties, and joint distributions: An analysis motivated by problems in paleoclimate studies

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Chronological uncertainties are a typical feature of paleoclimate datasets, making their analysis non-trivial. Recent advances in age modeling and paleoclimate proxy reconstruction methodologies have enabled the representation of age uncertainties as uncertainties in the proxy value, resulting in an error-free time axis of measurement. This results in an ensemble of proxy measurements which are effectively described by a marginal probability density of the proxy value at each time instant of consideration.

However, most complex systems methods that characterize time series are not easily applicable to analyze such probability densities, primarily because the covariance between the densities at any two given points is typically unavailable. The knowledge of the covariance (or equivalently the joint probability) of the proxy values, at pairs of time points of interest, is crucial for estimating system characteristics such as the auto-correlation, power spectrum, and recurrence properties.

We present here some ideas on how to analyze such a given sequence of time-ordered probability densities in the absence of the covariance information between the densities at two distinct times. We focus mainly on the recurrence properties of the system and estimate relevant recurrence network measures along with their uncertainties of estimation. We also present a test case where the joint distribution of such probability densities could be made available and how one can analyze the recurrences in such a case.