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Epochs of synchronous changes and dynamical transitions in African dust flux variability over the past 5 Ma detected by recurrence network analysis

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In the last decades, increasing interest has been spent on deciphering changes in the environmental conditions in Central and Eastern Africa during the last several millions of years and their relationship with the evolution of the human race. Among other sources of information, the atmospheric dust flux recorded in marine sediments serves as an excellent proxy for changes in land cover, vegetation, and atmospheric circulation. Like for other palaeoclimate records, the analysis of such data is however strongly challenged by properties such as long-term non-stationarity and unequal sampling in time domain.

In this work, we demonstrate the potential of recurrence networks, a recently developed method of nonlinear time series analysis, for tracing and quantitatively characterising changes of the environmental variability encoded in dust flux records. Since this method does not rely on the temporal order of observations, but is exclusively based on the mutual similarity of individual values or embedded state vectors (i.e., recurrences of values in some abstract phase space), it can be directly applied even to unequally sampled time series. Moreover, the topological properties of recurrence networks associated with a time series can already be estimated for rather short data segments in a meaningful way, which makes this approach especially suitable for detecting changes in the recorded variability by using running windows in time.

We apply our method to the dust flux records from ODP sites 659, 721/722, and 967, corresponding to three locations off Northwestern Africa, in the Eastern Mediterranean, and in the Northwestern Indian Ocean. Complex network measures such as average path length and clustering coefficient computed for the recurrence networks obtained for sliding windows in time identify hidden dynamical transitions in the environmental conditions. Comparing the overall temporal variability of these measures between the three considered records reveals epochs of synchronous behaviour, which indicates a large-scale impact of the corresponding changes in the temporal variability of vegetation patterns and/or atmospheric circulation.