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Disentangling synchrony from serial dependency in complex climate networks: Comparing Event Synchronization and Event Coincidence Analysis

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The quantification of synchronization phenomena of extreme events has recently aroused a great deal of interest in various disciplines. Climatological studies therefore commonly draw on spatially embedded climate networks in conjunction with nonlinear time series analysis. Among the multitude of similarity measures available to construct climate networks, Event Synchronization and Event Coincidence Analysis (ECA) stand out as two conceptually and computationally simple nonlinear methods. While ES defines synchrony in a data adaptive local way that does not distinguish between different time scales, ECA requires the selection of a specific time scale for synchrony detection.

Herein, we provide evidence that, due to its parameter-free structure, ES has structural difficulties to disentangle synchrony from serial dependency, whereas ECA is less prone to such biases. We use coupled autoregressive processes to numerically study the sensitivity of results from both methods to changes of coupling and autoregressive parameters. This reveals that ES has difficulties to detect synchronies if events tend to occur temporally clustered, which can be expected from climate time series with extreme events exceeding certain percentiles.

These conceptual concerns are not only reproducible in numerical simulations, but also have implications for real world data. We construct a climate network from satellite-based precipitation data of the Tropical Rainfall Measuring Mission (TRMM) for the Indian Summer Monsoon, thereby reproducing results of previously published studies. We demonstrate that there is an undesirable link between the fraction of events on subsequent days and the degree density at each grid point of the climate network. This indicates that the explanatory power of ES climate networks might be hampered since trivial local properties of the underlying time series significantly predetermine the final network structure, which holds especially true for areas that had previously been reported as important for governing monsoon dynamics at large spatial scales. In contrast, ECA does not appear to be as vulnerable to these biases and additionally allows to trace the spatiotemporal propagation of synchrony in climate networks.

Our analysis rests on corrected versions of both methods that alleviate different normalization problems of the original definitions, which is especially important for short time series. Our finding suggest that careful event detection and diligent preprocessing is recommended when applying ES, while this is less crucial for ECA. Results obtained from ES climate networks therefore need to be interpreted with caution.