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Climate network analysis of regional precipitation extremes: The true story told by event synchronization

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Over the last decade, complex network methods have been frequently used for characterizing spatio-temporal patterns of climate variability from a complex systems perspective, yielding new insights into time-dependent teleconnectivity patterns and couplings between different components of the Earth climate. Among the foremost results reported, network analyses of the synchronicity of extreme events as captured by the so-called event synchronization have been proposed to be powerful tools for disentangling the spatio-temporal organization of particularly extreme rainfall events and anticipating the timing of monsoon onsets or extreme floodings.

Rooted in the analysis of spike train synchrony analysis in the neurosciences, event synchronization has the great advantage of automatically classifying pairs of events arising at two distinct spatial locations as temporally close (and, thus, possibly statistically – or even dynamically – interrelated) or not without the necessity of selecting an additional parameter in terms of a maximally tolerable delay between these events. This consideration is conceptually justified in case of the original application to spike trains in electroencephalogram (EEG) recordings, where the inter-spike intervals show relatively narrow distributions at high temporal sampling rates. However, in case of climate studies, precipitation extremes defined by daily precipitation sums exceeding a certain empirical percentile of their local distribution exhibit a distinctively different type of distribution of waiting times between subsequent events. This raises conceptual concerns if event synchronization is still appropriate for detecting interlinkages between spatially distributed precipitation extremes.

In order to study this problem in more detail, we employ event synchronization together with an alternative similarity measure for event sequences, event coincidence rates, which requires a manual setting of the tolerable maximum delay between two events to be considered potentially related. Both measures are then used to generate climate networks from parts of the satellite-based TRMM precipitation data set at daily resolution covering the Indian and East Asian monsoon domains, respectively, thereby reanalysing previously published results. The obtained spatial patterns of degree densities and local clustering coefficients exhibit marked differences between both similarity measures. Specifically, we demonstrate that there exists a strong relationship between the fraction of extremes occurring at subsequent days and the degree density in the event synchronization based networks, suggesting that the spatial patterns obtained using this approach are strongly affected by the presence of serial dependencies between events. Given that a manual selection of the maximally tolerable delay between two events can be guided by a priori climatological knowledge and even used for systematic testing of different hypotheses on climatic processes underlying the emergence of spatio-temporal patterns of extreme precipitation, our results provide evidence that event coincidence rates are a more appropriate statistical characteristic for similarity assessment and network construction for climate extremes, while results based on event synchronization need to be interpreted with great caution.