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Prediction of the most extreme rainfall events in the South American Andes: A statistical forecast based on complex networks

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During the monsoon season, the subtropical Andes in South America are exposed to spatially extensive extreme rainfall events that frequently lead to flashfloods and landslides with severe socio-economic impacts. Since dynamical weather forecast has substantial problems with predicting the most extreme events (above the 99th percentile), alternative forecast methods are called for. Based on complex network theory, we developed a general mathematical framework for statistical prediction of extreme events in significantly interrelated time series. The key idea of our approach is to make the internal synchronization structure of extreme events mathematically accessible in terms of the topology of a network which is constructed from measuring the synchronization of extreme events at different locations. The application of our method to high-spatiotemporal resolution rainfall data (TRMM 3B42) reveals a migration pattern of large convective systems from southeastern South America towards the Argentinean and Bolivian Andes, against the direction of the northwesterly low-level moisture flow from the Amazon Basin. Once these systems reach the Andes, they lead to spatially extensive extreme events up to elevations above 4000m, leading to substantial risks of associated natural hazards. Based on atmospheric composites, we could identify an intricate interplay of frontal systems approaching from the South, low-level moisture flow from the Amazon Basin to the North, and the Andean orography as responsible climatic mechanism. These insights allow to formulate a simple forecast rule predicting 60% (90% during El Niño conditions) of extreme rainfall events at the eastern slopes of the subtropical Andes. The rule can be computed from readily available rainfall and pressure data and is already being tested by local institutions for disaster preparation.