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Indian Monsoon: complex network analysis, spatial patterns and the prospects for prediction

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The Indian Summer Monsoon (ISM) is a global climate phenomenon that affects half of the world's population. The prediction of the Indian Summer Monsoon rainfall and its extremes remains an important concern. In our study we aim to determine spatial distribution of patterns of extreme rainfall and their synchronization, because the understanding of the structure of the spatial heterogeneity of extreme rainfall is crucial for Indian agriculture and economy.

We use complex networks to identify dominant spatial patterns that govern the organization of extreme rainfall during the ISM season. We construct networks of extreme rainfall events during the ISM, the pre-monsoon, and the post-monsoon period from satellite-derived (TRMM, Tropical Rainfall Measurement Mission, product 3B42 V7) and rain-gauge interpolated (APHRODITE) datasets. The structure of the networks is determined by the level of synchronization of extreme rainfall events between different grid cells throughout the Indian subcontinent. Through the analysis of various complex-network metrics, we describe typical repetitive patterns that can be used as indicators of the ISM variability: North Pakistan (NP), Western Ghats (WG), Eastern Ghats (EG), and Tibetan Plateau (TP). These patterns appear during the pre-monsoon season, evolve during the ISM season, and disappear during the post-monsoon season. We compare obtained results with wind fields, temperature, and pressure networks in this region derived from re-analysis data provided by the National Center for Environmental Prediction and National Center for Atmospheric Research (NCEP/NCAR). The areas of Eastern Ghats, Western Ghats, and Tibetan Plateau were previously known as areas that influence the ISM dynamics. These patterns occur because of the intricate topography of this region. The Western Ghats pattern, specifically, the Kerala region, is commonly used by climatologists for the prediction of the onset of the ISM (Pai and Nair, 2009). However, North Pakistan has not widely been considered as an important region in the analysis of the ISM. We have identified a pattern in North Pakistan that plays an important role in the extreme rainfall organization during the ISM, because it is strongly influenced by winter westerlies during the pre-monsoon season and monsoon season, which strongly influence the ISM variability. Accordingly, this pattern may serve as a marker of winter westerlies. We suggest that our obtained spatial patterns are important meteorological features that may be useful for prediction of the Indian Summer Monsoon.