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Lagged Synchronizations of Hydroclimatic Extremes and Their Propagation Dynamics Revealed by Complex Event Coincidence Networks

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Extreme droughts and pluvials are recurrent natural hazards that often lead to disastrous socio-economic impacts. These hydroclimatic extremes are generally characterized by large-scale spatial-temporal patterns spanning thousands of kilometres with time-evolving features of expansion or shrinkage. The spatial-temporal dynamics of these hydroclimatic extremes can pose compound impacts across multiple locations. Understanding the propagation behaviour, including movement and propagation, is crucial for disaster response and mitigation. The spatial propagation dynamics of droughts/pluvials are inherently complex as they are often associated with and modulated by natural climate variability, such as El Niño-Southern Oscillation (ENSO), North Atlantic Oscillation (NAO), and atmospheric dynamics like Rossby waves. However, the specific influences of these drivers on the spatial propagation pathways of droughts and pluvials remain elusive. Here, we conduct a multi-layer complex network-based analysis to explore the interactions between drought/pluvial propagation pathways and potential modulating mechanisms with a focus on the conterminous United States. We first identify extreme drought and pluvial occurrences using self-calibrated Palmer Drought Severity Index (scPDSI) and Standardized Precipitation Index (SPI) during 1948–2016. We then apply event coincidence analysis (ECA) for all location pairs to construct fully-connected drought and pluvial complex networks, based on which we identify the spatial-temporal propagation pathways through community analysis. Subsequently, partial event coincidence analysis is carried out to elucidate the direct links from potential climate modulators (e.g., ENSO, NAO, and Rossby waves) to extreme event propagation. Our results provide insights into how climate variability and large-scale circulation patterns affect the spatial propagation of droughts and pluvials, offering valuable information for pre-emptive actions to mitigate remotely synchronized extreme events.