

Spatial Multi-site Drought Prediction Using Cross-station Dependencies in Data-scarce Regions

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Abstract:

Reliable drought assessment remains challenging in regions with sparse meteorological monitoring, where limited observations constrain effective drought preparedness and water-resource management. This study proposes a spatial multi-site modeling framework that uses information from neighboring monitoring stations to simultaneously estimate the Standardized Precipitation Evapotranspiration Index (SPEI) at multiple target locations. By explicitly exploiting spatial dependence across the monitoring network, the framework provides an alternative to conventional approaches in which each station is modeled independently. Its predictive capability is evaluated for SPEI at 3-, 6-, and 12-month accumulation periods, representing drought variability over short-, medium-, and long-term timescales. The results show that the proposed approach reliably reproduces drought behavior across a wide range of conditions, including moderate, severe, and extreme events. Beyond estimating SPEI values, the framework captures important drought characteristics such as intensity, duration, and frequency and successfully represents the temporal progression of drought episodes, including their onset, persistence, and recovery. The findings further demonstrate the value of jointly utilizing information from multiple stations to characterize nonlinear spatial dependencies and shared drought variability across a monitoring network. The proposed framework therefore provides a promising tool for improving drought prediction in data-limited regions and can support more informed water-resource planning, drought preparedness, and climate-adaptation strategies.

Keywords:

Drought prediction, Machine learning, Multi-site prediction, Spatial dependence, Spatial modeling.