EGU21-87, updated on 19 May 2022
https://doi.org/10.5194/egusphere-egu21-87
EGU General Assembly 2021

Spatiotemporal Clustering of Hydrological Droughts in Peninsular India

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Drought is considered one of the costliest climate extremes that have wide impacts on humans and ecosystems. Understanding different drought stages, for example, onset, propagation, and its recovery, especially for tropical (the vulnerable region in Earth's climate system) catchments are crucial for ecosystem sustainability and food security. Utilizing gauge-based quality-controlled daily streamflow records from 98 catchments of rain-fed Peninsular River Basins (PRB) in India, here we investigate different phases of hydrological droughts in a multi-stage framework. While several studies so far have investigated the propagation of hydrological droughts at a monthly resolution, a credible understanding of drought dynamics requires analyzing low-flow series at a higher spatial and temporal resolution, ensuring the issuance of timely alerts related to regional water scarcity. Owing to high seasonality in the daily streamflow records, a variable threshold approach is adopted to delineate streamflow-based drought events. To assess the temporal evolution of droughts, the events are categorized into various inter-related phases, i.e., growth, persistence, and recovery stage over the study period 1965 – 2018. For most of the gauges, the mean timing of drought onset mostly lies between August and September revealing failure of monsoon as the primary causal factor for drought development in peninsular catchments. Furthering this, we identify four distinct hydrological drought regimes, which includes, **Regime 1:** persistent droughts with longer duration and moderate deficit volume with average termination during mid-monsoon (in September). These gauges are mostly situated in Central India and typically show a longer recovery time coincided with shorter return times (i.e., the time between two consecutive drought events), making it one of the most vulnerable regions in PRB; **Regime 2:** droughts with a shorter duration, least deficit volume with average termination in October, the post-monsoon period. These gauges are located in the western part of the country; **Regime 3:** droughts with the highest variability in drought deficit volume with the largest subsurface contribution from groundwater recharge. These sites are primarily located in eastern India and do not show any specific trend in the termination period; **Regime 4:** droughts with least regularity in drought termination with the average termination month clustered around November. These gauges are mostly concentrated in the southwestern part of the country. Our findings add value to the systematic understanding of hydrological drought propagations in rain-fed catchments, which serves as a basis for exploring future changes in droughts under concurrent shifts in rainfall and temperature extremes in a warming climate.