

ABSTRACT

The flash drought (FD) events can have devastating impacts, such as increasing the risk of agricultural yield loss, heatwaves, and increased wildfire risk, and associated socio-economic conditions. FD events are characterized by the quick depletion of crop root zone soil moisture (rapid onset and intensification) and hence it is categorized as a form of agricultural drought. In this study, the FD is defined using the Standardized Percentile Drop Method (SMPD) and Standardized Change Anomaly of the Pentad Root Zone Soil Moisture (SASM) over the 40-year period (i.e., from 1981 till 2020 and during the winter, pre-monsoon, monsoon, and post-monsoon seasons) for the six Homogeneous Rainfall Regions (HRRs) of India. As per the results of SMPD method, the monsoon season (June–September) is found to be more prone to FDs with higher regional average values of total per pixel flash drought frequency (FDF), specifically over the Central Northeast (CNE ~ 54) and West Central (WC ~ 41) regions. However, the similar spatial and seasonal dynamics is inferred from the SASM approach and it is found to be better suited for Indian conditions. The FD properties are calculated to analyze the spatio-temporal evolution of the FDs over the period of 40 years and it has revealed interesting details of FDs in India. The areal extent of the FD events for different duration ranges infers that, 84% of the all-India pixels having the average FD duration varying from 30 to 60 days, estimated over the period of 40 years. The atmospheric regional drivers of FDs were analyzed using the PCMCI (Peter and Clark’s Momentary Conditional Independence) causal algorithm, which revealed that precipitation (prcp) is the dominant driver of FDs across India at both real-time and lagged timesteps. A strong real-time dependence of FDs with Total Cloud Cover (TCC), Net Solar Radiation (NSR), and Vapour Pressure Deficit (VPD) is observed, followed by precipitation. While the antecedent precipitation and soil moisture at a lag time step of one pentad, emerge as the primary drivers which controls FD occurrence at the current time step in India. The causal connection of the FDs with the global climatic drivers, which are, El Niño-Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) is also analyzed using the PCMCI algorithm. It is observed that the fraction of FDs during the El Niño years (38.3%) is higher as compared with that in Neutral (36.7%) and La Niña years (25%). The Southern Peninsula (SP) and West Central (WC) regions of India have significant direct and lagged causal links (lag time of one season) of average per pixel FDF with IOD. Whereas, similar (direct and lagged) causal

connections are observed between the ENSO and IOD, both at real and lag time step of 1 season. To explore the linkage between seasonal droughts (SDs) and FDs across the HRRs of India, the temporal characteristics of FDs based on SASM approach were quantified using Multifractal Detrended Fluctuation Analysis (MF-DFA) and compared with SDs represented by the Standardized Soil Moisture Index (SSMI) time series across all six HRRs. It is observed that, for all the six HRRs, the FD index time series (SASM) is exhibiting the LTP (Long-Term Persistence), however, the STP (Short-Term Persistence) nature for the SD time series. Overall, the current thesis has contributed towards novel multi-scale understanding of the FDs using the state-of-the-art tools of causality and multifractality focusing on the slow-onset SDs and rapid-onset FDs and provided the insights that can support regional stakeholders and policymakers for making improved decisions through forecast models.

Keywords: Flash drought, Root Zone Soil Moisture, atmospheric drivers, large-scale drivers, causal pathways, multifractal analysis.