Tracking of Moisture Sources of Hydrological Extremes

Abstract

Flooding stands as the most prevalent natural disaster around the world, leading to considerable economic and human losses. To comprehend extreme rainfall events that result in flooding, it is essential to identify the dominant sources of moisture, recognize the factors influencing anomalous moisture transport, and evaluate their effects on the response of the basin. This research presents frameworks aimed at exploring the spatio-temporal dynamics of flooding throughout India. A comprehensive examination of flood characteristics at 226-gauge stations across 15 major Indian river basins uncovered intriguing patterns. The prevailing trend shows a decline in annual maximum discharge at 138 stations, attributed to aligned rainfall patterns and regulated structures within the river network. There has been a notable rise in unprecedented flooding at 14% of the monitored stations across the country, particularly in key basins like the Ganga, Godavari, Krishna, Brahmani and Baitarani, and Subarnarekha. Based on these observations, we proposed a novel framework to investigate the sources of excess moisture transport associated with flooding, integrating atmospheric moisture tracking with basin response and tested it in the flood-prone Baitarani basin. In the initial months of the monsoon, the Indian Ocean and the Arabian Sea serve as the main contributors of moisture. As the monsoon progresses into the later months, the Bay of Bengal emerges as the primary contributor, indicating a systematic change in atmospheric pathways. In the later phase, land-based sources also play a vital role, with the Ganga basin becoming a significant source region. The changing moisture pathways affect catchment dynamics by determining how rainfall is distributed across the area, which in turn impacts the timing and magnitude of flooding within the basin. Further, to enable a more detailed investigation of standalone predictors of extreme events, the framework is extended to the Periyar River basin and subsequently scaled to the entire country by examining extreme rainfall characteristics across 34 meteorological zones to capture spatio-temporal variability. The findings reveal interesting patterns, highlighting a spatial antiphase association between the central and northeastern zones, influenced by large-scale climatic oscillations like the Pacific Decadal Oscillation (PDO). Additionally, a decrease in extremes across the Indo Gangetic Plains has been noted, attributed to the combined impact of the Northern Annular Mode (NAM) and the North Atlantic Oscillation (NAO). In contrast, the southern peninsular zones have exhibited an increase in extremes, associated with a southward shift of the low-level jet trajectories. The insights gained from this research deepen our comprehension of the dynamics of extreme rainfall and present potential paths for enhancing the predictability and reduction of flood risks across climate-sensitive regions.