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# Signature of Nonstationarity in Precipitation Extremes over Urbanizing Regions in India Identified through a Multivariate Frequency Analyses

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The statistical assumption of stationarity in hydrologic extreme time/event series has been relied heavily in frequency analysis. However, due to the analytically perceivable impacts of climate change, urbanization and concomitant land use pattern, assumption of stationarity in hydrologic time series will draw erroneous results, which in turn may affect the policy and decision-making. Past studies provided sufficient evidences on changes in the characteristics of Indian monsoon precipitation extremes and further it has been attributed to climate change and urbanization, which shows need of nonstationary analysis on the Indian monsoon extremes. Therefore, a comprehensive multivariate nonstationary frequency analysis has been conducted for the entire India to identify the precipitation characteristics (intensity, duration and depth) responsible for significant nonstationarity in the Indian monsoon. We use 1o resolution of precipitation data for a period of 1901-2004, in a Generalized Additive Model for Location, Scale and Shape (GAMLSS) framework. A cluster of GAMLSS models has been developed by considering nonstationarity in different combinations of distribution parameters through different regression techniques, and the best-fit model is further applied for bivariate analysis. A population density data has been utilized to identify the urban, urbanizing and rural regions. The results showed significant differences in the stationary and nonstationary bivariate return periods for the urbanizing grids, when compared to urbanized and rural grids. A comprehensive multivariate analysis has also been conducted to identify the precipitation characteristics particularly responsible for imprinting signature of nonstationarity.