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Rainfall and Flood Frequency Analysis Using High-Resolution Radar Rainfall Fields and Stochastic Storm Transposition

Daniel Wright, James Smith, and Mary Lynn Baeck
Civil and Environmental Engineering, Princeton University, Princeton, NJ, USA (dbwright@princeton.edu)

Spatial and temporal variability of rainfall fields, and their interactions with surface, subsurface, and drainage network properties, are important drivers of flood response. 'Design storms,' which are commonly used for flood risk assessment, however, are assumed to be uniform in space and either uniform or highly idealized in time. The impacts of these and other common assumptions on estimates of flood risk are poorly understood. We present an alternative framework for flood risk assessment based on stochastic storm transposition (SST). In this framework, "storm catalogs" are derived from a ten-year high-resolution (15-minute, 1 km^2) bias-corrected radar rainfall dataset for the region surrounding Charlotte, North Carolina, USA. SST-based rainfall frequency analyses are developed by resampling from these storm catalogs to synthesize the regional climatology of extreme rainfall. SST-based intensity-frequency-duration (IFD) estimates are driven by the spatial and temporal rainfall variability from weather radar observations, are specifically tailored to the chosen catchment, and do not require simplifying assumptions of storm structure. We are able to use the SST procedure to reproduce IFD estimates from conventional methods for small urban catchments in Charlotte. We further demonstrate that extreme rainfall can vary substantially in time and in space, with important flood risk implications that cannot be assessed using conventional techniques. When coupled with a physics-based distributed hydrologic model, the Gridded Surface Subsurface Hydrologic Analysis (GSSHA) model, SST enables us to examine the full impact of spatial and temporal rainfall variability on flood response and flood frequency. The interactions of extreme rainfall with spatially distributed land use, soil properties, and stormwater management infrastructure are assessed for several nested urban catchments in Charlotte. Results suggest that these interactions, which cannot be fully accounted for using standard frequency analysis techniques, are important controls on flood response. We compare the results of SST-based flood frequency analyses to peak streamflow observations and to the results of other frequency analysis techniques.