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Modeling Stochastic Boundary Conditions in a Coastal Catchment using a Bayesian Network: An Application to the Houston Ship Channel, Texas

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Recent research has highlighted the increased risk of compound flooding in the U.S. In coastal catchments, an elevated downstream water level, resulting from high tide and/or storm surge, impedes drainage creating a backwater effect that may exacerbate flooding in the riverine environment. Catchments exposed to tropical cyclone activity along the Gulf of Mexico and Atlantic coasts are particularly vulnerable. However, conventional flood hazard models focus mainly on precipitation-induced flooding and few studies accurately represent the hazard associated with the interaction between discharge and elevated downstream water levels.
This study presents a method to derive stochastic boundary conditions for a coastal watershed. Mean daily discharge and maximum daily residual water levels are used to build a non-parametric Bayesian network (BN) based on copulas. Stochastic boundary conditions for the watershed are extracted from the BN and input into a 1-D process-based hydraulic model to obtain water surface elevations in the main channel of the catchment. The method is applied to a section of the Houston Ship Channel (Buffalo Bayou) in Southeast Texas. Data at six stream gages and two tidal stations are used to build the BN and 100-year joint return period events are modeled. We find that the dependence relationship between the daily residual water level and the mean daily discharge in the catchment can be represented by a Gumbel copula (Spearman's rank correlation coefficient of 0.31) and that they result in higher water levels in the mid- to upstream reaches of the watershed than when modeled independently. This indicates that conventional (deterministic) methods may underestimate the flood hazard associated with compound flooding in the riverine environment and that such interactions should not be neglected in future coastal flood hazard studies.