Trivariate probabilistic assessments of the compound flooding events using Semiparametric Fully Nested Archimedean (FNA) copula approach

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Abstract

Flooding in coastal areas can result from the joint occurrence of multiple individual flood variables, resulting in compound flooding (CF) events. Individual variables may not be extreme but can result in a severe coastal impact if they occur in close succession or simultaneous. Bivariate joint distribution analysis is ineffective in assessing the likelihood of joint occurrence, thus demanding a more advanced higher dimensional probability framework. Incorporating higher dimensional joint simulation via traditional symmetric 3-D Archimedean or Elliptical copulas has statistical limits and would be incapable of preserving all lower-level dependencies. The heterogeneous dependency in hydrologic consequences can be modelled effectively via the fully nested Archimedean (FNA) copulas. Incorporating FNA under parametric distribution settings is not flexible enough since it is restricted by the prior distributional assumption of the function type for both its marginal density functions and copulas in parametric fittings. This study introduces a multivariate FNA copula under semiparametric distribution settings. The presented approach is based on relaxing the modelling of univariate marginal behaviour without any distributional assumption via the nonparametric kernel density estimation (KDE). The univariate marginal distribution of all the flood characteristics is constructed via normal KDE. The performance of FNA with nonparametric marginals outperforms the FNA copula built under parametric settings. The derived semiparametric FNA is applied to a case study in compounding the joint impact of rainfall, storm surge and river discharge observations on the west coast of Canada. The presented copula-based joint modelling is employed in multivariate analysis of flood risks in trivariate primary joint and conditional joint return periods. The trivariate hydrologic risk associated with compound events is analyzed using the failure probability (FP) statistics. Investigation reveals that trivariate hydrologic events produce a higher failure probability than bivariate (or univariate) events; neglecting trivariate joint analysis would underestimate FP. Also, it indicates that trivariate hydrologic risk values would increase with an increase in service time of the hydraulic facilities.

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