Multivariate analysis framework for estuarine flooding risk

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Coastal flood events are one of the most common and severe threats around the world. Because of variability and climate change, their magnitude and frequency may increase in the future, creating new challenges for urban planning. In estuaries, interactions between both freshwater fluxes (rainfall or discharge) and coastal water levels (tide, surge, waves, or combinations thereof) can lead to compound flooding. These separate but physically connected processes can often occur simultaneously (but not necessarily in extreme conditions), resulting in high impact events. Conventional risk assessment mainly considers univariate-flooding drivers and does not include multivariate approaches. Ignoring compound flooding analysis may induce considerable misestimations of flood risk.

Copula multivariate models are a good alternative to overcome this limitation of traditional univariate approaches and can incorporate the joint boundary conditions in riverine and coastal interactions in a statistically sound way. The use of copulas has been implemented in previous works (Harrison et al., 2021; Bevacqua et al., 2019; Couasnon et al., 2018, Moftakhari et al., 2017). However, the complex interactions between coastal flooding drivers imply multidimensionality, nonlinearity and nonstationarity issues, and consequently, more relevant uncertainties. Notably, a need for robust approaches that help to characterize the nature of compound hazard remains (Moftakhari et al., 2021).

Here, we develop a copula-based multivariate framework for the analysis of estuarine compound flooding potential, considering the interactions and dependency structures between oceanographic, hydrological, and meteorological processes and variables (rainfall, river discharge, waves, and storm tides). We show the potential of the framework in Santoña, a strategic estuarine ecosystem in Northern Spain. We focus here on estimating the most suitable structure capable of capturing the full joint distribution of the extreme regime, using Archimedean and Elliptical copula families. The choice of the copula function which best fits the data is guided by hypothesis testing.

This study aims to improve copula-based methodologies that can adequately estimate the compound flood probability in estuarine regions, considering more than two variables, including more sources of uncertainty into the stochastic dependence analysis, raising the degree of accuracy to risk inference.

References

Bevacqua, E., Maraun, D., Vousdoukas, M. I., Voukouvalas, E., Vrac, M., Mentaschi, L., & Widmann, M. (2019). Higher probability of compound flooding from precipitation and storm surge in Europe under anthropogenic climate change. Science advances, 5(9), eaaw5531.

Couasnon, A., Sebastian, A., & Morales-Nápoles, O. (2018). A copula-based Bayesian network for modeling compound flood hazard from riverine and coastal interactions at the catchment scale: An application to the Houston Ship Channel, Texas. Water, 10(9), 1190.

Harrison, L. M., Coulthard, T. J., Robins, P. E., & Lewis, M. J. (2021). Sensitivity of Estuaries to Compound Flooding. Estuaries and Coasts, 1-20.

Moftakhari, H., Muñoz, D. F., Song, J. Y., Alipour, A., & Moradkhani, H. (2021). Challenges for Appropriate Characterization of Compound Coastal Hazards. In Geo-Extreme 2021 (pp. 58-68).

Moftakhari, H. R., Salvadori, G., AghaKouchak, A., Sanders, B. F., & Matthew, R. A. (2017). Compounding effects of sea level rise and fluvial flooding. Proceedings of the National Academy of Sciences, 114(37), 9785-9790.