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Joint return periods in hydrology: a critical and practical review focusing on the synthetic design hydrograph estimation

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In several branches of engineering the selection of design variables is a common exercise. Recently, there is increasing interest in considering several variables at the same time in the design, which are likely to be associated with each other. In hydrology and hydraulics, applications such as the design of sewer systems or dams, the calculation of flood risks, etc. require the selection of characteristic variables of rainfall or discharge events with a predefined return period.

So far, well-established univariate frequency analysis methods have been a standard tool in practice. In contrast, newer methods show a tendency of describing hydrological phenomena with multiple variables. This is challenging practitioners to calculate the multivariate return period and to select a specific design event. In literature, several approaches for the latter problem have evolved over the years, however no study exists on how these methods compare to each other and a controversy on which approach is the right one is going on.

In this study, an overview will first be given on the state of the art for defining joint return periods. The construction of multivariate distribution functions will focus on copulas, given their practicality in multivariate frequency analysis. Subsequently, a case study focusing on the selection of design hydrograph characteristics is introduced. In this application, design values of a 3-dimensional phenomenon composed of peak discharge, volume and duration are derived (for given return periods). This case study investigates and compares the different definitions of joint return periods and allows to highlight important issues with respect to multivariate frequency analysis.