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Bivariate at-site frequency analysis of simulated flood peak-volume data using copulas

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In frequency analysis of joint hydro-climatological extremes (flood peaks and volumes, low flows and durations, etc.), usually, bivariate distribution functions are fitted to the observed data in order to estimate the probability of their occurrence. Bivariate models, however, have a number of limitations; therefore, in the recent past, dependence models based on copulas have gained increased attention to represent the joint probabilities of hydrological characteristics.

Regardless of whether standard or copula based bivariate frequency analysis is carried out, one is generally interested in the extremes corresponding to low probabilities of the fitted joint cumulative distribution functions (CDFs). However, usually there is not enough flood data in the right tail of the empirical CDFs to derive reliable statistical inferences on the behaviour of the extremes. Therefore, different techniques are used to extend the amount of information for the statistical inference, i.e., temporal extension methods that allow for making use of historical data or spatial extension methods such as regional approaches. In this study, a different approach was adopted which uses simulated flood data by rainfall-runoff modelling, to increase the amount of data in the right tail of the CDFs.

In order to generate artificial runoff data (i.e. to simulate flood records of lengths of approximately 10^6 years), a two-step procedure was used. (i) First, the stochastic rainfall generator proposed by Sivapalan et al. (2005) was modified for our purpose. This model is based on the assumption of discrete rainfall events whose arrival times, durations, mean rainfall intensity and the within-storm intensity patterns are all random, and can be described by specified distributions. The mean storm rainfall intensity is disaggregated further to hourly intensity patterns. (ii) Secondly, the simulated rainfall data entered a semi-distributed conceptual rainfall-runoff model that consisted of a snow routine, a soil moisture routine and a flow routing routine (Parajka et al., 2007). The applicability of the proposed method was demonstrated on selected sites in Slovakia and Austria. The pairs of simulated flood volumes and flood peaks were analysed in terms of their dependence structure and different families of copulas (Archimedean, extreme value, Gumbel-Hougaard, etc.) were fitted to the observed and simulated data. The question to what extent measured data can be used to find the right copula was discussed.

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