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Multivariate Return Periods based on Vine Copulas

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One aspect of the study of extremes is the prediction of the most extreme event to be expected within a given amount of time. In practical applications, this is for instance the strongest rainfall or the highest flood wave within the next 100 or 1000 years. These natural phenomena are typically multivariate and it is desirable to study their extreme behaviour jointly and not marginally as important dependencies would be ignored. The advance of copulas strengthens this approach as they allow for a disjoint estimation of marginal distribution and dependence structure. As the complexity of the dependence structure increases with the distribution's dimension, flexible multivariate copulas are needed. Unfortunately, many multivariate extensions of bivariate copula families lack this flexibility and may be too restrictive. Properties like symmetry and tail dependence might apply for certain but not for all margins. Decomposing multivariate copulas by vines into a set of bivariate copulas from different families leads to an approximation of the underlying dependence structure. These vine copulas are a powerful tool to achieve the desired high degree of flexibility.

We illustrate the application of vine copulas in the context of multivariate return periods. A 3-dimensional vine copula is fitted to a synthetic data set of annual maxima flood peak discharge, volume and duration related to a given dam. This copula is used to predict extreme events for the underlying random process. In the multivariate context, the notion of extremes is ambiguous. To address this ambiguity, we used besides the inverse of the multivariate cumulative distribution function a recently introduced approach based on the Kendall distribution associated with the vine copula to calculate the critical layer. This layer unites all the events related to a given return period. We show how the flexible vine structure adapts to the data set and provide a comparison of the differently derived critical layers. Furthermore, we outline the extension of the illustrated temporal example towards a spatio-temporal application.