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A flood frequency analysis framework to account flood-generating factors in Western Mediterranean catchments

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There are several factors influencing flood peak discharges in Western Mediterranean catchments in Spain. These factors are mainly associated with the high spatial heterogeneity of the physical characteristics of the catchment, the high spatio-temporal variability of the flood-generating storms, as well as the effect of the initial soil moisture condition. In these cases, the standard approaches of frequency analysis can lead biased results due to their hypothesis and they can have practical limitations due to the input data (e.g. ungauged or poorly instrumented catchments). To resolve such restrictions, a probabilistic framework for flood frequency estimation has been developed to take account of these factors and support decisions in a flood management context, where high return flood quantiles are considered.

The proposed framework is based on simulations obtained from stochastic rainfall modelling and distributed hydrologic modelling (at different time scales: continuous and event-based). First, a space-time rainfall generator is used, focusing on the reproduction of the internal structure of the convective storms, typical of the Western Mediterranean. Then, from continuous rainfall-runoff simulations, it is possible to obtain the historical soil moisture conditions prior to flood events. This result acts as an initial condition for the event-based model, which uses the synthetic storms as input. Finally, the methodology for the frequency analysis of the annual maximum flows (X), obtained from the event-based model, is based on a trivariate statistical distribution. It considers as inputs: (a) the point-rainfall daily-equivalent as a continuous random variable denoted as R; (b) initial soil moisture conditions -ISMC, as a discrete random variable denoted by H, and (c) the annual maximum flows X themselves. The objective is to determine the marginal distribution function of X from a sample of x values conditional on synthetic storms r and ISMC h, with known marginal distribution for R and H. To demonstrate that H and R are independent, two rank correlation methods (Spearman and Kendall) were applied. By application of the Bayes' theorem and Lagrange's Mean Value theorem, the value of the continuous distribution function can be approximated by a simple plotting position obtained from the sample x values.

A representative case study in the Spanish Mediterranean was implemented ("Rambla del Poyo" which is part of the Jucar Basin Authority). The results show an adequate adjustment between the observed and estimated frequency curves. A comparison with standard methods was done. The critical hypothesis of this kind of approaches were verified in this study: i) the equivalence between the rainfall and discharge return periods is not valid (differences up to two orders of magnitude were found); and, ii) the influence of the ISMC on the catchment response cannot be neglected (peak discharges differences up to five times were found for the same storm but with two dissimilar ISMC). Considering the results obtained, this method has been applied in other parts of the same Basin Authority and has been recommended to be applied for practical purposes in the Spanish program for flood hazard mapping.