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The quest for consistent representation of rainfall and realistic simulation of process interactions in flood risk assessment

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We present a methodological framework for the estimation of flood risk in the Boeoticos Kephisos river basin, in Greece, draining an area of 1850 km2. This is a challenging task since the basin has many peculiarities. Due to the dominance of highly-permeable geologic formations, significant portion of runoff derives from karst springs, which rapidly contribute to the streamflow, in contrast to the unusually low contribution of direct (flood) runoff. In addition, due to the combined abstractions from surface and groundwater recourses and the existence of an artificial drainage network in the lower part of the basin (where slopes are noticeably low), the system is heavily modified.

To evaluate the probability of extreme floods, especially in such complex basins, it is essential to provide both a statistically consistent description of forcing (precipitation) and a realistic simulation of the runoff mechanisms. Typically, flood modelling is addressed through event-based tools that use deterministic design storms and empirical formulas for the estimation of the "effective" rainfall and its transformation to runoff. Yet, there are several shortcomings in such approaches, especially when employed to large-scale systems. First, the widely-used methodologies for constructing design storms fail to properly represent the variability of rainfall, since they do not account for the temporal and spatial correlations of the historical records. For instance, it is assumed that the input storms to all sub-basins correspond to the same return period. On the other hand, "event-based" models do not allow for interpreting flood risk as joint probabilities of all hydrological variables that interrelate in runoff generation (rainfall, stream-aquifer interactions, soil moisture accounting). Finally, for the estimation of model parameters, the typical approach is to calibrate them against normally few historical flood events, which is at least questionable – the information embedded within calibration is far from being representative of the catchment mechanisms.

With the purpose of assessing flood risk in the aforementioned basin we employed a two-step procedure. First, we used an original multivariate stochastic rainfall model to simulate the daily rainfall in 13 stations, for which 40-year historical data exist. Particularly, the model reproduces sufficiently all the essential features of the observed rainfall, i.e. (a) the seasonal variation, (b) the probability dry, (c) the mean and the standard deviation of the marginal distribution, as well as the power-type asymptotic tail of it, which is strongly related to frequent occurrences of extreme events, (d) the lag-1 autocorrelations, and (e) the lag-0 and lag-1 cross-correlations among the stations. Next, the synthetic rainfall series of 1000-year length were imported to the recently adapted daily version of the conjunctive hydrological model HYDROGEIOS. The model has been calibrated against multisite discharge data for a six-year period, and then run in stochastic simulation mode to estimate the daily flows across the river network. The analysis of model results provided valuable conclusions, not only regarding the frequencies of extreme events, but also the key role of the karst aquifer in the amplification of the long-term persistence of the system responses.