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How to master forecast ensembles? A method for selecting representative parameter sets

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Ensemble hydro-meteorological simulation has become a common tool not only for forecasting but also for extreme flood estimation as it enables representing modelling uncertainties. Many state-of-the art uncertainty quantification methods rely on numerous simulations of the hydrological model with different parameter sets, where the ensemble of simulations is assumed to represent the range of possible system outcomes. However, if the hydrological model is part of a complex model chain, the number of required simulations might increase drastically, e.g., with numerous meteorological input scenarios. Such an analysis becomes computationally and timely intensive and is challenging even with today's computational possibilities. Therefore, some kind of selection of representative parameter sets for scenario simulations is required. Such a selection strategy is necessarily case-study dependent.

Here, we propose an innovative method to select a representative set of hydrological model parameters to be used within a complex extreme flood simulation chain. Ideally, a selection of representative sets (quantiles) should cover the spectrum of possible model realisations, while keeping the number of selected sets low enough to be dealt within the model chain. In this study, we test three different strategies to determine such representative sets for extreme flood simulation within a continuous rainfall-runoff simulation framework with a conceptual hydrological model (HBV).

The basic idea of the selection method is to rank all possible parameter sets according to their effect on the simulated annual discharge peak using different ranking strategies. These strategies are: (a) peak ranking, (b) peak ensemble, and (c) peak clustering. In strategy (a), in each year, we rank the simulated annual peaks with different parameter sets by their magnitude and identify three parameter sets that correspond to the 5%, 50% and 95% quantiles. The sets that, across all years, occur the most often for each of these quantiles are retained as representative sets. In strategy (b), we analyse all annual peaks across all years in the Gumbel space and then compute ensembles of the 5%, 50% and 95% quantiles. The sets lying closest to these estimated quantile values are chosen as representative sets. In strategy (c), we also analyse all annual peaks across all years but this time we cluster them into upper, middle and lower groups and select the sets lying closest to the cluster means as representative for these groups.

This methodology is tested in ten meso-scale sub-catchments of the Swiss Rhine catchment using 50 years of hydrological simulations at an hourly time-step. Our results show that both the peak clustering (c) and the peak ensemble (b) approach provide a more reliable choice of the representative sets than strategy (a). The success of the approach (a) decreases with increasing the variability of representative sets assigned across different years. A clustering approach arises thus as a promising tool to reduce the number of required model simulations while representing the range of possible model outcomes. It could therefore be of particular interest in computationally highly expensive applications such as flood forecasting or long-term continuous simulations at a high temporal resolution.