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Dealing with the uncertainty of hydrological model's parameters in a stochastic rainfall-runoff simulation for extreme flood estimation

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The SCHADEX method (Paquet et al., 2013) is a reference method in France for the estimation of extreme flood for dam design. The method is based on a semi-continuous rainfall–runoff simulation process: hundreds of different rainy events, randomly drawn up to extreme values, are simulated independently in the hydrological conditions of each day of a historical record. This allows generating an exhaustive set of crossings between precipitation and soil saturation hazards, and to build a complete distribution of flood discharges up to extreme quantiles.

The hydrological model embedded in SCHADEX is the MORDOR conceptual model (Garavaglia et al., 2017), which provides a complete schematization of the main hydrological processes involved in the runoff production. Both a lumped and a semi-distributed version (with several elevation zones) are available, with up to 20 free parameters to be calibrated, depending on the modeling options. The calibration is performed by the genetic algorithm, using a composite objective function which scores various features of the discharge distribution.

The uncertainty on the model's parameters is significant, and can be linked to the hydrological variability of the calibration period, the hydrometric uncertainty of the observed discharges used for calibration, and the equifinilaty of the parameters. Furthermore, different sets of parameters can produce very similar simulations based of observed climatology, but significantly different distributions of extreme discharges through the SCHADEX stochastic simulation (all the others hypothesis remaining the same). This means that, in some cases, the asymptotic behavior of the rainfall-runoff model is not robustly inferred by the calibration of the hydrological model on observed data.

A method to evaluate this uncertainty and to compute a credible extreme flood estimation is presented and illustrated with several examples of French catchments.

Firstly, the uncertainty of the rainfall-runoff model parameters is explored by two methods: bootstrapping of the calibration data, and systematic exploration of the credible range of the influent parameters. This allows to generate a great diversity of simulated discharge distributions, computed with several hundred sets of parameters. A scoring of each model is introduced, taking into account the fit of the model to the bulk of the observed distribution and to the highest observed quantiles. A limited set of models is finally selected, according to this scoring, and their simulations are combined to produce a single estimated distribution of extreme flood, accounting for this model uncertainty. This method is tuned and evaluated thanks to an original procedure.

References:

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