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Multivariate Probabilistic Analysis of an Hydrological Model

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Model predictions derived based on rainfall measurements and hydrological model results are often limited by the systematic error of measuring instruments, by the intrinsic variability of the natural processes and by the uncertainty of the mathematical representation. We propose a means to identify such sources of uncertainty and to quantify their effects based on point-estimate approaches, as a valid alternative to cumbersome Montecarlo methods.

We present uncertainty analyses on the hydrologic response to selected meteorological events, in the mountain streamflow-generating portion of the Brenta basin at Bassano del Grappa, Italy. The Brenta river catchment has a relatively uniform morphology and quite a heterogeneous rainfall–pattern. In the present work, we evaluate two sources of uncertainty: data uncertainty (the uncertainty due to data handling and analysis) and model uncertainty (the uncertainty related to the formulation of the model). We thus evaluate the effects of the measurement error of tipping-bucket rain gauges, the uncertainty in estimating spatially-distributed rainfall through block kriging, and the uncertainty associated with estimated model parameters. To this end, we coupled a deterministic model based on the geomorphological theory of the hydrologic response to probabilistic methods. In particular we compare the results of Monte Carlo Simulations (MCS) to the results obtained, in the same conditions, using Li's Point Estimate Method (LiM). The LiM is a probabilistic technique that approximates the continuous probability distribution function of the considered stochastic variables by means of discrete points and associated weights. This allows to satisfactorily reproduce results with only few evaluations of the model function. The comparison between the LiM and MCS results highlights the pros and cons of using an approximating method. LiM is less computationally demanding than MCS, but has limited applicability especially when the model response is highly nonlinear. Higher-order approximations can provide more accurate estimations, but reduce the numerical advantage of the LiM.

The results of the uncertainty analysis identify the main sources of uncertainty in the computation of river discharge. In this particular case the spatial variability of rainfall and the model parameters uncertainty are shown to have the greatest impact on discharge evaluation. This, in turn, highlights the need to support any estimated hydrological response with probability information and risk analysis results in order to provide a robust, systematic framework for decision making.