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Application of a precipitation dependent HUP to a small watershed in Southern Italy

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Adequate assessment of uncertainties for prediction and simulation purposes is an outstanding issue in hydrological research. The present study focuses on the application of a Precipitation Dependent Hydrologic Uncertainty Processor (PD-HUP) to assess the predictive uncertainty on water discharge predictions for a small headwater catchment located in Calabria (South Italy) through a complete example of the estimation procedure, modelling assumptions and results.
The applied HUP was firstly proposed by Krzysztofowicz in 1999, as a component of the Bayesian forecasting system (BFS) which provides a general methodology for probabilistic forecasting via any deterministic hydrologic model. Within the BFS framework, the task of the HUP is to quantify the effects of various uncertainty sources on the forecasts of river discharge, using a "given" model under "given" input forcing, initial and boundary conditions and set of parameter values.
According to the principle of Bayesian revision of a probability distribution, the general formulation of the HUP supplies the hydrologic uncertainty in terms of a family of posterior densities of discharge, for every possible realization of the model river discharge process and observation of river discharge at the forecast time.
This result is obtained through the revision of a prior distribution, which exists before the preparation of a forecast, on the basis of a likelihood function estimated from past evidence on model performance against observations.
The implemented HUP rests on the following assumptions:
1. precipitation dependent structure conditioned on the value of the precipitation over the forecast period;
2. nonstationarity of both actual river discharge and model river discharge process with the lead time;
3. meta-gaussian formulation for all the conditional distributions.
The study watershed is the test site of the Turbolo Creek catchment (29 km2), a tributary of the Crati River, located in Southern Italy. The hydrologic response in the HUP is simulated by the RISE (Runoff by Infiltration and Saturation Excess) rainfall-runoff model which is a process-oriented one, conceived for applications to small and medium size catchments with the aim of a realistic description of the mechanisms that are assumed to be dominant in controlling storm runoff production and saturated area space-temporal dynamics.
The HUP processor was specified by deriving parametric expressions for the family of the prior densities and the family of the likelihood functions through a detailed statistical analysis of available observed and simulated data, in order to reduce the conditioning of the likelihood functions and the prior distributions in the transformed space to the smallest dimension that is necessary to capture the dependence structures between the model output and the actual process.
The analysis of the obtained posterior distributions showed that under each hypothesis about the precipitation event, the hydrologic uncertainty increases with lead time as one would expect. Furthermore, hydrologic uncertainty increases with the forecasted discharge and it is relatively higher when precipitation is significant, confirming the merit of assuming a precipitation dependent HUP. A real-time simulation of several storm events was also performed. Results highlight and prove the deterioration of the processor performance with increasing lead times. Finally, the predictive ability of the processor was assessed through a back analysis and identifying the quantile of the posterior distribution provided by the PD-HUP that gives a perfect diagnosis of the observations exceeding a fixed threshold and that reduces the occurrence of missed alarms.