Spatial distribution of sensitivity indices and their contribution to the prediction of ungauged basins

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1. Introduction

As the power of mathematical models increases, uncertainty analysis attracts the attention of researchers to fully understand and define the real value of predictions. Uncertainty can be evaluated through sophisticated sensitivity analysis to identify influential parameters of a model, among which Sobol’ method is well known. In this work a distributed hydrological model is applied in Natori River basin, and its outputs are evaluated using the techniques mentioned above with the objective of analyzing the information content in sensitivity indices and their potential contribution to the prediction in ungauged basins (PUB).

2. Hydrological model and data set

A particular distributed hydrological model developed under the structure suggested by Kazama (2004) was used. The model accounts runoff through four components: overland flow described by the kinematic wave equation, routing through main channels described by a dynamic wave model, a linear infiltration model, and a storage function estimating storage depth in the groundwater reservoir. The model is applied in Natori basin (426km^2 at Yokata station), a mountainous region in the center of Miyagi Prefecture, northeastern Japan. Precipitation as the main input is taken from hourly records at three stations of the Automated Meteorological Data Acquisition System (AMeDAS). Daily discharge records taken at Yokata gauging station are used for model performance evaluation. Evapotranspiration is estimated from Normalized Difference Vegetation Indices derived from remote sensing data. Rectangular input grids considered are: elevation (500m resolution), areal precipitation and evapotranspiration estimated using the inverse distance method. To simplify the analysis, the evaluation is made in October, 1999 in daily resolution.

3. Methods and application

The Sobol method (Saltelli, 2004) is used to estimate sensitivity indices. The method relies on Monte Carlo simulations that generate random samples from probability distributions of model factors, which are later used in the hydrological model to calculate the outputs. Model outputs are then used to calculate sensitivity indices to theoretically account the variance contribution of model parameters to total variance. In this work only total order index is considered, since it represents the main effect of a parameter as well as its interactions, and is useful to identify non-influential parameters. Due to the nature of the method, computational cost is high (in practice it is recommended at least 1000 model runs).

The hydrological model is applied in Yokata basin, and eight parameters are selected: channel roughness n, $S_{max,min}$, $F_{max,min}$ as maximum and minimum conditions of soil saturation and initial infiltration respectively, days of rain to soil saturation *dayrate*, and parameters K (dimensional) and m (dimensionless) that control storage depth. Parameters are uniformly distributed within a wide range, 1152 sample sets are randomly generated to run the model, and indices are calculated at every time step. Model uncertainty is evaluated, and having improved our knowledge on model response, the procedure is repeated for parameters normally distributed within narrower behavioral ranges, and 576 sample sets are generated. Later, sensitivity indices are evaluated at each cell of the watershed. Their spatial distribution is evaluated through visual comparison, and under the percent rank function for the population central interval (i.e. between the 0.025 and 0.975 quantiles) as a way to evaluate the relative standing of a value within a data set.

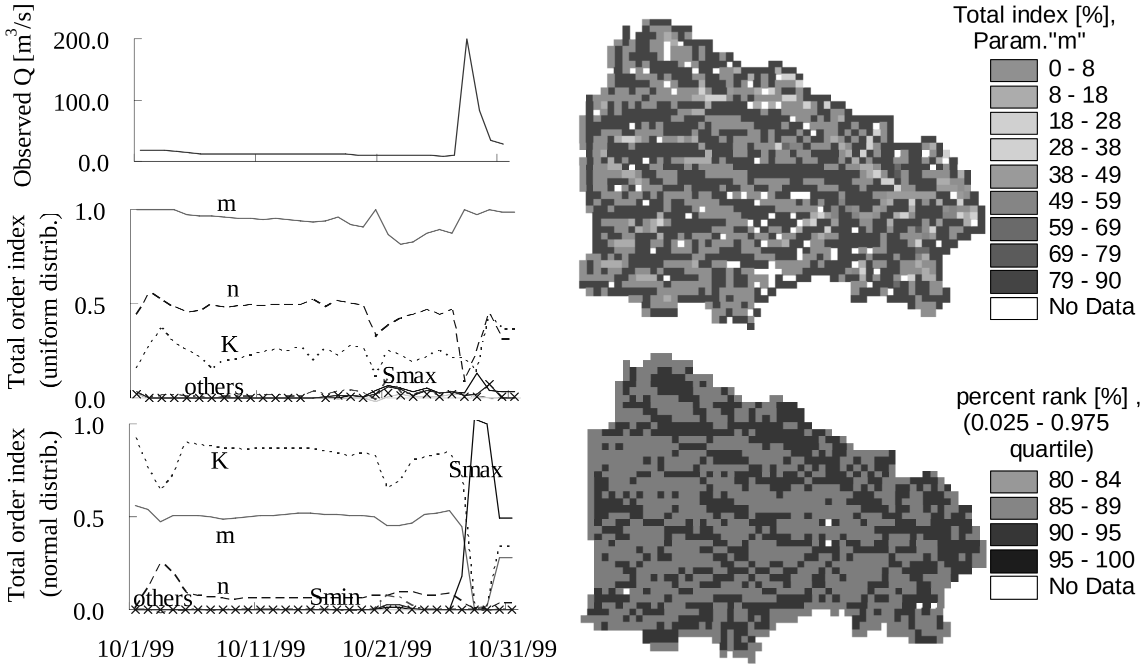

Figure 1a (left): Comparison between observed discharge and total order index (uniform and normal distributions) at Yokata station; Figure 1b (right): Spatial distribution of parameter “m” and percent rank for the time step “October 27th”.

4. Results and discussion

Indices can be evaluated temporally and spatially. Initial stages would deal with higher uncertainty since our knowledge of the response surface is vague, hence uniform distribution of model parameters is common. At this stage, comparison of sensitivity indices and observed discharge values could give an insight in model behavior, as shown in Figure 1a(center) where only few parameters (i.e. model components) drive model performance, for instance watershed response. Having increased our knowledge about the response characteristics (although only based on what observed in the outlet of the basin), and some implicit characteristics of the system, we are able to modify our previous expectations and “update” them. Figure 1a(bottom) shows a second stage of the process, where our parameters are normally distributed. To link sensitivity indices with physical characteristic in the watershed may not be the main purpose now, but to establish the regions where higher uncertainty might be present. Figure 1b pretends to exemplify what just said by comparing the spatial distribution of the parameter *m* (Figure 1b-top), and the spatial distribution of percent ranks of simulated discharges, as an attempt to evaluate a confidence level of the estimated parameters at each cell.

5. Conclusions

The potential of the techniques presented, and the power of the information contained in the products will highly depend on the interpretative capacity of the modeler. As presented here, an initial stage with wide behavioral ranges may allow a physical interpretation that can be reinforced when compared to other catchments with different characteristics, and a posterior stage can be important when evaluating the uncertainty of the predictions at different locations. The approach presented here aimed to contribute to solve the problem of predictions in ungauged basins. Researchers are encouraged to evaluate the techniques presented, and to advance the development of innovative alternatives.

References

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