Uncertainty in high and low flows due to parameter and model structure errors

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1. Introduction

Hydrological model simulations are inherently uncertain due to our limited understanding of nature and simplifications in representing hydrological processes. Uncertainty analysis should therefore be an integral part of each hydrological modelling study. The aim of this study is to investigate the uncertainty in simulated extreme low and high flows originating from hydrological model structure and parameters.

2. Study area and data

The study area consists of two sub-basins of the Qiantang River basin in eastern China: the Qu River (5290 km^2) and Jinhua River (5996 km^2). Qu River basin is dominated by mountains and hills, while Jinhua River basin mainly consists of flat areas. The climate in both sub-basins is semi-humid with an average annual precipitation of 1500 mm and 1800 mm for Qu River basin and Jinhua River basin respectively. Daily precipitation, potential evapotranspiration and discharge data for the period 1981-1995 are used, the first 10 years for model calibration and the remaining 5 years for model validation.

3. Methods

Three rainfall-runoff models lumped for each sub-basin with a daily time step are applied to estimate the model structure uncertainty: the GR4J model with 4 parameters (Perrin *et al*., 2003), the HBV model with 8 parameters (Lindström *et al*., 1997) and the Xinanjiang (XAJ) model with 13 parameters (Zhao, 1992).

The Generalised Likelihood Uncertainty Estimation (GLUE) approach is used to estimate the parameter uncertainty of each model. Uniform parameter distributions with upper and lower bounds based on previous model applications are employed to represent the prior distributions. In total 300,000 parameter sets are generated for each model. The Nash-Sutcliffe (NS) coefficient is selected as likelihood function and the threshold value for behavioural parameter sets is chosen to be 0.7.

Uncertainty in simulated extreme flows is evaluated by means of the annual maximum discharge (MHQ) and mean annual 7-day minimum discharge (MAM7) and their 90% confidence intervals. MHQ and MAM7 are fitted to the Gumbel and GEV type III distributions to estimate the indices for a return period of 50 years for each sub-basin.

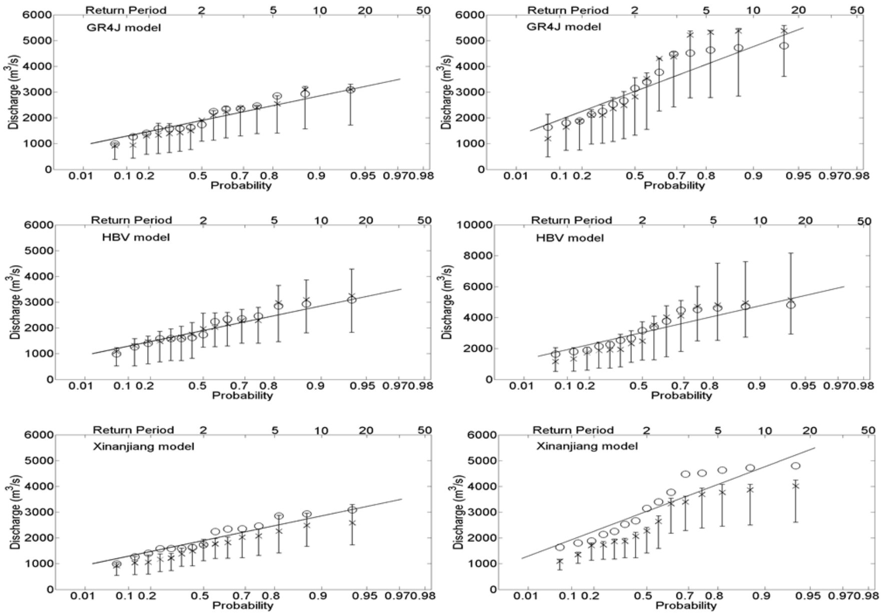

Figure 1 Comparison of annual maximum discharge (MHQ) as a function of return period and non-exceedance probability for Jinhua River (left) and Qu River (right) simulated with GR4J, HBV and Xinanjiang models. Circles represent the observed MHQ, crosses represent the optimum simulated MHQ, vertical bars represent 90% confidence intervals and straight lines represent the Gumbel distribution fitted to observed data.

4. Results

The results show that the three models perform well. The observed daily discharge is mostly captured by the 90% confidence intervals for all three models, however the 90% confidence intervals do not cover the extreme flows for the Xinanjiang model. Figure 1 shows that for extreme high flows, the bias is the largest for the Xinanjiang model and the smallest for HBV. The uncertainty in high flows increases with the magnitude of the discharge. This is most obvious for the HBV model, followed by GR4J and Xinanjiang. The parameter uncertainty in high flows is the largest in the HBV model and the smallest in Xinanjiang.

Figure 2 shows that low flows are more sensitive to the uncertainty than high flows. Low flows are mostly underestimated by all models with optimum parameter sets for both sub-basins and the largest underestimation is from the Xinanjiang model.

5. Conclusions

In general, the uncertainty originating from parameters is larger than the uncertainty due to model structure differences for high and low flows. These uncertainties and other, relevant uncertainty sources (e.g. input) should be taken into account for robust decision making.

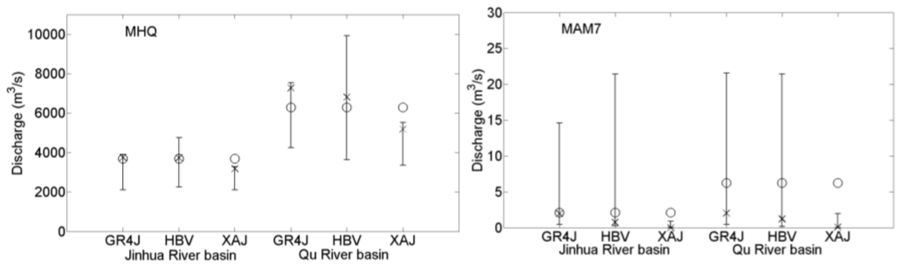

Figure 2 The 90% confidence interval of annual maximum discharge (MHQ) and mean annual 7-day minimum discharge (MAM7) for a return period of 50 years for each model and sub-basin. Circles represent the observed values, crosses represent the optimum simulated values and vertical bars represent the 90% confidence intervals.

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