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A Bayesian methodology for estimating prediction uncertainty of a distributed watershed model

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Distributed and physically based watershed models are required in watershed management for predicting the effects of water management strategies and land use change. However, the confidence of the model application relies on model uncertainty remaining after the model has been calibrated. Because of a large number of distributed parameters and uncertainties in model input, model parameters, and model structure, calibration and quantification of uncertainty in model output remain a challenging task. In many cases, heteroscedasticity, autocorrelation and outliers in the residuals invalidate the assumptions made to formulate the model likelihood function. This makes the uncertainty estimates unreliable. In this methodology, we combined several strategies to overcome these problems. (i) we used aggregate parameters that consider the prior knowledge on the spatial variation of distributed parameters to keep the number of calibration parameters at a moderate size; (ii) we applied the Box-Cox transformation to the results to keep the residuals within the dry and wet weather periods homoscedastic; (iii) we fitted different standard deviations of the stochastic variability of the residuals for the dry and rainy weather periods to keep the residuals between the dry and wet weather periods homoscedastic; (iv) we used a continuous time autoregressive model with different memory sizes for the dry and wet weather periods to account for the different degree of autocorrelation of the residuals within these two periods, with which it is very easy to omit the outliers. And then, a Markov Chain Monte Carlo technique was applied to get posterior samples of parameters and model results. This methodology was applied to the Chaohe Basin in China using the distributed watershed model SWAT (Soil and Water Assessment Tool). The results demonstrate that the statistical assumptions of the model are approximately fulfilled and thus that we can have confidence in the uncertainty estimates of the model predictions.