Estimation and Impact Assessment of Input and Parameter Uncertainty in Predicting Groundwater Flow with a Fully Distributed Model

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Regular abstract

Transient numerical groundwater flow models are used to understand and forecast groundwater flow systems under anthropogenic and climatic effects, but the reliability of the predictions is strongly influenced by different sources of uncertainty. Hence, researchers in hydrological sciences are developing methods for uncertainty quantification. Nevertheless, spatially distributed flow models pose significant challenges for parameter and spatially distributed input estimation and uncertainty quantification. The conventional treatment of uncertainty in groundwater modelling focuses on parameter uncertainty. In this study, we present a general and flexible Bayesian approach using uncertainty multipliers to simultaneously analyse the input and parameter uncertainty of a fully distributed groundwater flow model with consideration of the heteroscedasticity of the groundwater level error. Groundwater recharge and groundwater abstraction multipliers are introduced to quantify the uncertainty of the spatially distributed input data of the groundwater model in addition to parameter uncertainty. The heteroscedasticity of the groundwater level error is also considered in our Bayesian approach by incorporating a new heteroscedastic error model. The proposed methodology is applied in an overexploited aquifer in Bangladesh where groundwater abstraction and recharge data are highly uncertain. The results of the study confirm that consideration of recharge and abstraction uncertainty through the use of recharge and abstraction multipliers is feasible even in a fully distributed physically-based groundwater flow model. Heteroscedasticity is present in the groundwater level error and has an effect on the model predictions and parameter distributions. The input uncertainty affects the model predictions and parameter distributions and it is the dominant source of uncertainty in the groundwater flow prediction. When uncertainty of input data are not explicitly taken into account, the model parameters values are overly adjusted to compensate for errors from the input of the model, such as recharge rate and abstraction data. The observation coverage of the parameter uncertainty band increases from 8.5 % to 38.2 % if input uncertainty is explicitly considered along with model parameter and the parameters of the heteroscedastic error model. Additionally, the approach described also provides a new way to optimize the spatially distributed recharge and abstraction data along with the parameter values under uncertain input conditions. We conclude that considering model input uncertainty along with parameter uncertainty and heteroscedasticity of the groundwater level error is important for obtaining realistic model predictions and a correct estimation of the uncertainty bounds.