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Uncertainty and its propagation estimation for an integrated water system model: An experiment from water quantity to quality simulations

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Abstract: Multiple uncertainty sources directly impact the simulation performance of water-related processes for complicated integrated model, which is a chain of modules. Existing studies mainly focus on the uncertainties of model parameters and structures, and their effects on the model performance for a single process (e.g., hydrological cycle or water quality). However, comprehensive uncertainties of different modules and their propagations are poorly understood, particularly for the integrated water system model. This study proposes a framework of uncertainty and its propagation estimation for integrated water system model (HEQM) by coupling the Bootstrap resampling method and SCE-UA auto-calibration technique. The HEQM is proposed for preferable simulations in both hydrological and water quality processes at daily scale on the hypothesis that the cycles of water and nutrients are inseparable and act as critical linkages among all the coupled water-related processes (e.g., hydrology, biogeochemistry, water quality, agriculture crop and interference of human activities). The SCE-UA technique is adopted to auto-calibrate the selected parameters of hydrological and water quality modules, and the Bootstrap method is adopted to resample the residuals of runoff and water quality simulations. Parameter and structure uncertainties of hydrological cycle and water quality modules are estimated, including final distributions of parameters and simulation uncertainty intervals. Additionally, the effect of uncertainty propagation of hydrological parameters is investigated. Results show that: (1) HEQM simulates daily hydrograph very well with the coefficient of efficiency of 0.81, and also simulates the daily concentrations of ammonia nitrogen satisfactorily with the coefficient of efficiency of 0.50 by auto-calibration in the Shaying River catchment, China; (2) Compared to the initial ranges of interested hydrological parameters, the final ranges are reduced obviously, and all the parameter distributions are well-defined and show skew. The uncertainty intervals of runoff simulation at the 95% confidence level bracket 18.7% and 86.0% of all the runoff observations due to uncertainties of parameter, and both parameter and module structure, respectively. Thus, the model structure uncertainty has a more profound influence on model performance; (3) The uncertainty propagation of hydrological parameters does not obviously change the water quality simulation performance. The uncertainty intervals at the 95% confidence level only bracket 1.7% of all the water quality observations. Due to the further introduction of module structure uncertainties, 94.8% of observations are bracketed, only except the extreme high and low water quality concentrations; (4) The uncertainty intervals of water quality simulation at the 95% confidence level bracket 12.1% of total water quality observations due to the water quality module parameters. The figure increases to 21.0% and 92.0% if the uncertainty propagation of hydrological parameters, structure uncertainties of water quality module are considered, respectively. Therefore, although the parameter uncertainty and its propagation contribute a certain proportion of the whole simulation uncertainties, the module structure itself is the primary uncertainty source for the integrated water system model (HEQM), particularly for the water quality modules.

Keywords: *Uncertainty propagation, hydrological cycle, water quality, HEQM*