EGU24-18804, updated on 20 May 2024
https://doi.org/10.5194/egusphere-egu24-18804
EGU General Assembly 2024

Accelerating Hydrological Model Inversion: A Multilevel Approach to GLUE

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Inverse problems play a pivotal role in hydrological modelling, particularly for parameter estimation and system understanding, which are essential for managing water resources. The application of statistical inversion methodologies such as Generalized Likelihood Uncertainty Estimation (GLUE) is often obstructed, however, by high model computational cost given that Monte Carlo sampling strategies often return a very small fraction of behavioural model runs. There is a need, however, to balance this aspect with the demand for broadly sampling the parameter space. Especially relevant for spatially distributed or (partial) differential equation based models, this aspect calls for computationally efficient methods of statistical inference that approximate the “true” posterior parameter distribution well. Our study introduces multilevel GLUE (MLGLUE), which effectively mitigates these computational challenges by exploiting a hierarchy of models with different computational grid resolutions (i.e., spatial or temporal discretisation), inspired by multilevel Monte Carlo strategies. Starting with low-resolution models, MLGLUE only passes parameter samples to higher-resolution models for evaluation if associated with a high likelihood, which poses a large potential for substantial computational savings. We demonstrate the applicability of the approach using a groundwater flow model with a hierarchy of different spatial resolutions. With MLGLUE, the computation time of parameter inference could be reduced by more than 60% compared to GLUE, while the resulting posterior distributions are virtually identical. Correspondingly, the uncertainty estimates of MLGLUE and GLUE are also very similar. Considering the simplicity of the implementation as well as its efficiency, MLGLUE promises to be an alternative for statistical inversion of computationally costly hydrological models.