EGU2020-12224
https://doi.org/10.5194/egusphere-egu2020-12224
EGU General Assembly 2020

Data assimilation of subsurface flow via iterative ensemble smoother and physics-informed neural network

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Subsurface flow problems usually involve some degree of uncertainty. For reducing the uncertainty of subsurface flow prediction, data assimilation is usually necessary. Data assimilation is time consuming. In order to improve the efficiency of data assimilation, surrogate model of subsurface flow problem may be utilized. In this work, a physics-informed neural network (PINN) based surrogate model is proposed for subsurface flow with uncertain model parameters. Training data generated by solving stochastic partial differential equations (SPDEs) are utilized to train the neural network. Besides the data mismatch term, the term that incorporates physics laws is added in the loss function. The trained neural network can predict the solutions of the subsurface flow problem with new stochastic parameters, which can serve as a surrogate for approximating the relationship between model output and model input. By incorporating physics laws, PINN can achieve high accuracy. Then an iterative ensemble smoother (ES) is introduced to implement the data assimilation task based on the PINN surrogate. Several subsurface flow cases are designed to test the performance of the proposed paradigm. The results show that the PINN surrogate can significantly improve the efficiency of data assimilation task while maintaining a high accuracy.