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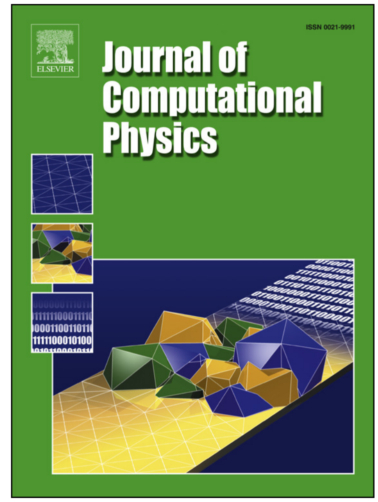

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A two-stage ensemble Kalman filter based on multiscale model reduction for inverse problems in time fractional diffusion-wave equations

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ABSTRACT

Ensemble Kalman filter (EnKF) has been widely used in state estimation and parameter estimation for the dynamic system where observational data is obtained sequentially in time. Very burdened simulations for the forward problem are needed to update a large number of EnKF ensemble samples. This will slow down the analysis efficiency of the EnKF for large-scale and high dimensional models. To reduce uncertainty and accelerate posterior inference, a two-stage ensemble Kalman filter is presented to improve the sequential analysis of EnKF. It is known that the final posterior ensemble may be concentrated in a small portion of the entire support of the initial prior ensemble. It will be much more efficient if we first build a new prior by some partial observations, and construct a surrogate only over the significant region of the new prior. To this end, we construct a very coarse model using generalized multiscale finite element method (GMsFEM) and generate a new prior ensemble in the first stage. GMsFEM provides a set of hierarchical multiscale basis functions supported in coarse blocks. This gives flexibility and adaptivity to choosing degree of freedoms to construct a reduce model. In the second stage, we build an initial surrogate model based on the new prior by using GMsFEM and sparse generalized polynomial chaos (gPC)-based stochastic collocation methods. To improve the initial surrogate model, we dynamically update the surrogate model, which is adapted to the sequential availability of data and the updated analysis. The two-stage EnKF can achieve a better estimation than standard EnKF, and significantly improve the efficiency to update the ensemble analysis (posterior exploration). To enhance the applicability and flexibility in Bayesian inverse problems, we extend the two-stage EnKF to non-Gaussian models and hierarchical models. In the paper, we focus on the time fractional diffusion-wave models in porous media and investigate their Bayesian inverse problems using the proposed two-stage EnKF. A few numerical examples are carried out to demonstrate the performance of the two-stage EnKF method by taking account of parameter and structure inversion in permeability fields and source functions.

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