Geoscientific Model Development Discussions

Geosci. Model Dev. Discuss., referee comment RC1
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Comment on gmd-2021-305

Anonymous Referee #1

Referee comment on "A Bayesian data assimilation framework for lake 3D hydrodynamic models with a physics-preserving particle filtering method using SPUX-MITgcm v1" by Artur Safin et al., Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2021-305-RC1, 2022

General comments: This paper introduces a noval DA approach for lake hydrodynamic model predictions. It is well motivated and very innovative piece of work, but I do find some major issues with the clarity in description of the new method, which make the results a bit hard to understand. The design of the DA approach is quite complicated, combining several non-traditional methods, and the application scenario is also quite different from the typical initial-value prediction problems. I suggest the authors to improve the paper with clearer presentation of each component (particle filter, neural network, and sampler) and discuss how each of them contributes (compares to traditional methods) to improve the accuracy of prediction. This would help convince the readers that such a novel approach has potential for further applications.

Major issues:

1. The authors claim that this paper serves as a proof of concept for particle filtering in other higher-dimensinoal problems (Lines 44-47). This is misleading since the particle filter component only updates (infers) two parameters from the hydrodynamic model, and the larger-dimensional model states are updated through the BiLSTM network. You are effectively running the PF in a reduced-dimension system, using a nonlinear operator to map between the full model states and the reduced states. So this needs to be clarified.

2. Related to #1, how challenging is the lake model prediction problem compared to for example mesoscale weather prediction? The difficulty in weather prediction is the chaotic nature of convections that amplifying initial condition errors rapidly. You mentioned that lake dynamics are also quite volatile (Line 126) and small errors can impact the model trajectory. However, you chose to estimate model parameters, which seems to be related to atmospheric boundary forcings, instead of the initial condition errors in lake states. Does this mean the problem is more in boundary forcing rather than initial conditions? Estimating model parameters are quite different from estimating the states, so this needs to be defined clearly.

3. The introduction of BiLSTM in section 2.4.3 could be improved if you adopt standard terminology in DA. For example, the bulk-to-skin conversion is essentially the observation operator, or forward operator, that maps lake model state variables (state space) to the observed skin temperature (observation space). A discussion of why using a neural network for this nonlinear function, rather than using some physical model, may help the reader understand better.

4. It is still a bit unclear what exactly are being estimated, the two parameters or the whole model states, in the Bayesian framework described in section 2. Figure 2 only shows the updating of the two parameters using the particle filter and sampler, but how does this connect to the observation (skin temperature) and other model states (temperature profiles)? Does the updated parameters change model states through a nonlinear model run? Maybe extending the schematic diagram to include all components and clarify their connection would help.

Minor issues:
Line 25: the fact that EnKF only assimilated a fraction of LSWT data is surprising, could you explain more what is the limitation? Is it because the high spatial heterogeneity that cause nonlinearity?

Line 30: particle method: do you mean particle filter method?

Line 145: add reference for EnKF (Evensen 1994), "highly popular blend", do you mean "brand"?

Line 154: add references for particle filter, and filter degeneracy issue and resampling technique

Line 159: what does EMCEE stands for? could you add a reference for this sampler?

Line 174: 10 particles per filter, ... 89 parallel workers. Figure 2 states n sets of parameters, so n=10 here? Please clarify.

Line 179: how is the uniform distribution and the upper/lower bounds chosen? Based on physical intuition or some prior studies?