

Review of “Further Insights on the Role of Accurate State Estimation in Coupled Model Parameter Estimation by a Simple Climate Model Study” by Yu et al.

This work used a simple conceptual model to provide insights on the role of atmospheric/oceanic state estimation in coupled model parameter estimation. They concluded that the accuracy of the atmospheric state is the crucial factor for such kind of parameter estimation. I regard this work is innovative and the manuscript is well structured. However, my main concern is whether the setup of the assimilation experiments and the conclusion of this work are applicable to the real world. My suggestion for this manuscript is major revision before it can be considered for formal publication. My main concerns are as follows.

Major comments:

1. The setup of the SE has an assimilation interval of 5 time-steps, which is shorter than the current atmosphere analysis update interval and can be regarded as a rapid update cycle. Such setup also greatly controls the signal-to-noise of the atmospheric condition. Although the authors claim that the results are not sensitive to the choice of update interval (Page 5, line 13), the accuracy of the atmospheric state could be seriously degraded with a longer update interval (or with only x_1 observations) and shed the relationship with the parameter.
 - Can the authors provide PE experiments using a longer update interval (e.g. 25 TU) or assimilate x_1 only to illustrate the condition that the atmosphere state is less optimally observed?
2. Do the parameter spread and the amount of inflation need to be well tuned? How important are the choices for tuning the parameter spread and the amount of inflation? I suggest that the authors could link the parameter uncertainties to those appear in realistic coupled model, e.g. a_2 mimics the heat flux for atmosphere and c_2 mimics the windstress for ocean (also see the comment #3).
 - The uncertainties of parameters a_2 and c_2 (Fig. 2 and Fig. 3) are one-order different. Are they chosen on purpose? What are the averaged ensemble spreads for these two parameters? What happened if one chooses to remain a larger and same amount of uncertainty for these two parameters?
 - If we can provide an unbiased a_2 , could assimilation w-only lead to a

successful parameter estimation for c_2 ?

- Page 4, Line 25: PE starts 40 TU later than SE. It should be clarified that the purpose is to constrain the accuracy of states (as stated at line 13, Page 7). Why is it so important?
 - Compared with Fig. 2b and Fig. 3b, the ensemble mean in Fig. 2c and Fig. 3c does not locate near the middle of the ensemble distribution after PE converges. Does this mean that the parameter ensemble distribution is skewed? Is there a particular reason for this result?
3. The ensemble spread of the parameter a_2 seems to be less than 5% (and will be inflated when the spread is smaller than 0.6%). Is this realistic? In realistic setup of climate modeling, the uncertainties in the parameters associated with air-sea interaction (wind stress, heat flux) could be as large as 10%, in addition to bias in these parameters. The setup of the PE experiments may be too ideal to project the conclusion to realistic coupled modeling. In reality, there are several challenging issues in parameter estimation within atmospheric/ocean assimilation frameworks. However, such real and major obstacles cannot be explained by the results of the simple model.
- In realistic parameter estimation using EnKF, how to construct a reliable error covariance between parameter and observation increments could be still challenging. In this simple model, one can easily perturb the parameter with the white noise without considering the characteristics of the horizontal structure. However, in reality, the structure of the ensemble perturbations of the parameter determines the pattern of the corrections away from the observations and how to keep a reasonable perturbation structure for parameters becomes a challenging task, especially for the parameters used in atmosphere model.
 - So far, we may not have enough observation information for parameter estimation or constrain the parameter uncertainty (e.g. surface/near surface atmosphere observations that can reflect the air-sea interaction).
 - I suggest the authors could provide some discussion about improving the accuracy of the atmosphere state for parameter estimation in real ocean modeling. What are the current limitations and what can be done?

Minor suggestions:

1. I suggest including the bias and root mean square error of the states and parameters in Table 1.
2. Line 5: “tuning” procedure?
3. Page 3, it will be easier for the readers if the authors can give a physical meaning for parameters a_2 and c_2 .
4. Page 6, Line 18: Shouldn't the zigzag shape mainly due to the update from assimilation of observations?
5. I suggest that some paragraphs can be clarified or re-arranged.
 - The first paragraph in Section 3 is somewhat confusing. I suggest starting from Table 1 and explain the differences among the experiments.
 - Is the experiment mentioned for Fig. 2a and Fig.3a (both atmosphere SE and ocean SE) included in Table 1?