Point-by-point responses for review #1

In general:

A few conferences were held for authors to discuss the comments of 3 reviewers. All comments of reviewer 1 have been fully addressed in the revision. The first authors learned a lot from such commented points, and here the authors want to express great appreciation for the advice of the reviewer. The paper is revised as the reviewer's suggestions. New tables have been added in the paper. We also exchanged the location of section 2.2 and 2.3. What follows is a point-by-point reply for reviewer 1:

General comment:

The manuscript investigates the impact of observational constraints, through data assimilation methods, on coupled model state and parameter estimation using a conceptual 5-variable model. I found the manuscript interesting and appropriate for the journal, especially to fill the existing gap of idealized studies in coupled data assimilation experiments. It is somehow less relevant, in my opinion, for parameter estimation, given the complexity of real-world CGCM, as the authors themselves discuss in the Conclusions.

I recommend the manuscript for publication after a few issues are considered by the authors, especially to improve the readability for a general readership.

RE: Thanks for your encouragement. All issues are replied point-by-point as below. We hope the whole manuscript has been essentially improved.

1. I think the title itself "Further insight" refer to a previous paper from the author ("further" with respect to what?) and might be simplified to "Insights on" or "On the role..."

RE: The title is changed to "Insights on the Role of Accurate State Estimation in Coupled Model Parameter Estimation by a Conceptual Climate Model Study".

2. There is some literature missing that can be added: for instance

i) the parameter estimation problem (Introduction, lines 1-10) may be approached also with adjoint techniques, and I recommend the authors to mention this alternative methodology;

RE: Three different choices for the parameter estimation including the adjoint techniques and related references are added in P2L10~11.

ii) in the description of twin experiments with perturbations (P4L1-6), there are many analogies with OSSEs (Observing system simulation experiments) that can be mentioned as well.

RE: Thanks for this suggestion. Our twin experiment is a kind of OSSEs. This and references of other PE under OSSEs are added in P5L11~12.

3. The authors often refer to simple climate/coupled model. I suggest them to always use the definition of "conceptual model" as it can hardly be considered a climate model

RE: Yes, done. Thanks.

4. {The reader is too much referred to literature in the Methodology section. For instance, I had to understand only through referred papers

i) the size of the conceptual model of Eq. (1) is never discussed (is it a single-column model or a limited-size model? What are the boundary conditions of the problems, if any?)}

RE: Our model is a low-order (limited-size) conceptual model. The boundary condition is a predefined seasonally-varying solar radiation S(t)=Sm+Ss COS(2*pai*t/Spd), which is a simple and idealized approximation of the real world boundary condition. New lines of this introduction are added in P3L22~25.

{ii} little is said about the EAKF, which might be better introduced from a theoretical point of view and in terms of advantages/disadvantages w.r.t. other filters and data assimilation methods. I guess the authors choose it for its ease in the parameter estimation, but this can be better clarified}

RE: Thanks for the suggestions. More details about the EAKF method including its advantages/disadvantages was added as an independent paragraph on the beginning of section 2.2, P4L1~10.

{iii) for such a small size problem, a 20-member ensemble size appears quite small without reason. Clearly the problem size is small, but it is worth mentioning sensitivity tests performed on the ensemble size.}

RE: Thanks for the suggestion. We performed sensitivity tests on the member size. The result is shown in the following figure. Generally speaking, the RMS error of the mean parameter will increase when lowering the ensemble size. But it can also be clearly seen from the panel (d) that no matter how big the ensemble size is, the result with an oceanic SE is unacceptable. We think size 20 is enough for showing the difference between the successful and the failure cases. We added new lines to clarify this problem in P4L24~28 and P7L18~20.

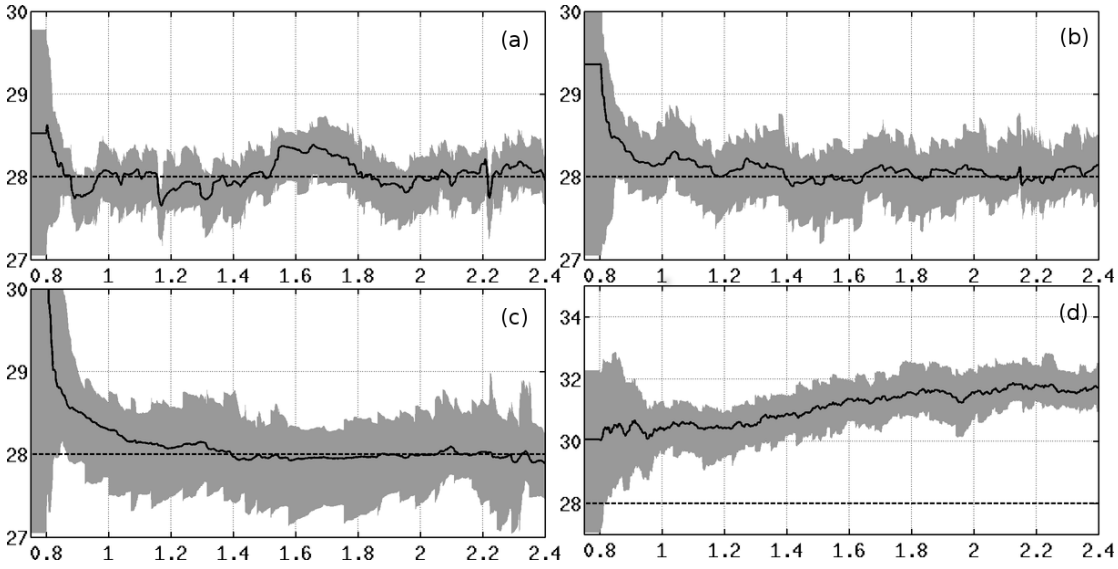

Figure caption: Time series of the parameter in 4 test cases with different

ensemble size settings. SE x_2, PE x_2 to a_2 (abc), SE w, PE w to a_2 (d). The ensemble size is 5 (a), 10 (b), 40 (c) and 40 (d) respectively.

5. {I found the conclusion in P7L3.9 on preferring atmospheric to ocean observations to determine ocean parameters very dependent on the conceptual model the authors use. First, some parameters (c2) are not ocean parameters but coupling parameters, strictly speaking;}

RE: Thanks for this comment. The c_2 is more like a coupling parameter than pure ocean parameter. Therefore we performed experiments about c_6 as an complementary (Fig. 5). The necessity of an atmospheric SE still holds.

{second, the "first guess" of the ocean parameters themselves, determining time scales and interactions, may not necessarily represent the real world; }

RE: The conceptual model cannot fully represent the real world. But it has great advantage for clarifying the PE problem without sufficient observations. The parameters are set to simulate the parameterization of CGCM. We added more description and discussion about the simple model parameters in P3L25~28.

{third, the observing network that observe ocean and atmosphere state may be not representative of the real observing networks. I would mention the limits of the conceptual model rather than emphasize this conclusion.}

RE: Thanks for the reviewer's suggestion. The real world observation generally has strong temporal and geographical dependency. The real data are always with all kinds of incomplete. All these flaws motivate us carrying out this partial SE research at the first place. Some of them cannot be represented in our model because this conceptual model does have its limits though its dynamics and transferring of the uncertainty is crystal clear. Following the suggestion, we added new lines to discuss these limits in section 4, P11L19~27.

6. Since Section 3 contains a lot of information and experiments, I suggest to add a paragraph between the 1st and 2nd paragraph of Section 4 to summarize some results from the experiments on individual/combined state and parameter estimation.

RE: A new paragraph summarizing all experiments and the direct results was added as the reviewer's suggestion in section 4, P11L4~11.

Language issues

{weak coupled → weakly coupled (P4L10 and further occurrences) }

RE: Done. Thanks.

P4L21 "And also considering...visualization" sounds very awkward

RE: The sentence was rewritten to "Therefore we set the ensemble initial values of a_2 as a Gaussian distribution N(30, 1) (30 as the mean value and 1 as the standard deviation), and the spread is enough for the model ensemble uncertainty. The ensemble initial values of c_2 are set as N(0.8, 0.5)." as in P5L30~32. Thanks.