

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

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.

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...”

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;

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.

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

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?)

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

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.

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; second, the “first guess” of the ocean parameters themselves, determining time scales and interactions, may not necessarily represent the real world; 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.

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

Language issues

weak coupled → weakly coupled (P4L10 and further occurrences)

P4L21 “And also considering...visualization” sounds very awkward