The authors present innovative low-cost strategies for online model parameter estimation, which can potentially be applied for climate field reconstruction with coupled GCMs. The manuscript is written in a transparent way and authors explain very well all the assumptions used in their study. The paper moves the time-averaged data assimilation efforts a small but very important step forward. I recommend publishing the paper after minor revision.

General Comments:

1) Scientific significant:

The manuscript represent a substantial contribution to modeling science within the scope of this journal. The ideas and methods are original.

2) Scientific quality:

The scientific approach and applied methods are valid and the assumptions are well introduced. However, the results are not discussed in a balanced way and could be improved (see below). The models, technical advances and/or experiments described have the potential to perform calculations leading to significant scientific results.

3) Scientific reproducibility

The modeling science seems not to be reproducible. I think if the authors share their code, this problem will be solved. However, their methodology is well described and traceable.

4) Presentation quality

The presentation quality is fair and could be improved in a new version. Number of figures presenting the results can be revised.

5) Overall, the manunscript is understandable for experts working in the field but not easy to follow for general readers. There are too many acronyms in the manuscript. Please spell out when possible.

6) Given that this paper belongs to the category of “Development and technical papers” (see:https://www.geoscientific-model-evelopment.net/about/manuscript_types.html#item2), I encourage the authors to make their code available online (at least for the 1D experiment). This might help the community very much and improve the code itself. According to the journal policies, the authors have to include the model’s version in the title (e.g., Model XXX (version Y)).

7) Page1Line3 (P1L3): Explain how model’s parameters have relationship with proxies!

8) P1L6-7 is too complicated!

9) P1L6 : Authors mix two approaches: model's parameter estimation (atmosphere and ocean) and fresh water melting parameters estimation. Have they done separate experiments? They describe, the latter might be essential for North Atlantic circulations. However, there might be nonlinear relationships between these two and they could contaminate each other. Which one impacts the error reduction larger?

10) P2L12: Could you provide references for that?

11) P2L32-33: How should one do this? Reference?

12) P2L5: Explain the "generally positive results"!

13) P3L20: Aren't the parameters not being updated at each DAW? Aren't they time varying when the new observation is available? How could one do that in future projections without observations? What are the challenges? How could tuning the model for the past improve projections? Please clarify!

14) P6L10: Explain briefly the gradient descent algorithm, learning rate, number of iterations, etc...

15) P8L6-7: However, aren't the parameters updated based on time-averaged obs?

16) P11L18-19: How do you define the learning rate in gradient descent?

17) P15L19: Why analyzing only 10 years? 90 years for spin up of 1d model?

18) P18L27: "not shown", but is interesting to put in supplementary.

19) P19L2 : is it a typical set-up of CESM?

20) P20L9: Could you explain and discuss the problems of multi-component DA in your set-up? Differences in time-scales of proxies, etc.

21) P20L13: Have you done other experiments with other sets of parameters? For example more or fewer numbers of parameters?

22) P24L10: In figure 3 it is really hard to see the differences. Maybe centering the colorbar with zero might help. How do you explain that the error reduction is due to DA and not the lack of sensitivity of the model to perturbation of the parameters. For example Figure 4 upper left panel shows that the model is not sensitive to changes of cldfrc_rhminl in Arctic and Antarctic regions.

23) You focus on the ocean where the observations where assimilated, how about the atmospheric variables? Is there any error reduction happening there? Could you show for example global T2m quantities?

24) Figures similar to Fig.4 for other perturbed parameters could be shown in the supplementary. This will clarify the sensitivity of CESM.

Specific Comments:

1) P3L6: “in section?”

2) P3L7: “problem of CFR” which problem?

3) P22L12: How about the uneven time resolution of observations?

4) figure 2, 3, 4: for the results one has to switch between figure 2, 2 and 4 to follow the line of discussions. You could at least put the observation locations on figure 3 and 4. Note that the land-sea mask is also shifted between the figure 2 and 3-4.