** **reviewer's comments in black and italics Author's comments in red**

Reviewer 1:

This study presents parameter estimation experiments utilizing the CESM model to assimilate Sea Surface Temperature (SST) and Temperature/Salinity (T/S) profiles for initializing ENSO prediction. The results demonstrate the potential of parameter estimation over state estimation, revealing enhanced ENSO prediction skills achieved through more accurate parameter estimates. This work is interesting and worthy of publication. However, some minor revisions are necessary before acceptance.

Reply:

We sincerely thank the reviewer for the suggestions and comments that help us improve the quality of our manuscripts.

Major Comments:

Starting from line 141, the authors conducted sensitivity experiments by perturbing multiple parameters to assess the model's temperature and salinity variables' sensitivity to those parameters. It is noted that parameters were perturbed simultaneously. Have the authors considered perturbing these parameters individually? Could the sensitivity of variables to different parameters differ?

Reply:

That's a good question. In fact, we have done previous experiments where we perturbed a single parameter and calculated the average ensemble spread of the results of the sensitivity experiments with the following results:

In these experiments, we still used the same initial field, and perturbed parameters to integrate the model. In these experiments, we perturbed only one parameter at a time, while keeping the other parameters constant. Thus, calculating the ensemble spread of the integration results allows us to assess the sensitivity of the model variables to this perturbed parameter.

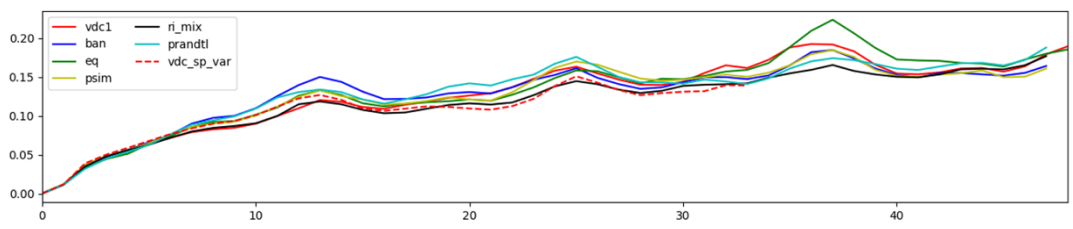

Figure 1. Evolution of ensemble dispersion obtained after slightly perturbing different parameters and integrating the model for a period of time.

Figure 1 shows the global average of the ensemble spread of the SST with integration time, and the different coloured lines represent the integration results of perturbing different parameters. It is not difficult to find that the dispersion of the integration results of perturbing the four parameters is not much different, which indicates that the sensitivity of the temperature variables to the four BVDCs is not much different. The situation is similar for salinity. So we chose the scheme of simultaneous perturbation in the sensitivity experiment.

We put this conclusion in the discussion section of the sensitivity experiment results.

Thanks for the suggestion and comments.

From line 188, the authors mention that during the first phase of Parameter Estimation (PE), parameters were perturbed but only State Estimation (SE) was used, lasting for a year. The state variables employed for PE and the motivation for this approach need clarification.

Reply:

The motivation of this strategy is indicated by section 2.4 (experimental design and verification data). Zhang et al. (2012) showed that the signal-to-noise ratio of the state-parameter error covariance in a coupled model can be significantly improved after the state estimation reaches quasi-equilibrium. Thus, using the observation-constrained states that have reached equilibrium can effectively improve the accuracy of CPE (Zhang 2011a, b). In the PE experiment, we utilized perturbed parameters to perform state estimation in the beginning. After about 1 year, the model's errors in the state variables, especially temperature and salinity, were significantly reduced, and we assumed that the state estimation process had roughly reached equilibrium, and then enabled the parameter changes.

We have indicated this in the lines in section 3.2 as you pointed out.

Thanks.

In Figure 8, the authors present Root Mean Square Error (RMSE) without specifying the reanalysis data it pertains to. Despite earlier indications of similar results from different reanalysis datasets, it is advisable to explicitly mention the data used.

Reply:
We have calculated the RMSE for the analysed field and EN4 data in figure 8 and figure 9, which we have pointed out in the revised manuscript.

Thanks.

Additionally, line 219 asserts that the maximum error occurs at the depth most sensitive to parameters, which is not immediately apparent. It is recommended to include a subfigure depicting parameter sensitivity along the equatorial range, using a logarithmic depth coordinate. Similar concerns are noted in Figure 9.

Reply:
It is a very good suggestion, and we have modified figure 8 accordingly. Inside the new figure, we find a high degree of matching between the error of the SE results and the ensemble spred of the sensitivity experiment results, which highlights our conclusions even more.

As for Figure 9, we have revised the whole figure based on another reviewer's comments. Since the improvement in Atlantic is not due to parameter sensitivity but based on other mechanisms, we do not include the sensitivity results in this figure.
Thank you for your suggestion.

Minor Suggestions:

In lines 56-58, apart from the atmosphere, ocean, land, and sea ice, CESM encompasses other modules as well. The authors should use "as well as other modules" to accurately depict the model.

Reply:
Changes have been made as you suggested, thanks.

Is Equation (1) valid outside the Banda Sea region, using a value of 1.0 within the Banda Sea? Clarify this description for improved understanding.

Reply:
Yes, the default background vertical diffusivity parameter is 1.0 in the Banda sea. We have re-written this part and clarified the description, thanks.

Regarding line 108, the authors mentioned "daily profiles were merged and assigned to the final day of each sequence". Is there any other references employed the same approach to process the data?
Reply:

In our previous study, e.g., Chen et al. (2022,2023), In our previous study, we used the above methodology to process the profile data. The main reason for this is that the EN4 profile data are unevenly distributed in both space and time, and if they are not processed using the appropriate method, overfitting may have occurred due to the

assimilation of too much data. Previous studies have shown that this processing method can produce effective state estimation results.

We have cited these papers in the manuscript. Thanks.

- Chen, Y., Shen, Z., & Tang, Y. (2022). On Oceanic Initial State Errors in the Ensemble Data Assimilation for a Coupled General Circulation Model. Journal of Advances in Modeling Earth Systems, 14(12). https://doi.org/10.1029/2022MS003106
- Chen, Y., Shen, Z., Tang, Y., & Song, X. (2023). Ocean data assimilation for the initialization of seasonal prediction with the Community Earth System Model. Ocean Modelling, 183(102194).

Line 109 mentions interpolation to 31 layers. Could the specific depths of these layers be provided?

Reply:

Specific vertical depths were obtained from the EN4 analysis data. We've added that to the draft, thank you.

Finally, we would like to thank the reviewers again for their valuable suggestions, which helped us to refine the details of our experiments and to better present the relevant results. Thanks.