Review of "Parameter estimation for ocean background vertical diffusivity coefficients in the Community Earth System Model (v1.2.1) and its impact on ENSO forecast"

This study investigates parameter estimation (PE) in improving climate forecasts of a coupled general circulation model by adjusting the background vertical diffusivity coefficients in its ocean component. Comparing the model states between the PE experiment and a state estimation (SE) experiment reveals that PE can significantly reduce the uncertainty of these parameters and improve the quality of analysis. The forecasts obtained from PE and SE experiments further validate that PE has the potential to improve the forecast skill of ENSO. The work is interesting and may has potential application in practice. However, there are some issues unclear in the manuscript. I would suggest that it should be published in **GMD**, subject to **major revisions**.

1. Major concerns:

(1) The manuscript focuses on improving the background vertical diffusivity and its impact on ENSO forecast. However, the background vertical diffusivity is only important in the deep ocean and the coefficients of the KPP dominate the mixing process of the upper ocean. Therefore, results show that the main differences between PE and SE are in the deep ocean, and the improvement on the upper ocean is not significant as the authors mentioned. From the text, the author pays more attention to the process of ENSO which is mainly associated with the upper ocean process. So why do the authors not adjust and optimize the parameters of KPP?

(2) The key issue of adjusting model parameters with real data is how to ensure the physical meaning of the parameters. The manuscript does not explain how to avoid the parameters from exceeding their physical values, specially for the spatial varying parameters.

(3) It is unclear how the adaptive spatial averaging is calculated. How big is the specific average bin? Does it cause spatially discontinuous?

(4) Table 1 involves 4 parameters and the use of parameters is regional. Do you only adjust the corresponding parameters in specific regions such as the equator and the Banda Sea?

(5) How are the 20 sensitivity experiments and other experiments set up and operated? A figure regarding this should be added. Based on Table 2, the parameter adjustment is quite small, and the parameters tend to reach a certain equilibrium state. However, the observations (number and locations) used each year are different. Why do the adjustment of parameters not change year by year?

(6) Line 215: “The highest error is observed in the sea surface layer, ...” I can't see the relevant results in Fig.7. The main differences are still at the depths of 600m-1200m in the Atlantic and tropical regions.

(7) Based on the sensitivity experiments, the main impact is in the upper 100m. However, from the assimilation results, the main differences are still at the depths over 600m in the tropical and Atlantic regions. Why is this?

(8) Line 221: “It is noted there is substantial improvement in areas where the errors are significant, except for the deep Atlantic Ocean”. Estimated from the magnitude of SE-PE, the proportion of error reduction is less than 5%. It can't be said “substantial improvement”.

(9) Fig.9 only mentions the differences in the Atlantic Ocean. How about the tropical ocean?

(10) The forecast of ENSO does improve to a certain extent, but the improvement is not significant (The change of RMSE is less than 0.1°). Shown From Fig.11, it seems that most differences locate in the equatorial region. It may connect to the reduction of diffusivity in the region (smaller mixing and higher SST?). The authors should give more explanations regarding this issue.

2. Minor Concerns:

(1) The assimilation just involves the ocean component. It seems not a couple assimilation system.

(2) In Fig.7, is it the ORAS5 or ORAS4？

(3)Line 116: “These factors were determined empirically and verified in prior studies.” References should be added here.

(4) Units should be added in Figs.6, 7 and 10.