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**Manuscript Title:** Climate impacts of stochastic atmospheric perturbations on the ocean

In the following, the text with italicization indicates the reviewer’s comments, and the normal text is our response.

**Reply to Reviewer 3:**

***Comments to the Author***

*Review of "Climate impact of atmospheric perturbations at the air-sea interface and the roles of climate system feedbacks" by Zhang, Xue et al.*

*The paper introduces an Interactive Ensemble (IE) Platform adapted to a climate model, CSM, and describes the impacts of ocean-atmosphere feedbacks causing cooler mean state in IE than CES. The reviewer appreciates the effort of the authors to explain the feedback mechanism, but feels that the analysis is not completed and the draft needs a significant improvement. Here are comments that may help for further consideration.*

*General:*

*1. The paper should address more on the benefit of using IE system and prove improved prediction skill. Introduction is mainly made with this point, but the authors do not show anything about it in the analysis and only leaves it for future works. It should be also noted that a cooling induced by IE has been already addressed by the papers by Kirtmann et al. as cited and is not new to be an another paper. The authors also may compare their results with* *Kirtman and Shukla (2002), which may help to justify the performance of CSM and strategy of IE with the model as pointed below. If the authors still want to focus only on the mechanism causing cooling, introduction should be completely re-written by addressing these.*

**Response:** We try to explain the possible mechanism causing the cooling but also want to share some improvements in the IE system. We examined the ENSO variability and compared it with *Kirtman and Shukla (2002)* in the revised manuscript*.* The IE platform shows better skill in reproducing the annual cycle of SST in the tropical Pacific. As suggested, we modified the Introduction in the revised manuscript to more clearly state the objective of the paper, which is to illustrate the role of the stochastic forcing on the mean climate. Our results complement Kirtman et al. (2011) and Kirtman and Shukla (2002). But different from the strategy in Kirtman and Shukla (2002), each atmospheric member in our IE platform is firstly coupled to a land surface model and then coupled to a single ocean model and a single sea-ice model with the ensemble fluxes. That is, the IE strategy here is active at the air-sea and air-ice interfaces but not at the air-land interface. In Kirtman et al. (2011), the surface temperature changes are largest over land and ice. And surface temperature over ice are typically warmer than that in the standard coupled model (CCSM3.0). However, our IE platform results present a colder climate in comparison with the SC model with pronounced cooling changes at high latitudes.

*2. Model performance: It is hard to find a performance of the CSM in representing the ocean and atmosphere in the draft and published papers. Authors may allocate one or two sections to* *present the CSM's ability by comparing with observations or other IPCC type models, which may include the top of the atmosphere radiation balance, atmosphere ocean temperature evolution from spin-up phase to stabilisation, SST bias, Atlantic Meridional Overturning circulations.*

**Response:** We renamed the CSM to the Standard Coupled climate model (SC) and evaluated its performance as you suggested in section 2.1. After the initial adjustment, the SST, sea-ice concentration and the Atlantic Meridional Overturning Circulation reach a quasi-equilibrium state with minimal drift. Despite the common problems in coupled climate models such as the so called “double ITCZ”, the SC captures fairly well the SST and precipitation at large scales. Globally and annually averaged, the net shortwave radiation is nearly compensated by the outgoing longwave radiation at TOA.

*3. IE model design: If the reviewer's understanding is correct, the atmosphere is coupled to sea ice and ocean model separately, which may cause strong shock or mismatch in ocean-sea ice coupling. Ocean-sea ice coupling is also very important especially in freshwater and heat exchanges, and thus stability in the high latitude. This is especially worrying when the difference between IE and CSM is larger in high-latitude in particular in the Southern Hemisphere (e.g. Fig. 2c).*

**Response:** The coupling in the IE model with sea ice is the same as with the ocean. There is therefore no strong mismatch between the ocean and sea ice. The schematic diagram of the IE model in the original paper (Figure 1 in the previous draft) was not right and it has been eliminated.

***Specific:***

*1. CSM: Naming a climate model can be a subject choice of developers, but* *CSM may cause confusion with the other model that exists already, e.g. CCSM. It is suggested to use better specific name.*

**Response:** Done. We renamed the CSM to the Standard Coupled climate model (SC) in the revised manuscript.

*2. P4 L25-51: References in the model description cannot be found in the list of reference (Craig et al. 2005) and not available for review (Li et al. 2013). Please also introduce CSM reference paper if available.*

**Response:** Reference paper for the Standard Coupled climate model (SC) is not available now. We evaluatedthe SC's performances in section 2.1. The references Craig et al. 2005 and Li et al. 2013 are updated.

*3. P5 L42: Please describe how the initial conditions are selected, e.g. every 10 years or so. Also need to show that 7 members are enough to make the initial conditions are independent. This is important as the internal decadal or cetennial variability, particularly in the Southern Ocean as mentioned in the draft by citing Li and Conil (2003), matter for the choice of sufficient number of ensembles and their intervals. I am concerned that the impact of ocean states may overwhelm the effect of reducing noise.*

**Response:** The initial conditions are selected from the SC equilibrium run every 5 years apart from year 420 to 450. We have clarified this on Page 7 Line 13-17.

The effects of traditional initial-condition ensemble and the interactive-ensemble are quite different. Therefore, in the revised manuscript, we focus on the differences between the IE model output and one single SC model output. Considering the high computational cost, the interactive-ensemble in this study is performed with 7 atmospheric components as a compromise. Yeh and Kirman (2004) demonstrated that, the amplitude of internal atmospheric variability at air-sea interface decreases proportionally to the increasing of number of AGCM realizations. We have clarified this in Page 7 Line 9-13.

*4. P5 L54: Need to indicate coupling time step.*

**Response:** The single ocean model and the sea ice model are coupled with the ensemble mean flux of the multiple atmospheric members at every coupling step, one day for the ocean model and 60 minutes for the sea ice model. We have clarified this on Page 7 Line 17-19.

*5. Fig. 2: Need to show SST bias compared with observation (refer to also general comments)*

**Response:** Done as suggested. The SST and precipitation biases are shown in Figure 2e and 2f, respectively. The SC model evaluation is presented in section 2.1.

*6. Figs. 2, 3, 4, 5, 6, 7, 8: Need to show significance by using hatch or shading only significant area for IE-CSM difference. Also depending on the argument, showing the evolutions of time series for certain physical quantities (e.g. NH and SH sea ice extent, Maximum Atlantic Meridional Overturning Circulation strength at 30^oN) will be necessary to prove the mean states are significantly different.*

**Response:** Done as suggested. We assessed the statistical significance of the changes and redrew figs. 4, 5, 7-10.

The evolutions of time series for surface air temperature (Figure 4a), net downward surface radiation (Figure 6a), surface latent heat flux (Figure 6b), surface sensible heat flux (Figure 6c), and the AMOC (Figure 10a) are examined in the revised manuscript in Section 4.

*7. P7 L40: Authors may address the tropical changes by comparing with Kirtman and Shulka (2002) and may describe Walker Circulation changes if possible.*

**Response:** We examined the ENSO variability in section 4.3. The NINO3.4 auto-correlation is examined. Same as that in Kirman and Shukla (2002), the tendency of phase transition is strong in both the IE platform and the SC model (Figure not shown). In our SC model, the irregular ENSO variability with wide ranges of period can be reasonably reproduced. The ENSO interannual variability is more concentrated at biennial period with the weakest spectrum power in the IE platform.

The Walker Circulation changes can be represented by the changes in 200-hPa velocity potential (Figure S1). In accompany with the significant cooling, there is a strong subsidence in the tropical eastern Pacific and the North Indian Ocean. Vertical convection is enhanced in the tropical central and western Pacific, creating a local excessive rainfall. We described the changes of convection on Page 8 Line 24-Page9 Line 3.

SLP_VP

**Figure S1** 200-hPa velocity potential (106 m2s-1) anomalies in IE, in relative to the SC results.

*8. P7 L55: It is difficult to see clearly the similarity (in particular in the Northern Hemisphere) between Fig 2b, 4a, and 4b to argue that they are related. Pattern correlation (globally or NH and SH separately) among these quantities will be of useful to support.*

**Response:** The spatial correlation coefficient between the surface stress and surface temperature anomalies in the ocean grids is 0.25. The spatial correlation coefficient between the surface stress and MLD anomalies in the ocean grids is 0.24. The correlation coefficient is significant at the 5% level using student’s ***t*** test. We described this in Page 10 Line 2-5 and Page 10 Line 13-15.

*9. P10 L20: Xin et al (2013) is not available for review.*

**Response:** The reference to Xin et al. (2013) was deleted.

*10. P 12 L43: Need to show time series of the MOC strength, e.g. 30^oN*

**Response:** Done as suggested. The time series is shown in Figure 10a.

*11. Fig. 8: Need to show mean AMOC streamfunction for CSM.*

**Response:** Done as suggested. The mean global MOC and Atlantic MOC for the standard coupled climate model (SC) are examined in Figure 10b and 10c. Details can be found on Page 14 Line 18-Page 15 Line4.