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**Manuscript Title:** Climate impacts of stochastic atmospheric perturbations i 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 2:**

***Comments to the Author***

*This paper discusses some of the effects of the weather variability on the mean state of the ocean and the atmosphere, based on an Interactive Ensemble (IE) strategy with the CSM model. Reducing the influence of weather noise leads to a surface cooling, which is largest in most polar regions and is attributed to weakened evaporation, enhanced by the positive ice-albedo feedbacks and a weakening of the meridional overturning circulation (MOC). The changes in rainfall are also discussed.*

*Although some of the results are of interest, the analysis is mostly superficial and descriptive. Some of the effects of the weather forcing are obvious, and in most cases little new insight is provided, except in the discussion of the impact of the MOC changes. Hence, more work and major revisions are needed before the paper can be considered for publication in IJC.*

**Response:**Thank you for your insightful comments. In the updated manuscript, we focused on the influence of stochastic noise generated by atmospheric dynamics on the ocean. The sea surface heat budget, the oceanic meridional overturning circulation (MOC) and the ENSO variability were examined. The possible roles of the stochastic perturbations in the atmosphere were discussed. Here is the item-by-item reply to your comments.

***Major comments***

1. *The style is poor, wordy at time, and the English often approximate. Please try to improve them.*

**Response:** Done as suggested. The text has been extensively reworded

1. *The discussion is often limited to showing figures and describing the differences between standard and IE simulations. It should also give physical insights, and always explain or speculate on the reasons for the differences. For example, no explanation is provided when remarking that* *the spread due to initial conditions occur where the differences are largest. Is it that hard to figure it out?*

**Response:** We have revised the paper to include more discussions of the physical mechanisms. To gain some insight into the surface cooling in the upper ocean, the sea surface heat flux budget and the roles of ocean current are examined in the revised manuscript. The results show that the deterministic part of the surface cooling is the decreased net radiation income at surface. The oceanic upwelling and downwelling associated with the surface wind curl are responsible for the surface cooling and warming at regional scales. We have clarified this in Section 4.1.

The spread of surface temperature of the SC ensemble runs with different initial conditions occurs where the differences between the SC simulation and the IE simulation are largest. This is because atmosphere strongly forces the ocean at high latitudes. Therefore, the place where the atmospheric stochastic noise is more active is also the region with stronger surface temperature variability. We have clarified this in Page 8, Line 12-13

1. *The main surface stress differences in Fig. 4 should be discussed and explained. Why does the stress increase in some regions and decrease in others?*

**Response:** We have revised to point out that the wind stress at the peripheries of the storm tracks, especially on the poleward side, is reduced in the IE (Fig.5 in the revised manuscript). These regions are where the atmospheric stochastic variability is large. The cancellations among the ensemble members are responsible for the surface stress weakening. The maintenance of significant surface stress weakening may be also partly explained by the positive feedback of surface stress to surface temperature changes. Convective instability over warmer water will lead to a deeper boundary layer in the atmosphere and result in intensified surface stress over the warmer water, and vise versa (Samelson et al., 2006). We have clarified this in Page 9 Line 20 to Page 10 Line 9.

1. *Evaporation depends on wind speed, not on wind stress. Again, there is no discussion, just a (repetitive) description of some of the differences. Also, please briefly summarize here the possible links to the NAO and the PNA.*

**Response:** In the revised manuscript, we suggested that the deterministic part of the surface cooling is the decreased net radiation at surface. The oceanic upwelling/downwelling associated with the surface wind curl are responsible for surface temperature changes at regional scales. The surface latent heat flux and surface sensible heat flux are climate response to the surface temperature changes. The examination of evaporation was deleted in the revised manuscript.

As shown in Figure S1, there are not significant NAO-like or the PNA-like changes in the IE simulation. But a positive AAO – like changes are evident and suggested to be related to the increased precipitation in eastern China (Figure S2). We have clarified this in Page 9 Line 3 to Line 12.

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**Figure S1** (a) Spatial structure of the sea level pressure anomalies in IE averaged from year 541 to year 570, units: hPa. (b) is the same as (a), but for the geopotential height at 500hPa, units: m. The shading area represents the differences significant at the 5% level using student’s ***t*** test.

SLP_VP

**Figure S2** Sea level pressure (hPa) anomalies in IE, in relative to the SC results.

1. *Section 4.1: the cooling does not only depend on the surface turbulent fluxes, but also on the radiation fluxes. The latter are mentioned in section 4.2, but shouldn’t they be included when discussing the global balance? What about cloudiness? Any significant changes?*

**Response:** We reorganized the manuscript as suggested. We examined the sea surface heat flux budget in section 4.1, including the net radiation at sea surface, surface latent and sensible heat fluxes.

We examined the cloud radiative forcing in Figure 7d. The cloud radiative forcing partly offsets the warming effect of net incoming radiation increase in the Arctic and coastal region along 70°S and tends to amplify the role of net surface radiation at mid and low latitudes (Figure 7a). The cloud cover changes in the IE platform are mainly due to the anomalous low-level cloud amount, decreasing/increasing over cold/warm sea surface. We have clarified this in the second paragraph on Page 12.

1. *The discussion of the sea ice differences does not distinguish between causes and effects, and it should not ignore the possible direct effects of the weather forcing.*

**Response:** You are right and thank you for this suggestion. The direct cause of the difference is stochastic forcing. Sea ice further amplifies the cooling through a positive feedback. This is now included in the revised text (Page9 Line 19 to Page10 Line9, Page12 Line1 to Page12 Line 12).

1. To better (and more concisely) explain the MOC changes, it would be useful to show the changes in the oceanic mixed layer depth at the end of winter, when deep water is formed. Also, the changes in the wind stress curl should be shown.

**Response:** We examined the changes in the oceanic mixed layer depth at the end of winter in Figure S3. The MLD weakening is strongest during the boreal winter. Although the annual mean results are weaker than that during the wintertime, they can well describe the main MLD changes in both the Northern and Southern Hemispheres. So we only showed the annual mean results in the revised manuscript (Figure 5c). We have clarified this on Page 14 Line 12-15.

The changes in the wind stress curl are shown in Figure 9b. The regional ocean current adjustments to surface wind stress curl may be responsible for the changes at regional scale. The changes in the wind stress curl and the associated sea surface temperature anomalies are now discussed on Page 13 Line 1 to Page 14 Line 3.

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**Figure S3** Mixed-Layer Depth (MLD) differences between IE and SC outputs. Values significant at the 5% level using student’s ***t*** test are shown. Units: m.

***Miscellaneous***

1. *There are a large number of unnecessary statements that distract the reader, such as line 3 to 5 in the Introduction, or most of the upper half of p. 24.*

**Response:** We deleted the unnecessary statements in the Introduction and have tried to polish the entire manuscript.

1. *Reference to Collins and Allen: somewhat outdated. Newer results suggest enhanced predictability.*

**Response:** We have rewritten the Introduction The reference to Collins and Allen was deleted.

1. *p. 3: I thought that the main interest of ensemble simulations is to reduce the signal to noise ratio, not the sampling uncertainty.*

**Response:** The original statement has been deleted.

*4. Fig. 1 does not bring much and could be omitted.*

**Response:** Done as suggested.

1. *p. 6: CSM or CCSM?*

**Response:** The specific name for the standard coupled climate model in the previous manuscript is CSM, which may cause confusion with the other model that exists already, e.g. CCSM. Therefore, the specific name for the standard coupled climate model is revised to SC in the revised manuscript.

*6. p. 6, middle: the spread is small for 50-yr averages.*

**Response:** The 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.

*7. Please do not call “drought conditions” a decrease in precipitation, unless precipitation has become very small.*

**Response:** The statement was revised as suggested.