

Replies to Reviewer #2:

Thank you very much for these constructive comments. We have revised the manuscript carefully based on these suggestions. The followings are our point-to-point replies.

"While most of my concerns have been addressed, I am still worried about a couple of things. I expect that these worries can be solved easily with a bit of rewriting. However I would prefer to see the paper again before it is published."

"The changes have also brought up a couple of minor technical issues for me."

Major points:

1. *From the figures that are currently in the paper, you cannot attribute changes in vertical salinity diffusion to wind (as you do on line 321). You need to back up this statement somehow, showing that it is \kappa that changes in stage-I and not the vertical salinity gradient. If you cannot get the vertical diffusivity \kappa, then perhaps you can just plot d2S/dz2 on its own? You could plot this in figure 8b, because the current figure 8b does not add anything to the paper.*

Response: Thank you very much for your suggestion. Here we plotted the temperal change of vertical diffusivity κ in Fig. R1. κ is calculated using KPP scheme in CESM. The KPP scheme is detailed in Large et al (1994). The diffusivity κ is formulated to agree with similarity theory of turbulence in the surface layer and is subject to the condition in both the surface atmospheric forcing (wind forcing, heat and freshwater flux) and upper ocean vertical structure (Large et al., 1994). The KPP scheme exchanges properties between the mixed layer and thermocline in a manner consistent with observations.

The CESM outputs include the κ (i.e., it is calculated online in CESM). Fig. R1 shows the κ change in NoTibet, with respect to Real. It is increased in the first 100 years and then decreased 100 years later, suggesting an enhanced and then an weakened vertical mixing and diffusion in the North Atlantic, consistent with the change of vertical salinity diffusion ($\kappa\partial^2S/\partial z^2$) shown in Fig. 8b. We think the κ plays a dominant role in the change of vertical salinity diffusion. We also think the enhanced κ can be mainly attributed to the increased wind in first 100 years, and the weakened κ can be mostly attributed to the increased freshwater flux due to the southward sea-ice expension and melting.

Fig. R1 is also included in Fig. 8 as Fig. 8c. The discussion on the mechanism of SSS change in section 4.2 is carefully revised.

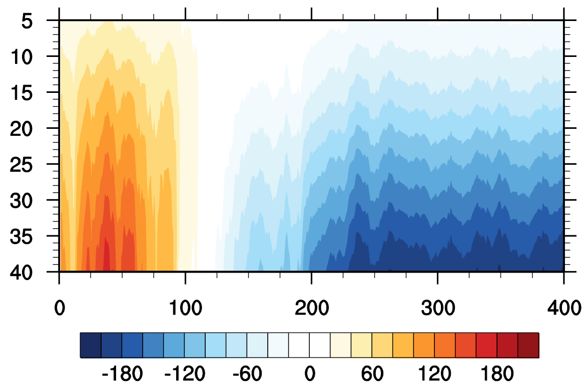

Fig. R1 Temporal changes in vertical diffusivity coefficient Kappa (κ, cm^2/s) in NoTibet, with respect to the Real

Large, W. G., J. C. Mcwilliams, and S. C. Doney, 1994: Oceanic vertical mixing: A review and a model with a nonlocal boundary layer parameterization. *Reviews of Geophysics*, **32**, 363-403.

2. *The description of how you get the grey line in figure 3 is unclear to me. When is the line chosen? It cannot be over Stage-II or it would be aligned with the color contours in figure 3c.*

Response: Thank you very much for the concern. The grey curves in Fig. 3b and c is the ***zero*** contour of March MLD change, **between 40°-70°N, 60°W-20°E**. The region outlined includes the Labrador sea and GIN seas, representing roughly the deep water formation region in North Atlantic. Fig. 3b is averaged over Stage-I and 3c is averaged over Stage-II.

The grey curves are aligned with the latitude 40°N, 70°N and longitude 60°W and 20°E first, and then they are aligned with zero color contour within the region of 40°-70°N, 60°W-20°E.

Minor issues:

3. *Lines 46-47: Can you give more explanation of how dust in the atmosphere leads to freshening in the ocean? This is not obvious*

Response: Thank you very much for this concern. The atmospheric dust over the ocean have two effects: on the one hand, it can reduce the sunlight absored by the ocean, through increased the atmospheric aerosol, leading to the surface cooling; on the other hand, the atmospheric dust increases the nucleus of condensation of moiture, leading to more cloud, more precipitation and weaker evaporation, and thus the fresher surface ocean. For the mid-high latitude ocean, usually the freshening effect on the density can dominate over the cooling effect on the density, leading to a lighter surface ocean, which can eventually weaken the deep-water formation.

4. Line 152: the AMOC index has no relation to the grey line in figure 3c as far as I can tell.

Response: Thank you very much for pointing out the mistake. We deleted the "(see the grey line in Fig. 3c)".

5. On line 171, you refer to the subtropical cell, but you are actually referring to 2 cells, one either side of the equator.

Response: Thank you very mcuh for this concern. Yes, the wind-driven subtropical cell has two branches, which locate roughly symmetrically to the equator. We can see from Fig. 2c and d, the two cells are hardly changed.

6. You need to clarify what you mean by an SST or SSS budget. Presumably you are actually doing a budget in the top grid-cell of the ocean domain? Can you tell us what depth this grid cell ends at?

Response: Thank you very much for the suggestions. The SST and SSS budget are doing for the top grid-cell of the ocean model and the depth of the top cell is 30 m. In line 247 of this revision, we added " The terms in Eq. (1) and (2) are calculated over the top grid-cell (with the depth of 30 m) of the ocean domain."

7. Figure 2b: plotting things with different units on the same axis is not really OK. Can you either remove temperature and salinity, or add two more axes to this figure?

Response: Thanks for your suggestion. Fig. 2b is reploted (also shown in Fig. R2), with two more Y-axis added for SST and SSS.

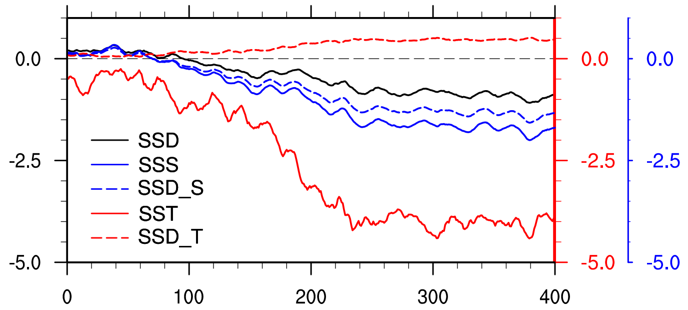

Fig. R2 Temporal changes in sea surface salinity (SSS, psu, blue), sea surface temperature (SST, °C, red), and sea surface density (SSD, kg/m3, black). SSD changes due to SSS and SST are plotted as dashed blue and dashed red curves, respectively.

8. *Line 346: "Note that the decline of the AMOC is triggered by the surface freshwater flux related to EMP". This statement is a bit too strong. I would say that "The decline of the AMOC appears to be triggered by the surface freshwater flux related to EMP."*

Response: Thank you very much for the suggestion. Revised as suggestted.

9. *Line 108:"in accompany with"->"accompanying"*

Response: Thank you very much for the suggestion. Revised as suggestted.

10. *Line 493: I suggest "We have also done experiments that show that with globally flattened continents, a sudden uplift of the TP can lead to AMOC formation"*

Response: Thank you very much for the suggestion. Revised as suggestted.