

Interactive comment on “The effect of greenhouse gas concentrations and ice sheets on the glacial AMOC in a coupled climate model” by Marlene Klockmann et al.

Anonymous Referee #2

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By using the coarse resolution version of the Max Plank Institute Earth System Model (MPI-ESM), the authors investigated the response of the AMOC and deep ocean water masses to glacial forcing. The authors' sensitivity simulations clearly demonstrated that the low greenhouse gas concentration contributes to causing the weaker AMOC and shoaling of NADW, whereas effects of the ice sheets tend to cause the stronger AMOC and deepening of NADW; balance of these two effects mainly controls the glacial response of the AMOC and NADW. Contrary to the proxy data, the authors' reference LGM simulation leads to the stronger AMOC and deepening of NADW. By applying additional cooling by setting 149ppm of CO₂ concentration, the authors obtained the AMOC closer to the proxy data. By performing the simulations under various level

C1

of CO₂ concentrations (149, 185, 230, 284, 353ppm), the authors investigated the changes in the AMOC and water mass properties. The authors found that brine release over the Weddell Sea becomes dominant for determining surface density flux there in lower CO₂ (149, 185ppm) cases. The authors concluded that this brine release is important for a shoaling of glacial NADW, which was supported by their sensitivity simulations where the brine release is artificially reduced.

The manuscript is well-written and I think this is valuable contribution toward our understanding the glacial AMOC. Therefore, I would like to recommend the publication. Followings are several comments on the manuscript, which I hope will be helpful for the authors to prepare the final version of the manuscript.

Overall comments)

(1) The authors concluded that changes in convective system around the Weddell Sea, shifts from open convection to shelf convection, are important for shoaling of glacial AMOC. The changes in convection system in the Southern Ocean were not explicitly displayed in the manuscript, and addition of such figures might be important supporting evidence about the authors' conclusion.

(2) The authors obtained the shallower AMOC in their simulation LGM-149. However, even in LGM-149, the maximum value of the AMOC is still stronger than pi-CTL. This fact appears not directly mentioned and discussed in the manuscript, but explicit statement on this fact and discussion on it might be valuable.

(3) In the authors' model simulations, Fig. 8 (convection around the North Atlantic) suggests that the response of convection in the Labrador Sea is somewhat complicated: no Labrador Sea convection in pi-CTL → active convection in LGM-353 and LGM-284 → decreased convection in LGM-230 and LGM-ref → active again with shifted location in LGM-149. Considering the fact that the authors' model failed to reproduce the Labrador Sea convection in pi-CTL due to coarse resolution, I feel the possibility that this bias might affect the glacial response of the AMOC. Discussion on the role of the

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Labrador Sea convection might be an additional important viewpoint for understanding the glacial response of the AMOC in the authors' model simulations.

Specific comments)

P4.L5: Why ICE5G is used for land-sea mask instead of that of PMIP3 ice sheet?

P4.L11: Please explicitly state what the letter "TOPO" stands for, or rename the experiment name (TOPO appears to remind us of topography effect and might be a little bit confusing).

P11.L24: What do the authors mean by "the last wet layer"?

P14.L10-11: The authors state that "the northward shift is consistent with an increased open-ocean convection". Would the authors explain explicitly what do they mean by "consistent"?

P15.L16: Here, the authors concluded that "the shoaling takes place once the shelf-convection contribution to AABW becomes dominant". I think this is one of the most important conclusions of the manuscript. Although the Figure 10 indicates that brine release is actually important for determining the surface density flux over the shelf regions, changes in convective system (i.e. shifts from open convection to shelf convection) are not explicitly displayed in the manuscript. I suggest the authors to add the figures which display changes in convective system in the Southern Ocean (also see my overall comment 3).

Fig.6: I think that addition of the AMOC figure in other simulations (LGM-353, LGM-284, LGM-230, LGM-149) will be meaningful information for the readers, although I understand that shoaling of the AMOC in LGM-149 can be confirmed from Fig.7.

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