Answer to RC2

We thank the reviewer for those useful comments, and especially for motivating a more precise description of some aspects related to the AMOC model. Below, we address each comment individually and outline planned modifications to the manuscript.

This study discusses the AMOC stability under meltwater forcing from both Greenland and West Antarctica. The paper is interesting and sound if we accept the conceptual representation of AMOC. However, I struggled when trying to put these discussions in the context of real ocean. It may help the readers by including more comparison with the real world in the revised manuscript.

In particular, I wonder whether the AMOC sensitivity to WAIS meltwater has been exaggerated too much in this toy model. In a recent paper (https://doi.org/10.1175/JCLI-D-22-0433.1), which uses a more realistic model to examine the overturning responses to meltwater fluxes, they found that the AMOC is rather insensitive to Antarctic meltwater at least on timescales of 150 years. I think the "overestimated" sensitivity of the AMOC to WAIS meltwater in this toy model is because they parameterize the AMOC strength using density differences between the North Atlantic (n) and Southern Ocean (ts), rather than the density differences between the North Atlantic and the mid-latitude box (t) – the latter appears more plausible by physics (e.g., https://journals.ametsoc.org/view/journals/phoc/42/10/jpo-d-11-0189.1.xml). Processes in the Southern Ocean could affect the subsurface stratification in the low-mid latitudes, but this connection likely occurs on millennial timescales.

Reply: as suggested by the reviewer, it is to be expected that different models present different sensitivities to forcing, especially when comparing conceptual and comprehensive models. However, we note that the study of Li et al. (2023) and ours are not incompatible for at least the two following reasons:

1. The forcing used in Li et al. (2023) is very different. Namely, it is uniform in time, while ours assumes different parabolic profiles for both ice sheet meltwater fluxes;

2. Li et al. (2023) found a limited sensitivity to Antarctic freshwater fluxes on a present-day AMOC, which is also the case for the model used in this manuscript. For example, they found an increase of the AMOC strength of approximately 0.63 Sv (or 2.8%) for a constant Antarctic freshwater flux of 0.06 Sv (Fig. 9 in Li et al. (2023)). In our model, the steady state of the circulation in terms of the AMOC strength is increased by approximately 1 Sv (or 6.9%) when a WAIS meltwater flux of 0.08 Sv is applied (Fig 3.a).

On the parametrization of the AMOC strength (here taken as the downwelling strength q_N), we note that the box ts does not stand for the southern ocean (which is rather represented by the box s), but for the southern thermocline, or the part of the Atlantic Ocean between the Antarctic Circumpolar Current and the southern tip of Africa. This choice of parametrising the downwelling strength q_N using the density of the southern thermocline box ts rather than than the thermocline box t is further motivated in Section 2.1 of Cimatoribus, Drijfhout, and Dijkstra (2014).

Changes in text: the signification of the box ts will be clarified in Appendix A.

I also have a few questions regarding the configuration of the AMOC model.

1. Why including the box "ts"? If I read it correctly, the overturning between ts and t is the same as the overturning between s and ts or d and s.

Reply: the addition of the southern thermocline box ts is extensively motivated in Cimatoribus, Drijfhout, and Dijkstra (2014). To summarize, it allows for computing the density gradient within the Atlantic basin, and represents a region in which the isopycnal slopes are greater than in other parts of the thermocline.

Changes in text: the role of the box ts will be made explicit in Appendix A.

2. It should be clarified that the meltwater flux is applied as virtual salt flux not as freshwater flux, which won't influence the salinity content in box "t".

Reply: we thank the reviewer for this sensible remark. It is however clear that, whether it originates from freshwater or virtual salinity flux, any change of salinity in any of the boxes will ultimately impact the salinity in other locations via the dynamics of the model.

Changes in text: the use of virtual salinity fluxes will be made explicit in Section 2.

3. How is temperature evolved in each box? As the authors mentioned in their introduction, a perturbation to the overturning circulation also modifies the ocean's thermal structure, which necessarily will feedback to the system and may affect the AMOC stability.

Reply: temperatures are fixed in this model. Note that the temperature of boxes n, ts and the reference temperature T_0 (which are the only ones explicitly used in the model) are given in table A1.

Changes in text: the treatment of temperatures as fixed parameters will be made explicit in Appendix A.

References

Cimatoribus, Andrea A., Sybren S. Drijfhout, and Henk A. Dijkstra (Jan. 2014). "Meridional overturning circulation: stability and ocean feedbacks in a box model". en. In: *Climate Dynamics* 42(1), pp. 311–328. ISSN: 1432-0894. DOI: 10.1007/s00382-012-1576-9. URL: https://doi.org/10.1007/s00382-012-1576-9 (visited on 10/07/2022).

Li, Qian et al. (May 2023). "Global Climate Impacts of Greenland and Antarctic Meltwater: A Comparative Study". EN. In: *Journal of Climate* 36(11). Publisher: American Meteorological Society Section: Journal of Climate, pp. 3571–3590. ISSN: 0894-8755, 1520-0442. DOI: 10.1175/JCLI-D-22-0433.1. URL: https://journals.ametsoc.org/view/journals/clim/36/11/JCLI-D-22-0433.1.xml (visited on 03/22/2024).