

Interactive comment on “Impact of mid-glacial ice sheets on deep ocean circulation and global climate: Role of surface cooling on the AMOC” by Sam Sherriff-Tadano et al.

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Received and published: 2 July 2020

Sam Sherriff-Tadano and co-authors conducted an AOGCM study investigating the impact of an expanded North American mid-glacial ice sheet on the ocean circulation. By using partially coupled experiments, they found that an ice sheet-induced cooling in the North Atlantic and Southern Ocean can lead to a weakening of the AMOC in their model, which competes with the strengthening effect of an enhanced wind forcing. The overall effect is a relatively small change in the strength of AMOC during MIS3 compared to the pre-industrial. The authors examined in detail the dynamics and processes at play with sensitivity and partially coupled experiments.

C1

I find the study very interesting and I am overall positive on the manuscript. It fits the scope of the journal, and would serve as a useful reference for the community that work on understanding the millennial-scale climate variabilities in the last glacial period. However, I do have some comments which I hope can help improve the manuscript.

Major comments:

>L24-34: I suggest that the authors add a schematic figure illustrating the time evolution of certain climate variables from paleo records (e.g. summer insolation, CO₂, sea level, δ¹⁸O etc.) from last interglacial to the present day. This can provide a more clear context and would be especially beneficial to a wider audience.

>section 2.1: Could the authors add a short paragraph briefly summarizing the performance of MIROC4m for the preindustrial and/or present day simulations, especially for the metrics that are relevant for the analysis later in the main text? Such metrics can include, but not limited to, sea ice concentration, mixed layer depth, ocean profiles/stratification in the North Atlantic. Climate sensitivity would be useful to mention as well. Any significant bias and therefore its implication for the conclusions drawn in this work should also be discussed where relevant.

>L121: Did the authors perform any sensitivity experiment with regard to the opening/closing of the Bering Strait by any chance? If yes would be useful to briefly discuss it here. Some studies have shown how an opened/closed Bering Strait could have some significant impact on the North Atlantic ocean state.

>L355-357: It is not immediately clear to me how do subsurface warming and southern ocean warming are able to re-strengthen the AMOC. The latter due to reduced production of AABW? How about subsurface warming? Please elaborate a bit more on the dynamic links here.

>L358-359: Once again, it is not clear to me the link between the expanded sea ice and a weakening surface wind. My understanding is that a more extensive sea ice cover in

C2

the North Atlantic 'protects' the ocean surface from the wind stress above, which tends to spin down the ocean circulation, and is favorable for maintaining a weak AMOC.

>L340-364: I appreciate the authors' efforts in explaining some of the interesting modelling results here. However, to me this part has a very limited contribution to the main points of the paper, and could be a distraction to the readers in this section. I think by removing it or moving it to supplementary material could help enhance the legibility of this section. It is up to the authors to decide though.

>Fig. 11: this schematic is not adequately discussed/referred to in the main text. There are several places in the text (mainly in 'Discussion') where the relevant processes are described and should refer to this figure. In addition, the feedbacks indicated by the black solid arrows are not straightforward to me. Please consider elucidating it more explicitly in the main text or in the caption where appropriate.

Minor and technical comments:

>title: I think that it is good practice to try to avoid abbreviations in the title (e.g. AMOC).

>L8: should spell out that it is about the expansion of ice sheet in North America.

>L10: it would be useful to mention the MIS3 and 5a time slices that the authors chose in this study, such that the readers can get a quick grasp by reading the abstract.

>L55-59: suggest to rephrase the sentence as "... which can cause either a strengthening of the AMOC by ..., or a weakening of the AMOC by..." This also applies to L246-248.

>L65: you mean "For" these two periods?

>L71: "... whose effect of surface cooling is prominent." This reads a bit ambiguous to me; please consider rephrasing it.

>L108-109: is it relevant to include the information in the square bracket? If not please consider removing it.

C3

>L146-147: To my understanding, it should be stressed that surface heat flux cannot be imposed because it is strongly coupled to SST, whereas surface freshwater flux can because there is no direct SSS feedback to the flux.

>L168-170: I am a bit surprised the simulated LGM climate is only about 0.2 deg-C colder than the MIS3 climate, considering that there is a CO2 difference of 20 ppm plus some (supposedly moderate) difference in the distribution of ice sheet. Could the authors comment on this?

>L184: perhaps the reference of Dokken et al. and Sadazki et al. in lines 193-194 can be moved here.

>L186: I find it a bit odd to say "the western part of the Southern Ocean"; suggest to change to, for example, Pacific/Indian/Atlantic Ocean sector of the Southern Ocean.

>L220: it is not clear from Fig. 4 that there is 'stronger surface cooling'. I see a relatively homogenous distribution of ocean cooling in Fig 4(a,b). Is this the case or it has to do with the color bar?

>L222: "and increases the deep ocean salinity, ..." error in grammar. Also, should spell out the increased deep ocean salinity is via brine rejection.

>L235: suggest to move "Fig. 7c,d" to the middle of L234.

>L261: change "are replaced with" to "replace with"?

>L265: "compensates"

>L269-271: "Due to ... AMOC (Fig. 10b)." To me the main effect of sea ice in weakening the AMOC in the north Atlantic is because of its insulation that reduces air-sea flux and therefore ocean convection. The effect of melting of sea ice, if one can do a back-of-envelope calculation converting the melted sea ice into sverdrups, should be relatively small.

>L272: again, the more stable ocean column is not clear to me from Fig. 4c.

C4

>L273: suggest to tone down “overcomes” to “tends to overcome”.

>L283: “The results above demonstrate. . .”?

>L303: there are two full stops.

>L303-307: this reads very speculative to me, if I understand the authors’ point correctly here. Please consider removing it or providing more evidence (it’s up to the authors to decide).

>L329: ice sheet“-induced” cooling?

>L335: replace “deny” with “exclude”?

>L348: “resemble”?

>Fig. 9: the color of “PC-MIS3-5aice” in the legend is not correct.

Interactive comment on Clim. Past Discuss., <https://doi.org/10.5194/cp-2020-75>, 2020.