Response to the Referee #1

Dear Referee,

Thank you for the time that you spent on our manuscript. Below you will find a summary of the changes that we made throughout the manuscript to address all your suggestions.

Yours sincerely

On behalf of all the co-authors,

Guillian Van Achter

Summary

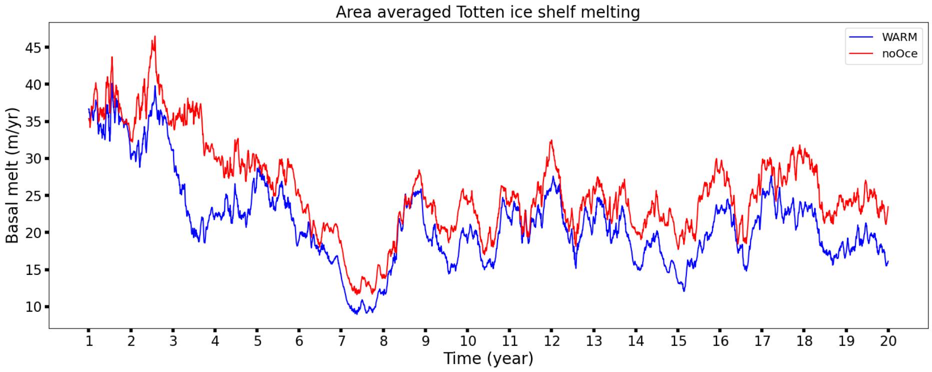
This is my second review for the paper "Influence of fast ice on future ice shelf melting in the Totten Glacier area, East Antarctica" by Van Achter et al. (egusphere-2022-94). I appreciate the authors for performing additional experiments (WARM_noAtm and WARM_noOce) to respond to my previous review comments. The results from these experiments are very helpful for understanding the findings in this study. However, after reading the revised manuscript, I have almost the same concerns as the previous review.

Specific comments

The abstract ends with the sentence, "This highlights the importance of including a representation of fast ice to simulate realistic ice shelf melt rate increase in East Antarctica under warming conditions.", and the second half of the abstract comes from the results in Table 2. Again, I think the conclusion is quite misleading. Because there is no pronounced difference in the future ice-shelf basal melting between the numerical experiments with and without the fast ice representation, and the difference in the ice-shelf basal melting is only found in the present-day condition. The manuscript in the present form gives the readers an impression that fast ice representation can control the future ice-shelf basal melting. We regret that there may have been some confusion about this sentence. Even if the melt rate sensitivity to fast ice is low in the end of the 21st century, stating that "including fast ice under warming conditions is important" is not misleading. The Totten ice shelf indeed shows a small but nevertheless significant 5% difference in melt rate with and without fast ice by the end of the 21st century. In order to avoid any further confusion, we **quantified** the sentence in both the abstract and the conclusion to make it clear that most of the sensitivity comes from the recent past but that the sensitivity is not trivial by the end of the 21st century. The abstract sentence is now: **"This basal melt rate increase sensitivity to the fast ice is explained by the strong melt rate sensitivity for present-day conditions (∼ 25% difference in m/yr) and by the low melt rate sensitivity in the end of the 21st century (∼ 4% difference in m/yr). Reduction of the fast ice extent in the future induces a decrease of the melt rate that partly compensates for the increase due to warming of the ocean. This highlights the importance of including a representation of fast ice to simulate realistic ice shelf melt rate increase in East Antarctica under warming conditions"**(see abstract lines 13-18 and see the conclusion lines 293-304)

L205-209 and Figure A3. I don't think that the stronger ASC in your model suppresses heat exchange across shelf breaks. In fact, Figure 7 clearly shows warm water intrusion across the shelf breaks, and furthermore, there are no differences in ice-shelf melting after three years in Fig A3. Related to this comment, the horizontal axis of Fig. A3 should extend to 20 years to be consistent with the other figures. Indeed, the stronger ASC does not suppress the heat exchange across the shelf, but that is not what we state in the manuscript. As discussed in the manuscript, a strong ASC tends to decrease the heat exchange across the shelf compared to a weaker ASC. This has been already mentioned in several studies, for instance in Nakayama et al. (2021) and this is confirmed by our own simulations. As a direct illustration, Figure 1 clearly shows that, with the same oceanic and atmospheric warming, the simulation with a strong ASC (WARM) has a lower basal melt rate than the simulation with a weak ASC (noOce). This is true for both cavities and for the whole period of simulation. The axis of Fig. A3 has been extended in the new version of the manuscript. Moreover, regarding your point about the warm water intrusion in Figure 7, there are indeed warmer waters across the shelf in WARM compared to REF but that does not mean that the accelerated ASC has no decreasing effect on the melt rate. This only shows that the warming due to the oceanic and atmospheric forcings has a greater effect on the melt rate than the acceleration of the ASC. We rephrase the sentence as :**"As hinted by Nakayama et al. (2021), at equivalent atmospheric and oceanic warmings, the ASC modulates the heat intrusion towards the continental shelf and the TIS and MUIS cavities. The basal melt rate for both cavities in WARM and WARM_noOce (see Fig. A3) shows higher values with low ASC intensity (WARM_noOce) and lower values with high ASC intensity (WARM). This implies that, whereas the ocean and surface air temperature increase induces the intrusion of warmer water into the cavities and higher basal melt rate, the accelerated ASC limits this basal melt rate increase. However, this ASC effect is hidden in Fig. 7 by the ocean warming due to the forcings"** (see page 13 lines 211-216).

(a) TIS basal melt rate



(b) MUIS basal melt rate

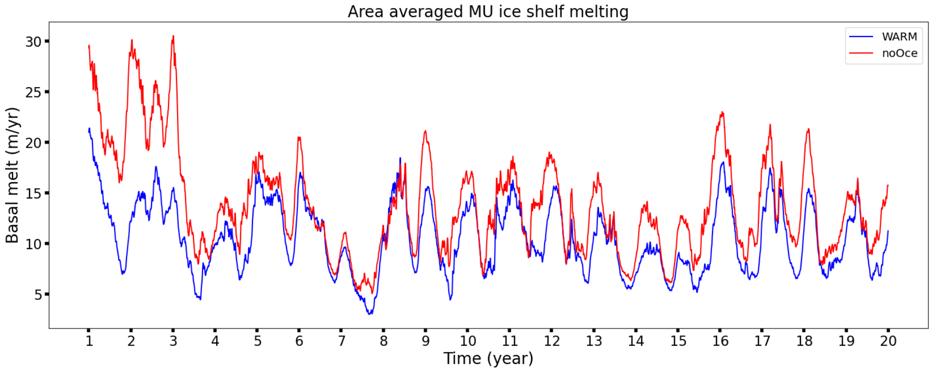


Figure 1: Area-averaged basal melt rate of the TIS (a) and MUIS (b) for the WARM and WARM_noOce simulations. WARM_noOce is the same simulation as WARM, except that the ASC is weaker.

Although there is a phrase "..., with particular focus on the ASC changes and their origins", I couldn't find how the ASC is changed. In the previous review, I suggested some analyses in the climate model results to understand the forcing/boundary conditions for the regional model, but the authors' response was "beyond the scope of this research". How can your readers (including me) understand the ASC changes? As mentioned before, we can only investigate the acceleration of the ASC with our boundary conditions, and everything happening outside of our model domain is not in the scope of our paper. Furthermore, we answered your previous comment by running the new sensitivity simulations WARM_noOce and WARM_noAtm, which allowed us to separate the atmospheric and oceanic forcing effect on the acceleration of the ASC. We were able to show that the ASC acceleration is not directly related to the atmospheric forcing but is related at 83% to the ocean velocity forcing. These changes in ocean velocity are likely driven by changes in winds outside our domain. However, we don't have the adequate model simulations for investigating the role of winds in the ACC acceleration outside of our domain and new experiments with the global model used to obtain the boundary conditions would be required. We agree that it is an interesting question but this is one study on its own and cannot be added as an additional side analysis to our present paper. We have removed the sentence "and their origins" in the introduction and we have rewritten our conclusion by adding more information on the role of winds in the oceanic circulation and how they will change in the future. We now state:**"Finally, as the easterly wind component is projected to weaken over the next century and will significantly impact**

the Southern ocean circulation (Neme et al., 2022), our ASC change analysis should be extended to a wider scale and to other regions" (see conclusion lines 322-324).

Appendix. Although I appreciate the additional experiments, I don't think that it is good enough to add the figures without any text/explanation. I suggest the authors integrate the figures in the Appendix into the main body and carefully restructure the contents. We followed your suggestion. The figures are now included into the main discussion.

Typos / editoral remarks

L31-32 "In this region, the surface covered by ..." What is the surface? ocean surface? fast-ice surface? The ocean surface. This has been clarified in the manuscript.

section 2.3 It is not clear how you performed the 20-year spinup. It is not clear how long you performed for WARM_noAtm and WARM_noOce. The 20-year spin-up is made by running the 20-year simulation twice (this is now specified).

Figure 3 Please use the rounded numbers for the horizontal axis (e.g.,-66.0, -65.0 etc.). Done.

Figure 4e-f Can you plot the boundary between fast ice and sea ice in winter? Since high sea-ice production areas (coastal polynyas) are formed at the edge of fast ice/coastline/ice front, showing the fast-ice edge would be helpful in understanding the difference in sea-ice production in Fig. 5. Done.

L181-182 It seems to me that the gyre intensification originated from the stronger ASC and the enhanced transport across shelf breaks between 120-125E in Fig. 6b. Some analysis on Warm_noOce would be helpful to separate the roles of the fast ice and lateral advection. As presented in Figure 2, the southern side of the Totten gyre, which is accelerated in WARM compared to REF, shows the same ocean velocities in both nFST, WARM_noOCE and WARM. As WARM_noOce and WARM have nearly the same ocean velocities in front of Totten, this suggests that the changes in ASC does not play any role in the acceleration of this coastal current (WARM has a much stronger ASC than WARM_noOce). Moreover, as nFST presents nearly the same ocean velocities as WARM in front of Totten, this proves that the changes in fast ice cover is the main cause of the changes in ocean current in front of Totten between WARM and REF. We adapted the section on the ocean velocity discussion in the paper with the nFST and WARM_noOce mean ocean velocity to justify this more clearly.

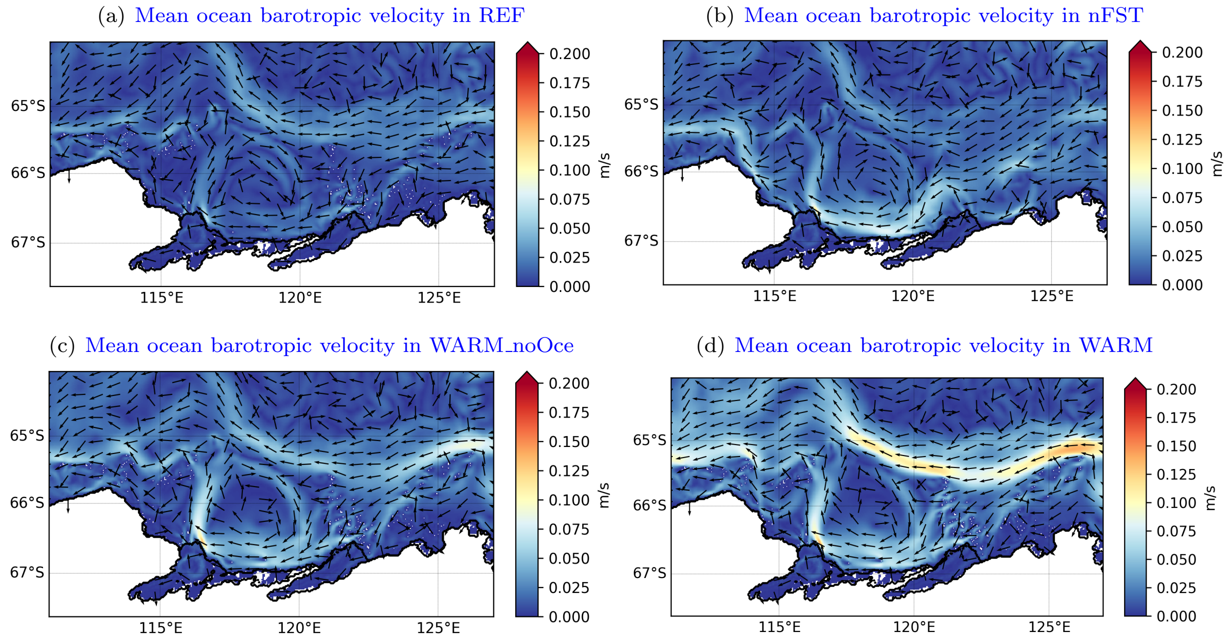


Figure 2: Mean ocean barotropic velocity for the REF (a), nFST (b), WARN_noOce (c) and WARM (d) simulations, averaged over the 1995-2014 period.

L190-204 What latitude range do you use for the quantitative comparison? The range selected was -65.6 to -64.7. This is now mentioned in the text.