Interactive comment on "Brief communication: A submarine wall protecting the Amundsen Sea intensifies melting of neighboring ice shelves" by Özgür Gürses et al.

Our reply is written in blue.

1 Summary

This paper is a direct response to one of the geoengineering solutions presented in Moore et al 2018. The authors use a global ocean model to determine how an engineered submarine wall in the Amundsen Sea might affect the integrated basal melt rate of Antarctic ice shelves. They find that, as deep warm water is prevented from entering the ice shelf cavities of the Amundsen Sea, basal melt rates in other locations are increased. The net effect of the submarine wall is an integrated 10% decrease in basal melt from a control case.

2 Recommendation

This paper is timely and well-written. It provides a concise response to an earlier publication (Moore et al 2018), and illustrates one specific aspect of the complexity of geoengineering problems. Namely, that if heat is blocked from melting certain ice shelves, it may well go elsewhere and cause additional problems. There are many ways this paper could be expanded, however, the authors have done well in isolating and investigating a specific problem and containing it to a brief comment. I recommend publication after a few minor modifications.

Thank you very much for your encouraging comments. We have inspected if heat is accumulated. However we do not see a clear signal which we can be easily link to erected wall and described easily within the short "Brief communication" format. We detect in the Pacific Sector a distinct warming approximately along and slightly south of the Antarctic Circumpolar Current (ACC) and upstream (relative to the direction of the Antarctic Coastal Current) of the walled region at 700 m depth, for instance. Between the coastal current and the ACC, we also detect "filament-like" colder (compared to the control run) water spreading paths originating apparently from the Ross Ice Shelf region. We interpret this pattern as a modification of the circulation pattern.

South of 65°S, we detect a warming in the upper 100 meters of water column, but we do not consider this change as significant, because the atmospheric fluxes are fixed between both simulations. Any change in the ocean surface condition that does not influence the atmosphere, which in turn would modify the ocean forcing. This missing feedback can lead to wrong conclusions (Mikolajewicz and Maier-Raimer, 1994). Since we aim for a coupled atmosphere-ocean model that includes explicitly the ocean-ice shelf interaction, we have decided to analyze these features in more detail in a coupled atmosphere-ocean model system, which deems to be more appropriate.
Anyhow we are confident that our main results are robust: a) A wall shielding the Amundsen Sea Embayment reduces basal melting rates within the protected region, b) the rejected warm water masses flows along the wall westward, c) west of the wall warmer water masses drive enhanced basal melting.

3 General comments

I strongly encourage the authors to make the data used for this paper freely available online. Ideally, this would include model source code, forcing files, and code used for analysis. At the least, the authors should deposit a subset of model output used for the calculations in a repository such as Zenodo.

We followed your suggestion and changed the former "Data availability" section into "Code and Data availability":
The FESOM1.4 model code is available at https://swrepo1.awi.de/projects/fesom/ after registration. The here used atmospheric forcing data set named "CORE-II" (Large and Yeager, 2008) is freely accessible online (for example at https://data1.gfdl.noaa.gov/nomads/forms/core/COREv2.html). The topography data set RTOPO could be obtained from https://doi.pangaea.de/10.1594/PANGAEA.741917. The temporal average of the fractional basal melting changes between the CTRL and the WALL simulations is obtainable from Zenodo via https://dx.doi.org/10.5281/zenodo.3240250. The remaining data is available from the first author ÖG upon reasonable request.

There are several interesting points of discussion the authors do not address. As this paper is a direct comment on Moore et al 2018, it is up to the authors if they want to include further speculation. Here I list several of these points, for both the authors and the broader community to consider:

- Where does the heat go? If the integrated basal melting loss around Antarctica is 10% lower in the WALL experiment, the heat that would have caused melt must be somewhere else. Is it still in the ocean (and what part), transferred to the atmosphere or to sea ice melt, or somewhere else?

  As described above, we have analyzed if a warm water pols it created. However the vague signal does not allow to draw a strong conclusion, because the atmospheric flux are described and, hence, identical between our two sets of simulations. We deem it more appropriate to perform such a study with a model version under development, where the ocean and atmosphere is coupled. In this model the heat flux between atmosphere and ocean evolves freely and would allow quantifying the impact of heat flux changes.

- The model uses forcing for present day conditions. Under future warming scenarios, would the WALL experiment cause more or less integrated basal melt?

  We've planned the suggested experiments in a model version, where the ocean is interactively coupled to the atmosphere.

- Both this paper and Moore et al 2018 focus on sea level rise and investigate geoengineering possibilities that may also affect aspects of the climate outside of sea level. In this case of a wall, oceanic heat is redistributed and water circulation in ice shelf cavities in the Amundsen Sea is reduced. This has implications for the local ecosystem that is controlled by ice shelf cavity circulation (e.g., St. Laurent et al 2017). It would be useful to note that geoengineered 'solutions' to sea level rise affect more than just the target area or problem, as the climate system is not separable into individual pieces.

Good point. We have missed this specific side effect. We follow your advice and add the following sentence:
"Iron is a micronutrient essential for algal production in the Amundsen Sea (St-Laurent et al., 2017) and the erected wall affects its availability. The wall blocks in inflow of warm and iron-rich CDW and influences the outflow of iron-rich glacial melt water coming from melting ice shelves. How the changed nutrient supply impacts the marine biological web or the uptake and sequestration of carbon dioxide by the ocean is unclear and goes beyond this study."

4 Line comments

Line 58-60 - It would be useful here to know that the WALL in your simulations does not match the wall in Moore et al 2018. Option to include a brief discussion why, or refer the reader to a later section.

We added the following new lines and adjusted the related discussion:
"The wall proposed by Moore et al. (2018), which blocks only the circulation in troughs leading directly to Pine Island and Thwaites Glaciers, would have a length of about 50—100 km and would need 10—50 km3 of material. By comparison, the construction of the Suez Channel required the excavation of about 1 km2 of material (Moore et al., 2018). The simulated wall (length of about 800 km) is substantially larger than the originally proposed wall in size and it shields the entire Amundsen Sea Embayment."

Line 81 - Remove the fraction; use only the 85% value

Done.

Line 135+ - A portion of the references are redundant.

We have checked and cleaned the references.

5 References

Large, W. G. and Yeager, S. G.: The global climatology of an interannually varying air–sea flux data set, Clim. Dyn., 33(2–3), 341–364, doi:10.1007/s00382-008-0441-3, 2008.

Mikolajewicz, U. and Maier-Reimer, E.: Mixed boundary conditions in ocean general circulation models and their influence on the stability of the model's conveyor belt, J. Geophys. Res., 99(C11), 22633–22644, doi:10.1029/94JC01989, 1994.

Moore, J. C., Gladstone, R., Zwinger, T., Wolovick, M. (2018). Geoengineer polar glaciers to slow sea-level rise. Nature, 555(7696), 303-305.

St-Laurent, P., P. L. Yager, R. M. Sherrell, S. E. Stammerjohn, and M. S. Dinniman (2017), Pathways and supply of dissolved iron in the Amundsen Sea (Antarctica), J. Geophys. Res. Oceans, 122, 7135–7162, doi:10.1002/2017JC013162.