The Cryosphere Discuss.,
https://doi.org/10.5194/tc-2018-95-AC1, 2018

Interactive comment on "Stopping the Flood: Could We Use Targeted Geoengineering to Mitigate Sea Level Rise?" *by* Michael J. Wolovick and John C. Moore

Michael J. Wolovick and John C. Moore

wolovick@princeton.edu

Received and published: 14 June 2018

We thank Dr. Gabl for his comment on our article. We now respond to specific points below:

Abstract and page(P) 13 line(L) 15: The 30% probability of success is an estimate based on which calculation or boundary conditions?

The 30% number is based on the isolated pinning points scenario, in which the sill blocks none of the warm water but still provides buttressing should the ice shelf reground on it. Isolated pinning points is the easiest to build of the designs that we

considered, which is why we used the 30% number in these two locations. The abstract already clarified that the 30% number refers to the smallest design, and we have clarified the wording in the discussion as well.

The water level is fixed for the calculation time because it is comparable small to the ice sheet. I couldn't find a comment on this in the discussion part.

That is correct, we kept sea level constant throughout the simulation. Although there are many factors that contribute to the sea level budget, they are all relatively small compared with the bed depth below sea level (500-1500 m). The maximum potential sea level contribution from Greenland is 7 m, (Bamber et al., 2013), while smaller glaciers and ice caps provide less than a meter and thermal expansion may contribute 1-2 m over a millennial timescale (Levermann et al., 2013).

The potential sea level contribution from Thwaites itself and from the rest of Antarctica is more complex, since near-field sea level actually falls when an ice sheet loses mass due to gravitational effects. We expect that the sea level changes due to Thwaites itself and to the rest of Antarctica to be a stabilizing feedback potentially counteracting the destabilizing effect of mass loss in Greenland, consistent with the results of Gomez et al. (2010) that we cite in the introduction.

As above mentioned, I'm not an expert in this particular research field. Consequently, in my opinion it would be very useful if in the section Methods (or alternatively in the supporting information) the simplifications are summarised, which gives the reader a previous overview of the used model and its assumptions.

Thank you for pointing out that this wasn't necessarily clear to all readers. The beginning of the Methods (P4, L27) mentions that we use a flowband model, and the supplement mentions that we employ the Shallow Shelf Approximation (also called the Shelfy-Stream Approximation, both abbreviated SSA). What "flowband SSA" means is that we treat the flow of the glacier in a width- and depth-averaged sense. We have added a bit of wording at the beginning of the Methods section clarifying this. We still present the model equations in detail in the supplement, but if other reviewers feel that a more lengthy list of model assumptions is needed in the main text, then we can add that too. However, for now we think that it is sufficient to mention the two biggest assumptions involved in a flowband SSA model, namely that the model is depth-averaged and width-averaged.

P6 L10: The construction time of 10 years seems to be a very conservative approach but it's reasonable keeping the difficult boundary conditions as well as the length in mind. The fixed beginning of the work in 100 years should be questioned; especially, when looking at the animations. Except of the animation 5 all other scenarios would suggest that the sill is built under the floating ice shelf, which would lead to a dramatic increase of the difficulty and cost of the intervention. Maybe a flexible starting point of the work based on an ice-free sea on top of the potential cross section would be a good starting point.

The way that we implemented sill construction in the model code required that the start date, location, sill dimensions, and construction duration all be specified before the model run began. In future work we could explore the effect of implementing a dynamic sill construction code that decides when to build the sill based on the condition of the model glacier, and potentially modifies the sill dimensions in response to the glacier geometry. This would also be a good place to test different levels of societal foresight: how does it change things if society begins construction when the glacier first starts retreating, as compared to a society that only starts building once the retreat has become very severe?

P9 L7: How did the authors define the collapse of the ice sheet? Which criteria was used? Please clarify this.

The model glaciers had a very bimodal response depending on whether they entered a runaway marine ice sheet collapse or not. For those that did not collapse, the grounding

line never strayed more than 10 km behind the present-day position and ice volume stayed close to the present-day value. For glaciers that did enter a runaway retreat, the grounding line retreated hundreds of kilometers inland, volume above flotation collapsed, and the rates of both retreat and volume loss increased drastically. In practice we defined a collapse as any run in which the grounding line retreated more than 25 km, however alternate thresholds based on volume loss, rate of retreat, or rate of volume loss would have produced similar results.

Figure 5: It would be good to have a clear connection the individual subfigures and the added animations.

All snapshots in Figure 5 come from animation 3. We have clarified this in the figure caption.

The discussion starts with a general comment and some further (research) questions and ends with the geoengineering. In the middle part the used approach is discussed and ranked as a first step. I would suggest to split this into two different subsections. One with a general discussion and an additional part, in which all assumptions are summarised.

We will consider this possible reorganization depending on what the reviewers say.

The animation 1 and 2 only cover 120 years of the total investigated 1000 years. It would be nice to see the full period to compare it to those with the intervention. All animations show the similar first 100 years and in consequence the novelty of these videos are only 20 years.

Those animations only have 120 years to show because the model became numerically unstable in the late stages of collapse, and we included code that automatically terminated the model run if numerical instability was detected. The final snapshot of those animations shows an extremely thin ice shelf extending far out into the sea; this ice shelf would have rapidly calved away in the ensuing year. Since our numerical scheme always uses the same number of grid cells no matter the length of the glacier, a retreating calving front causes the grid cells to shrink, and since the timestep remains constant, this would eventually cause a numerical stability threshold to be crossed. Steep ice thickness gradients and fast ice velocities in the late stage of a collapse also lower the threshold for numerical instabilities to grow. Setting a timestep short enough to preserve numerical stability in the late stages of a collapse would have increased processing time in the rest of the model runs.

We did not prioritize the ability of our model to simulate the late stages of a collapse since the assumptions behind a flowband model break down in the late stages of a collapse anyway: width-averaged models assume that the cross-flow structure of the glacier remains the same over time, but large retreats should change the ice sheet geometry sufficiently to draw in substantial ice from the sides and destabilize neighboring glacier basins. We assume that Thwaites finishes collapsing after the model run ends, and brings the rest of West Antarctica with it (Feldmann and Levermann, 2015).

If I understand it correctly, the animation 1 and 2 show the same result hence the build structure has 0% blockage. It would be very useful, if in the section Movies in the supplement documents the choice of the presented movies would be explained and also the main findings summarised.

As mentioned in the methods section (P6, L13-14), we use the scenario with 0% water blocking to represent isolated artificial pinning points instead of a continuous artificial sill. In other words, the structure provides no water blockage but it does provide physical buttressing if the ice regrounds on it. Animations 1 and 2 show the same behavior because the ice shelf never regrounds, resulting in a failed intervention. However, if the shelf had been able to reground in animation 2 then the subsequent model evolution would have been different. We have added wording on P6 L14 to clarify this.

I would like to thank the authors for their very interesting paper and I'm looking forward to the final version. Thank you!

Thank you for your comment, and you're welcome!

References

Bamber, J. L., Griggs, J. A., Hurkmans, R. T. W. L., Dowdeswell, J. A., Gogineni, S. P., Howat, I., et al. (2013). A new bed elevation dataset for Greenland. The Cryosphere, 7(2), 499–510. https://doi.org/10.5194/tc-7-499-2013

Feldmann, J., Levermann, A. (2015). Collapse of the West Antarctic Ice Sheet after local destabilization of the Amundsen Basin. Proceedings of the National Academy of Sciences, 112(46), 14191. https://doi.org/10.1073/pnas.1512482112

Gomez, N., Mitrovica, J. X., Huybers, P., Clark, P. U. (2010). Sea level as a stabilizing factor for marine-ice-sheet grounding lines. Nature Geoscience, 3, 850.

Levermann, A., Clark, P. U., Marzeion, B., Milne, G. A., Pollard, D., Radic, V., Robinson, A. (2013). The multimillennial sea-level commitment of global warming. Proceedings of the National Academy of Sciences, 110(34), 13745–13750. https://doi.org/10.1073/pnas.1219414110

Interactive comment on The Cryosphere Discuss., https://doi.org/10.5194/tc-2018-95, 2018.