Comment on tc-2022-105

Michele Petrini (Referee)

Referee comment on "The stability of present-day Antarctic grounding lines - Part B: Onset of irreversible retreat of Amundsen Sea glaciers under current climate on centennial timescales cannot be excluded" by Ronja Reese et al., The Cryosphere Discuss., https://doi.org/10.5194/tc-2022-105-RC1, 2022

General comments:

In this paper, Reese et al. use the 'Parallel Ice Sheet Model' (PISM) and the sub-shelf melt module 'Potsdam Ice-shelf Cavity mOdel' (PICO) to analyse the multi-millennial evolution of the Antarctic grounding-lines under a constant, present-day climate forcing, and the reversibility of associated large-scale changes. The authors first calibrate the sub-shelf melt module PICO against observed (Dotson ice-shelf) and modelled (Filchner-Ronne ice-shelf) melt sensitivity to ocean temperature changes. Optimised PICO parameters are then used in an ensemble of continuous spin-up (pre-industrial forcing) - historical (1850-2015 forcing) PISM simulations, which are evaluated against present-day observations. Simulations showing best agreement are then extended for 10,000 years beyond the historical period under constant present-day climate forcing and bathymetry. The evolution of the Antarctic grounding-lines is then analysed, and reversibility is tested for simulations showing large-scale retreat by reverting climate forcing to pre-industrial conditions.

In my opinion, this is a great paper, addressing an extremely relevant scientific topic (future states and reversibility of Antarctic grounding-lines) with the use of advanced modelling tools (*e.g.*, PICO instead of simpler sub-shelf melt parameterizations) and innovative techniques to calibrate numerical modelling results against observations (*e.g.*, PICO parameters optimisation, PISM ensemble scoring methods). The study presents some limitations (*e.g.*, no isostasy, no full equilibrium reached at the end of the simulations), but these are clearly discussed throughout the manuscript, and are in my opinion acceptable considering the technical challenges (and, likely, computational costs) associated with this type of study.

In view of this, I consider this work definitely worthy of publication, and I commend the authors for the great deal of technical work they have undertaken.

I have only two major comments, mainly related to the quality and number of figures included in the manuscript. In fact, I think some important figures are missing, and some of the included figures do not allow the reader to easily verify what is stated in the main text.

- As stated in the main text (L140–141), I fully agree that the PICO calibration proposed in this study approach has a great potential to be used in further Antarctic studies, including future sea-level projections. However, I was a bit disappointed not finding any 2D-map of sub-shelf melt rates, and I think some of these figures should definitely be included (either in the main text or as Supplementary material) to see the outcome of the calibration procedure, and also to get a sense of the magnitude and spatial variability of the sub-shelf melt forcing. For instance, 2D maps of sub-shelf melt rates could be included for ANT2/ANT2+0.1K/ANT2+0.3K simulations at pre-industrial and present-day snapshots. Moreover, since the calibration goal is to obtain correct melt rates and sensitivity (P.7, L179-180), I think it is necessary to include one additional figure showing the comparison between present-day PICO and observed sub-shelf melt rates, and briefly discuss this comparison in the text. Another interesting thing (but I leave this as a suggestion, rather than a request) would be to show, for one or two snapshots, a comparison of PICO sub-shelf melt rates and same melt rates calculated off-line using the simple two-equation quadratic parameterization. In fact, in this study PICO is calibrated to 'behave' like the two-equation quadratic parameterization in terms of sensitivity to ocean warming, but it would be interesting to see the difference in terms of spatial variability within the ice-shelf cavities.
- I found it very difficult to track the evolution of the Antarctic integrated ice volume in the spin-up, historical, 10,000-extension and control simulations, since these are included in three different figures (Fig. 4, Fig. 5, Fig. B2) with different scales. I fully understand why the evolution under historical forcing is highlighted in Fig. 4, but then I would also like to have time series similar to Fig. B2 for the present-day forcing and recovery simulations (maybe in the Supplementary). I was very confused when looking at Fig. B2, as it seems that at the end of the control runs the ice-sheet is not in full equilibrium - which is also stated in the text (P16, L365-367). However, by looking at Fig. 4, it seems that before introducing the historical forcing there is full equilibrium - maybe I am missing something, but I think some work should be done to show these results more clearly. I also think that a panel with integrated sub-shelf melting (perhaps averaged over ice shelf area?) like in Fig. 4 should be included also in Fig. 5. More in general, I think that the quality of some figures should be improved:
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  - Fig. 4: it would be nice to include the figure with the observed ice thickness change from Smith et al. 2020, so that the reader can directly compare modelled and observed pattern/magnitude. The ensemble-average and BedMachine grounding-lines are a bit difficult to distinguish, I suggest using different colours/line thickness. I also think that the time series should also include total ice volume, not only dV. Finally, I think that in the caption it should be specified whether BMB refers to sub-shelf melting + grounded ice melting at the base (frictional heating, GHF), or sub-shelf melting alone (I'd rather include sub-shelf melting alone, but I leave this choice to the authors);
  - Fig. 5: it would be nice to also have the time series for the evolution of sub-shelf melting and grounding-line flux;
  - Fig. 6: I suggest either showing this figure for the whole domain, or including a pan-Antarctic map to show the area considered in the zoomed figures;
  - Fig. 7: this figure is a bit too small, and there is a dark blue line labelled 'revere' which I assume is a typo. It would also be very nice to have this type of figures also for the 10,000–extension runs + recovery runs.

Specific comments:

P1, L8: I would add to the abstract the fact that isostatic rebound is not accounted for in the simulations, *e.g.*, "…under constant present-day climate forcing *and bathymetry*".

P2, L54-56: I suggest rephrasing, and including a citation for CMIP5.

P3, L62: '... let the ice sheet states evolve'.

P3, L65: '... to occur eventually under…'.

P3, L65-67: I suggest rephrasing, *e.g.*, 'To test … retreat, the simulations showing large-scale retreat are extended for 20,000 years under reverted pre-industrial forcing'.

P5, L125-126: I suggest rephrasing.

P6, L134: 'The present paper can be understood to investigate*s*…'.

P6, L149: '...which differ in between *across*…'.

P6, L.160-165: I found these sentences not very clear, I suggest rephrasing.

P7, L165: '...we hope *aim* to represent'.

P11, Section 4.1: I suggest including how the SMB is calculated in PISM, either in this section or in Section 4.2.

P12, L291: I suggest specifying how many thousand years, rather than stating 'several'. Also, I'd use 'at 8 km horizontal resolution'.

P12, L301: I suggest including the notation Hmax as in Table 2.

P13, L315: I would remove 'the best run is used … in Urruty et al.', as this is not relevant for this paper.

P15, L326: I would expand here on what quasi-equilibrium means, and what are the implications. I think it would be enough to move the text at P16, L365-369 at the beginning of the section.

P15, L335: I would add some text linking the discrepancy from observation to simulated and observed sub-shelf melt rates pattern (either here, or in the discussion section). Also, the same could be done with simulated and observed SMB.

P15, L343-345: I would split this sentence in two.

P15, L348-350: I suggest rephrasing.

P16, L374-376: I suggest rephrasing.

P21, L468: I would use 'Moreover' instead of 'in particular'.

P21, L468-470: I would also add something like '...as well as glacial isostatic rebound, which can induce changes in the local bathymetry and ice shelf cavity geometry'. Also, I think the paper by Whitehouse et al. 2019, ('Solid Earth change and the evolution of the Antarctic Ice Sheet', Nature Comms.) should be cited here.

P24, L541: Rather than '...change in sub-shelf melt rates is thought to be a major trigger…' I would use something stronger, *e.g.*, '... recent observations and modelling suggest that…'.