Title: Calibrated sea level contribution from the Amundsen Sea sector, West Antarctica, under RCP8.5 and Paris 2C scenarios
Authors: Roiser et al. (2024)
Journal: The-Cryosphere

Overview:
In this research article, Roiser et al. present numerical ice sheet modeling results of the Amundsen Sea Embayment (ASE), a dynamic region of West Antarctica that is rapidly contributing to global sea level, to 2100 and 2250 under RCP8.5 and Paris-2C emission scenarios. Central to the paper is the development of a new framework for quantifying uncertainties associated with these modeling results by training a surrogate model. Overall, the authors find that the sea level contribution of the ASE through 2100 is nearly identical in both RCP8.5 and Paris-2C, tending to the lower range of other published sea level projections of this region. Grounding line migration is minimal through 2100; however, iceberg calving drives near-total loss of all floating ice shelves. Beyond 2100, the simulations diverge as snowfall ramps up in RCP8.5. In terms of the uncertainty quantification, the authors found that parameters related to model initialization (e.g., hE and the inversion coefficients) comprised a majority of the uncertainty, followed by ice flow parameters, basal mass balance parameters, and surface mass balance parameters.

Overall, I find this manuscript to be of very high quality and I expect the results will be of wide interest to the glaciological and cryosphere community. I also believe that the methods of uncertainty quantification are exceptional and provide critical insight into ice sheet modeling parameters. I do share some similar concerns with the other reviewers in that I would like to see further interpretation of the forward simulation results. In particular, I find it very interesting that there is minimal grounding line retreat but near-complete loss of floating ice shelves through 2100 – I would like to see the authors dig into the reasons for this as well as into the reason why their estimates are on the lower end of published sea level estimates of this region. I also have a note in the general comments section that I think it would be appropriate for at least a subset of the ice sheet modeling results to be made publicly available given the broad interest in this region. Lastly, I also have a couple more minor line comments that should be easily addressed. Once these issues are addressed, I would be very happy to support prompt publication of this work in The-Cryosphere.

General Comments:

- **Additional discussion related to modeling results**: Like the other reviewers highlighted, I think that the results of this paper can be bolstered by diving deeper into analysis of the Ua_fwd projections at both 2100 and 2250. In particular, the authors present a unique implementation of the buoyant plume parameterization and a new way of prescribing oceanic temperature and salinity inputs to this parameterization (using the modeled depth of the thermocline as a depth-cutoff in applying T/S). Given that this region of Antarctica is primarily forced by the ocean, I would like to see how these modeled melt rates compare to contemporary estimates and how they change in time with evolving cavity geometry. I also think that comparisons of how much ice mass is added by atmospheric processes versus how much ice mass is advected across the grounding line in the different simulations would be helpful to diagnose why mass loss is generally low in these simulations. Lastly, as I mentioned below in the line comments, I would like to see the introduction of the manuscript expanded to provide an overview of ASE modeling efforts.

- **Some consistent formatting fixes**: Throughout the manuscript, I noticed that in-text citations were not formatted correctly (e.g., in-text citations should be Lazeroms et al. (2018) and not Lazeroms et al. 2018). Also, there are many times in the manuscript where there needs to be a space between the value and the unit (e.g., 1mm should be 1 mm).
- **Data Availability**: While the authors state that no new datasets were used in this article, they did generate ice sheet numerical modeling outputs that would be of great interest to the cryosphere community given how active numerical modeling efforts are in this area. While I understand that depositing all of the data might be challenging since there are so many model runs, I would implore the authors to deposit a representative subset of the results (or at least the data needed to replicate the figures) in a publicly curated data repository.

Line Comments:

- Abstract: Much of the paper focuses on the development and implementation of the surrogate model and Bayesian calibration, so I was surprised to see that there was no mention of this in the abstract. If there is room, I would add a sentence about this.
- L17: Capitalize "Pine Island"
- L20: Change "rate" to "rates"
- L27: What do you mean by " . . . the complex response of the ocean and ice shelf cavities to atmospheric forcing"? Is this referring to changes in wind stress that impact ocean circulation? For the ice shelves, does this mean enhanced surface melt that might lead to hydro-fracture? Are there studies that you can highlight that show the connection between atmospheric circulation and sub-ice shelf ocean cavity circulation for ASE glaciers? It would be good to specify and connect this to the next sentence because it feels a little ambiguous and out of place currently.
- L37: Please add a citation for the plume model.
- L15:42: I was hoping to get a little more background on ASE glaciers and recent ice-ocean model studies of this region. I think this will be particularly important if you choose to include additional discussion regarding the results of your ASE sea level rise projections. For example, this would be a great place to discuss what sea level projections of this region exist, what are their shortcomings, what are the partitions of sea level contribution between Thwaites and Pine Island, what ocean and atmospheric forcing datasets and parameterization have been used, have tipping points been found in previous studies (note that these are examples and you can select what you think would be appropriate)? A bit more background information to help put your research in the context of what has been done already would be very useful.
- L44: Add a comma after "uncertainties"
- L45: Change comma to a period after "together"
- L62: What was the minimum and maximum mesh resolution?
- L65: Please add a citation for Glen's flow law.
- L72: Please add a citation for the friction law. Also, what does *m* control in this friction law?
- L100: Where did the value of 1.66 come from?
- L127: ". . . in a coordinate system X oriented along the . . ."
- L138: What was the reasoning for picking C_d^{1/2}Gamma_{TS} as the uncertain model parameter rather than C_{d}, the ice-ocean drag coefficient?

- L142: Remove “of”
- L148: Was there a specific reason you left out melting from geothermal heat flux? It seems like this would be a relatively simple addition to the model since you can assume it stays constant through 2100. I don’t think this would be a reason to re-run the simulations, but I am just curious.
- L151: Check the formatting of your references here – I think they should be “Pollard et al. (2015) and DeConto et al. (2021)
- L158: General comment about units, make sure to add a space between the value and the unit (e.g., 1.5 m/yr rather than 1.5m/yr). I saw this come up in a couple of lines now. The only unit that should be directly against the value is the degree-symbol.
- L174-175: Citation should not have parentheses
- L200: What version of BedMachine do you use?
- L206: What specifically are these assumptions? Do you assume floating ice is at hydrostatic equilibrium? If so, please state this and other assumptions explicitly.
- L235-237: This description of how ocean T/S is applied to the plume model is a bit vague. So within each of the three major ice shelf cavities (Pine Island, Thwaites, and Crosson/Dotson), you extract the thermocline depth and T/S above and below that depth. So you get 15 values (5 for each of the three ice shelves), but how is that T and S applied within the plume model? At all ice shelf depths above the thermocline, you apply the average T above the thermocline, and vice versa for below the thermocline? Is this done at every time-step? How does the location where you obtain these T/S/depth variables change as the ice shelf cavity geometry changes in time (i.e., do you always sample from the same locations, or does the location follow migration of the grounding line and ice front)?
- L415: It might be nice in this section to also mention the rate of sea level rise of the ASE, not just the final 2100 contribution. In figure-5, it looks like the rate of sea level contribution from RCP8.5 starts to decrease after 2070, do you know why that is?
- L435-455: I agree with the other reviewers that further discussion of these results would be really valuable! In particular, it is quite surprising that you see little grounding line retreat across both Pine Island and Thwaites Glaciers – some analysis on the ice shelf melt rates that were applied throughout these simulations would be very helpful. Perhaps you could show what the melt rates look like at a couple of different time-steps? You could also show a time-series of total integrated ice shelf basal melt across the main shelves in the domain.
- L451 In figure-6, do you know why Pine Island Ice Shelf ends up shaped like a triangle at both 2100 and 2250? I am very surprised to see that this same ice front shape holds throughout the whole simulation.
- L478: Remove “in the” once; you have it written twice consecutively in this line.
- L481: This comparison to past results is a great starting point! I do think that you should go a step farther and try to deduce why your modeled sea level contributions are on the low end of other published results. Like I said before, I think it is worth looking at what your ice shelf basal melt rates look like in the Ua_fwd simulations and how they change in time (a figure of this would be valuable, maybe in an appendix or supplement). Another possible cause of limited mass loss could be the treatment of surface mass balance, which you could look into by quantifying how much snow fell over the simulation period and how much this offsets ice loss at the grounding line. Do the other projections you cited include atmospheric forcing as a positive degree day

parameterization, or do they directly apply CMIP anomalies in SMB within their model without correction?

- L495: Is this statement about your melt rates true? I thought that the plume parameterization updates ice shelf melt based on changing ice shelf basal slopes and the depth of the grounding line? Maybe it would be more accurate to say that you cannot resolve 3-dimensional sub-ice shelf ocean circulation.
- L505: Might be worth comparing to the new Science Advances paper by Prof. Morlighem (https://www.science.org/doi/10.1126/sciadv.ado7794). They do not find any evidence for MICI over the next 50 years, so this supports your findings well.
- L525-530: A similar analysis of results for your 2100 simulations might be helpful in determining why mass loss is on the lower end of published projections.
- L533-535: Can you determine or at least speculate on why there is a decrease in RCP8.5 mass loss prior to 2100?
- L541: The sea level contribution is similar up until 2100, but not through 2250. Please specify this.
- L560: Check the format of the citation, should have parentheses.

Figure Comments:

- Figure 1: This is a very helpful figure and I like that you included the associated section and appendix numbers in each of the boxes. In the figure caption, can you please include the definition of acronyms (e.g., RNN, LSTM, and Del GMSL).
- Figure 2/3: Should there be a color bar associated with this figure? Also, is the top row showing surface ice speed, or the change in surface ice speed (as would be consistent with a divergent colorbar)? This last comment applies for figure-3 as well – should this say change in surface ice speed? Lastly, for figure-3, why are there no changes shown over floating ice?