Review of "Representation of basal melting at the grounding line in ice flow models"

Dan Martin

July 24, 2018

This work explores the convergence and accuracy characteristics of a set of choices in representing subshelf melting near marine ice sheet grounding lines. Since grounding lines often fall in the interior of computational grid cells, modelers are presented with a decision on how to represent subshelf melting in partially-grounded cells. One can either restrict melt in the model to cells which are entirely floating, include full representations of subshelf melting in all partially- and fully-grounded cells, or use some sort of scheme which reduces the model melt in partially-grounded cells to account for the fact that such cells are only partially floating. Existing model results in the literature employ the full range of these approaches, with unknown impacts on the model projections.

In this work, the authors employ four schemes to represent melt near grounding lines: (1) a scheme in which melt forcing is only applied to fully-floating cells (their "NMP"), (2) a scheme in which melt is applied fully to all cells which are even partially floating ("FMP"), and (3) two schemes which attempt to represent a subgrid-scale distribution of the melt forcing (in which forcing will tend to zero as the floating area in the cell tends to zero) ("SMP"). They apply these choices to an idealized marine ice stream problem (MISMIP+) with two melt parameterizations designed to test two different regimes. The experiments are carried out over a range of model resolutions, designed to examine the convergence behavior of each scheme. They find that schemes which apply melting to partially-grounded cells (both the "FMP" and "SMP") tend to over-represent ice sheet response, particularly at coarse resolutions, while the no-melt ("NMP") scheme tends to under-predict ice sheet response, while also displaying better accuracy and convergence properties. Therefore, their conclusion is that one should use schemes which don't apply melt to partially-grounded cells, particularly at the coarse resolutions typically used for full-ice-sheet-scale models.

Given the importance of subshelf-melt forcing to marine ice sheet dynamics and its relevance to projections of ice sheet contributions to sea level rise, and the fact that many studies predict large melt rates near the grounding lines, this work is a very important step toward understanding how to incorporate subshelf melt into modeling efforts in an accurate way. The paper itself is well-constructed, clearly-written, and was a pleasure to read. The authors present a convincing explanation of their results, and their conclusion is well-supported by their results. I fully support publication, after a few minor fixes.

Specific notes:

1. (p1, line 5): "which ultimately add..." – add → adds
2. (p2, line 20): It would be nice if you would also specify boundary conditions here to give a better feel for the problem without having to look up the citation for those unfamiliar with the Asay-Davis paper.
3. Figure 3 (and accompanying text): It would be helpful to see a convergence plot like figures 7&8 for the steady-state initial condition (or the results of Experiment 0) in order to see how the model itself is converging independent of the melt behavior (to better place the melt convergence results into context).
4. Experiments 1 and 2: How far does the GL (centerline) retreat in these experiments? It's useful to have some context relative to the coarse mesh spacing. (i.e. if it's only retreating O(10) 2km cells, that could be relevant, particularly in terms of how smooth the NMP and FMP parameterizations would appear to the ice sheet (since they're discontinuous in time, while the SMP ones are continuous as the GL retreats).
5. (Figure 4): It's apparent that the 2km results aren't even in the asymptotic convergence regime. (just an observation, which would be clearer if there was a figure like I suggest in (3) above)
6. (p7, line 6): "type sub-element" → "type of sub-element"
7. (p7, line 7): "with a mass loss" → "with mass loss"
8. (p7, line 10): Are the different experiments all converging to the same solution? I think they are, but you never actually say that, and it's hard to tell exactly from the figures given their size)
9. (p8, line 5): "why the difference" → "while the difference"
10. (Figures 5 and 6): I find the mesh-independence of the Weertman NMP case surprising, particularly for experiment 2, since you're potentially omitting a fair bit of melt near the GL. Any idea why this case looks that way?
11. (p.10, line 3): "overestime" → "overestimate"
12. (p.10, line 8): "mass by a factor" → "mass loss by a factor"
13. (p.10, line 9): "the grounding" → "the grounding line"

14. (Figures 7 and 8): I *think* you're referencing each scheme to its own 125m result, which is problematic given that you observe that not all of them are fully resolved at 125m for experiment 2 (this will tend to underestimate the real error being made here for those cases, since figures 7-8 imply that all of the models have error which goes to 0 at 125 m.). I'd suggest instead referencing them all to the same baseline result. Since the 125m NMP run appears to be converged, I'd suggest using that result as the baseline value to compare all of the other results to. Or, you could run a single 62.5m NMP run (which should be very close to the 125 NMP) and use *that* as the baseline solution. Regardless, you should clarify what the reference choice is.

15. (Figures 7 and 8): It might help to mention that you're plotting the abs(error) in these plots, which winds up being the negative of the actual difference for the NMP case. (I spent some time trying to figure out why the NMP line in the Experiment 1 Tsai figure was above the FMP line, until I remembered the sign difference)

16. (p. 11, line 5): This conclusion likely holds broadly for any model which applies melt forcing over the entire cell (including finite-difference and finite-volume approaches), not just simply the ISSM FEM model. For example, I'd expect the finite-volume BISICLES to behave the same way.

17. (p. 11, line 8): guaranty → guarantee

18. (p. 11, line 13): "even other" → "even over"

19. (p. 12, line 6): This is an important point which can't be repeated enough. You could cite Cornford et al (2016) here, which also makes the point about the necessity to quantify or clarify the effects of mesh resolution; both this work and that one provide a template for how to go about doing it (mesh convergence study).

    References:

20. (p. 14, line 11). My name is spelled incorrectly

21. (p. 14, line 29). "West Antarctica"

22. (p. 15, line 3): "andvvan" → "and V van"