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Interactive comment on "Results of the third Marine Ice Sheet Model Intercomparison Project (MISMIP+)" *by* Stephen L. Cornford et al.

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Overall assessment

This paper reports on a follow-up of a series of marine ice sheet model intercomparisons (MISMIP) in which particular attention is paid to the effect of buttressing on the stability of grounding lines on retrograde slopes. The geometry of the experiment is taken from Gudmundsson et al (2013), i.e., a narrow overdeepened channel in the marine portion of the grounded ice sheet. Several models, from full Stokes to models of intermediate complexity (including membrane stresses in a variety of ways) participated in the experiment that consist of applying sub-shelf melt starting from an initial steady-state configuration on a retrograde bedrock slope. All participating models show

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the same qualitative behaviour, meaning that a steady-state configuration across a retrograde section of the bed is obtained due to buttressing and grounding line retreat is initiated when sub-shelf melt is applied. The paper is definitely interesting for publication in TC and will become a benchmark for future model development. Nevertheless, I have a few points that need some clarification.

From the start (abstract) the authors promote the experiment as a test for the treatment of viscous stress sufficient for buttressing. However, throughout the paper, the emphasis is on the response of the different models in relation to basal sliding rules and differences in stress balance, but further discussion on buttressing remains absent. What are the implications of the results in our understanding of buttressing of ice flow on retrograde slopes?

It is also important to note that all models qualitatively show the same results. It is not necessary to dive immediately into their differences. It is important to highlight that models are capable of reproducing stable grounding lines on retrograde bed slopes in case of strong buttressing, irrespective of sliding rules or approximation to the stress balance.

Another point is that the majority of models are from the intermediate complexity group, i.e. higher-order models that include membrane stresses one way or the other. The authors particularly focus on two outliers, a HySSA model and two full Stokes models (Elmer/Ice and ISSM). Most of the attention goes to the HySSA model, but the similar behaviour of the two FS models is intriguing but left out without further discussion, especially since these are the models containing most of the physics. Both FS models are different and use different sliding laws/rules. One of them also solves for L1Lx and has a comparable behaviour to the other L1Lx models, showing that numerical issues should not be the culprit. The minor advance in the Ice1ra experiment therefore requires more discussion in the context of why the other (L1Lx) models advance so much more in this particular experiment when sub-shelf melt is halted. It could inform more on viscous stress important in buttressing, for instance.

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Detailed remarks

Line 3: what is meant by 'sufficient' buttressing? Please also state what is meant by the testing of the models. What is tested and what for? It is not clear what the precise goal of the experiments is, especially in relation to buttressing (see major remark).

Line 40: strongly buttresses instead of buttresses

Line 47: configurations

Line 60: This was also the case for the MISMIP3d experiments

Line 104: suggest to continue the sentence: where u is the horizontal ...

Line 105: Weertman (1957) sliding law/rule

Line 107: is continuous

Line 109, eq 4: define α^2

Line 130: this is not the definition of steady-state. can it be mentioned over what time scales the models were run to reach the 'pseudo steady state'?

Line 188: Has this controversial modification been applied by any of the participating models? In either case, it should be stated.

Line 244: 'the use or otherwise': I don't understand this sentence. Moreover, it is not clear where and how this transformation is applied and Bueler et al (2015) does not shed further light on this. Some more details should be given, as this is also mentioned further down in the manuscript.

Line 274: in comparison with the other models, this description is really short. For the sake of balance, some more details should be given.

Line 286-289: Any reason why this is the case? This should be mentioned.

Line 297: Last sentence: does this apply to the Ice0 experiment?

Line 349-350: See major remark. It is not because they are underrepresented that you are loath to make much of these differences. I would say that L1Lx models are over-represented in this case.

Line 355-356: Or there are too many models of a particular category.

Line 388: This doesn't seem to apply to the FS models it seems.

Line 396-397: See major remark: It is important to note that all models qualitatively show the same results and to highlight that models are capable of reproducing stable grounding lines on retrograde bed slopes in case of strong buttressing, irrespective of sliding rules or approximation to the stress balance. Even the HySSA qualitatively shows a similar behaviour; its exception is can then be further discussed as is done in this paragraph.

Line 422-425: There is also no Coulomb-limiting factor in MISMIP3d. Furthermore, the friction coefficient in MISMIP3d leads to a sharp contrast between grounded and floating ice (higher friction that in this experiment).

Discussion: more discussion on the FS models is needed as well as buttressing in general (see major remark).

Line 439-440: I wouldn't say that the distinction between FS and other models is minor. The Ice1ra experiment proves otherwise.

Line 442: Either add that HySSA has qualitatively the same behaviour, or more general state in the summary that all models exhibit qualitatively the same behaviour and are capable of reproducing stable grounding lines on retrograde slopes in case of strong buttressing.

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