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Interactive comment on "On the substantial influence of the treatment of friction at the grounding line" *by* O. Gagliardini et al.

Anonymous Referee #2

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1 General statement

The manuscript "On the substantial influence of the treatment of friction at the grounding line" by O. Gagliardini and others analyzes the impact of different treatment of basal friction in the immediate vicinity of the grounding line using a Stokes finite element model implemented in Elmer/Ice. The study shows that the method applied to set up the friction in the elements immediately in contact with the grounding line has an impact on ice velocity, grounding line position in steady state as well as grounding line dynamics for different MISMIP benchmark tests used by the ice sheet modeling community.

The paper describes different possible methods for applying basal stress for elements

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adjacent to the grounding line and discusses their impact on ice flow simulations for both flowband and three dimensional simulations. The title and abstract suggest that these different methods have a large impact on the simulations performed using the Stokes equations (e.g. “substantial influence”, “significantly different velocity fields”), however the results do not support this statement. The grounding line position reached using the three different methods lead to similar results for meshes with sufficiently high resolution (see Fig. 3 for example). For coarser meshes, the results are different but the differences between the three solutions are on the same order of magnitude as other numerical errors: Fig. 3 shows similar differences between advance and retreat grounding line positions (Fig. 3b) and between the different method adopted for the treatment of basal friction (Fig. 3c). These differences are decrease with mesh resolution until the mesh is refined enough and the three methods lead to similar results. Furthermore, the three solutions seem to converge at a similar rate, and the discontinuous (DI) method only leads to small improvements at coarse resolution. In short, I don’t see the point of comparing different basal drag parameterizations for numerical models that are still mesh dependent. Since the different methods of basal friction parameterizations are themselves mesh dependent, the results have to be different. What would be a problem on the other hand, would be that these 3 methods yield different results at a mesh resolution that is fine enough.

The authors conclude by saying that the MISMIP experiments are probably unrealistic as the friction remains very high up to the grounding line, while more realistic setups would have a basal friction reduced in the vicinity of the grounding line. Comparing results with such a friction would be of great interest for the paper as this is one of the main points of the discussion and conclusions. This manuscript is relatively short and the conclusions not fully supported by the results presented here, so adding such results would be appropriate and would make the paper much more relevant.

Finally, as mentioned in the introduction, results from Stokes models have been considered so far to be the reference for comparison with lower order approximations.

However, the results described here suggest that Stokes models are sensitive to both mesh resolution as well as treatment of basal conditions in the vicinity of the grounding, similarly to lower approximation models. If the latter have now implemented schemes to reduce their dependency to these numerical parameters (Feldmann et al., 2014; Leguy et al., 2014; Seroussi et al., 2014a), this remains a challenge for Stokes models and no solution seems to exist today. The discontinuous basal friction at the grounding line seems the more physical parameterization as mentioned in the manuscript, and the results presented with this method are closer to results obtained with lower order approximations and hydrostatic assumptions for grounding line positions. We would therefore treat grounding line result of simulations performed with the Stokes equations with more caution, instead of considering them as a reference.

2 Specific comments

p.3479 l.23: σ_{nn} is not defined

p.3481 l.8: I think that this condition is not appropriate for transient models. $u \cdot n = 0$ is a condition similar to the no penetration of ice in the bedrock for grounded ice. This works for ice shelves in steady state (and in the case of zero melting) but not always in the case of transient runs. The boundary condition at the base of the ice shelf is:

$$\frac{\partial z_b}{\partial t} + u \cdot n \left(\left(\frac{\partial z_b}{\partial x} \right)^2 + \left(\frac{\partial z_b}{\partial y} \right)^2 + 1 \right)^{1/2} = m \qquad (1)$$

with m the melt rate at the ice shelf base. So the condition $u \cdot n = 0$ can be applied only if $m = \frac{\partial z_b}{\partial t}$

p.3481 l.8: consider adding names for the boundary conditions (even simply BC1, BC2, BC3)

TCD

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p.3482 and p.3484: there is absolutely no description of the MISMIP and MISMIP3d experiments. These tests are commonly used in the ice sheet modeling community but a little bit of background on the set up of these tests would be appropriate to have a self consistent paper.

p.3486 l.2: It is not clear what “the behaviour in advance and retreat is not symmetrical” means. The behavior should actually be symmetrical, and the difference is caused by steady state not being reached in 100 years.

p.3486 l.7: Why are meshes different if the steady states are different? Are the meshes automatically refined during the simulation to better capture the grounding line position?

3 References

Feldmann, J., T. Albrecht, C. Khroulev, P. F., and A. Levermann, Resolution- dependent performance of grounding line motion in a shallow model compared with a full-Stokes model according to the MISMIP3d intercomparison, Journal of Glaciology, 60, 353–359, doi:10.3189/2014JoG13J093, 2014.

Leguy, G., X. Asay-Davis, and W. Lipscomb, Parametization of basal friction near grounding lines in a one-dimensional ice sheet model, The Cryosphere, 8, 1239–1259, doi: 10.5194/tc-8-1239-2014, 2014.

Seroussi, H., M. Morlighem, E. Larour, E. Rignot, and A. Khazendar, Hydrostatic grounding line parameterization in ice sheet models, The Cryosphere, 8, 2075–2087, doi:10.5194/tc-8-2075-2014, 2014.

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