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The Cryosphere Discussions

Interactive comment on "Marine ice-sheet experiments with the Community Ice Sheet Model" *by* Gunter R. Leguy et al.

Anonymous Referee #1

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I apologize for my late review.

Proper modelling of grounding line dynamics remains one of the main challenge for ice-sheet models. A suite of inter-comparison exercise has shown that models results are particularly sensitive to the mesh resolution in the vicinity of the grounding line. Sub-grid parameterisations have been shown to reduce the mesh size sensitivity allowing to give good results at resolutions that become achievable with typical grid sizes used in large scale simulations. Here the authors used two benchmark experiments (MISMIP3D and MISMIP+) to study the sensitivity of the results to sub-grid parametrisations of the basal friction and basal melting. The authors already studied the basal friction parametrisation in Leguy et al. (2014) with a flow line experiment and, here, extend this previous study to a 3D experipment. For the basal melting they describe sub-grid

scheme implemented in CISM.

Intercomparison exercices usually focus on the inter-model differences and I found always usefull to have detailled studies with individual models.

Most model report that sub-grid parametrisations decrease the model sensitivity to the grid size. In agreement with their previous 1D study, the authors found that the grid size sensitivity is decreased when there is a smooth transition of the basal friction in the GL vicinity. Results for basal melting are in contrast to previous studies that have reported that applying melt in partially grounded cells might lead to inaccurate results.

In conclusion, this in an interesting numerical study with a well established ice-sheet model. The manuscript is well written and clearly describe the experiments and results and I have only minor comments or questions detailled below.

Minor comments :

- Page 2, line 31, *depth-integrated versions of the Blatter-Pattyn approximation*: not sure if this is the good formulation, these cited models are indeed depth intergrated but they approximate the 3D Blatter-Pattyn model.
- Page 2, line 31, *The required resolution is coarser for sliding laws in which basal stresses are continuous across the grounding line*. Maybe this is not as easy and depends on the transition. See for example results from Gagliardini et al. (2016) and discussion on this subject in Galdstone et al. (2017).
- Page 2 Line 54, *but less so for models configured to solve the full Stokes flow equations*. Cheng et al. (2020) report that similar accuracy is obtained using sub-grid modeling with more than 20-times-coarser meshes in a Full-Stokes model. Please provide more references for sub-grid scheme in FS model to support this sentence.
- Page 3, Line 64 : *to obtain more accurate results*. Explain the meaning of ac-

curate in this context. Seroussi and Morlighem (2018) and Conford et al. (2020) report that sub-grid schemes can result in numerical errors not inaccuracies.

- Section 2 *model description*; I think not all readers will be familiar with the staggered grid. As this is used for both parameterisation maybe it could be benefical to have a small subjection before 2.1 to describe the CISM grid and introduce here that friction has to be computed at cell vertices and melt at cell corners.
- Section 2.2 Grounding line parametrisation for basal friction, from lines 144 to 151 ; It would be usefull to add a figure (or maybe in Fig.1) to illustrate this example.
- Page 6, line 153. Maybe start to say that you compute an *effective* basal friction coefficient using the friction law presented in 2.1 then that the sub-grid scheme is applied to ths coefficient.
- Figure 2. Maybe add the cell centers in your Figure.
- Page 7, Line 165-166 : *For buttressed ice shelves, however, the dynamics are more complex (Gudmundsson, 2013), and it is not obvious which melt treatment is best.*. Please explain what do you mean by more complex and not obvious.
- Page 8, Lines 188-192 : I don't really unsderstand this part and why this is here. In seems stange to say here that CISM usually the quadrant method but that another method has been presented before. See prvious comment ; maybe it would be benefical to have a specific section in the beginning of section 2 to explain how grounded fractions are computed at cell vertices and corners.
- Page 8, bottom line. *uniform basal shear stress factor*. C was introduced as a *coefficient* (page 4 top line) and is referred to as *shear stress factor* in the tables. Maybe better to use *basal shear stress factor, C,* eveywhere.

- Page 9, line 221 : *We will consider an experiment to be reversible if the difference in grounding-line location is 4 km or less*. Maybe give a better justification for this 4km.
- Section 3.2 ; might be beneficial to have distinct sub-sections for the setady state solution and the transient.
- Page 9 bottom line , *When the grounding-line position no longer changes significantly as resolution is increased, we consider the solution to have converged.*. Please quantify *significantly*.
- Page 10,top line ; Maybe would be more clear to break this sentence in two ; and following previous comment it would be more precise with a given threshold to define the convergence. Or avoid to use *converged* if there is no given criteria.
- Page 11, Line 249 : *and far cheaper than BP*. Could you give numbers ?
- Fig. 5. For p=0 there is no difference between Stnd and P75R ?
- Table 5 ; would be usefull to direcly add the values from Seroussi and Morlighem (2018) here.
- Page 21 lines 414-415 : *For a given melt parameterization, increasing the lubrication at the bed should lead to faster flow towards open water and greater IMAF loss* . Not sure if this is as simple as the rate factor is tune so that the grounding line is at the same postion, so in steady state the fluxes through the grounding line should be the same ; and as the rate factor has been adjusted this might also change the buttressing ?
- General comment on the sub-melt scheme ; In Cornford et al. (2020), the effect of the basal melt parametrisation is discussed and shown in their high melt scenario. The difference is especially visible in the evolution of the gorunded area

and position of the grounding line on the edges of the domain where the ice is relatively thin. I would find usefull here to show the same plots and maybe to repeat their experiment 2 ; to see if the results of PMP are consistent with the results of the subgroups using sub-grid schemes in Cornford et al. (2020).

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