EGUsphere, referee comment RC1
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Comment on egusphere-2022-492

Frank Pattyn (Referee)

Referee comment on "ISMIP-HOM benchmark experiments using Underworld" by Till Sachau et al., EGUsphere, https://doi.org/10.5194/egusphere-2022-492-RC1, 2022

The paper describes a particular application of the Underworld model. Underworld2 is an open-source, particle-in-cell finite element code tuned for large-scale geodynamics simulations, which allows for the tracking of history information through the high-strain deformation associated with fluid flow. In this paper, Underworld is applied to large-scale ice flow and compared to known solutions given by other full-Stokes model following the benchmark experiments given in Pattyn et al. (2008). The authors demonstrate that the results of their model is in overall agreement with results for other full-Stokes models, which shouldn't be surprising. The major differences are related to different numerical approaches that are imbedded in Underworld and the authors show what numerical approach is more appropriate for this particular application.

While this is in itself an interesting model application, to me this is a stepping stone towards a more in-depth study of ice dynamics/mechanics and especially ice rheology. Indeed, Underworld is a far more sophisticated model than the application to an isotropic ice mass without taking into account kinematic constraints (the geometry is fixed for most experiments with exception for experiment F). The authors mention a series of potential applications in the introduction, but it remains a limited list. In the outlook section, the potential is again given for improving flow laws of ice, but it remains limited to this (radar stratigraphy isn't mentioned anymore). A more exhaustive discussion of where potentially Underworld can be applied and how it can improve our understanding of ice mechanics, rheology, fabric, etc. would be more than welcome. Especially the link with ice core and seismic/radar studies are of importance. For instance, studies based on phase-sensitive radar (pRES) allow for quantifying COF in ice sheets using polarimetry and could greatly profit from the full capability of Underworld (e.g., Ershadi et al. (2022) and reference herein; Drews et al., 2015). Other examples are the elastic and visco-elastic response on short time scales due to drainage of supraglacial lakes within ice shelves, which have an effect on the ice shelf rheology (Banwell et al., 2019; MacAyeal et al., 2021), to name a few. Strengthening and emphasising this part is important, as Underworld has certain advantages over other ice sheet models, but also certain limitations. Ice sheet models, and definitely the majority that participated in ISMIP-HOM, are designed to make prognostic runs of ice sheets and glaciers across different time scales. Certain approximations are therefore made to make them computationally efficient and their focus is often on more complex boundary conditions to deal with atmosphere and ocean interaction, for instance. Underworld can be used to study certain aspects of ice dynamics, as the examples cited above. This should be stressed and strengthened.

Minor comments:

Line 48: The correct website: https://frank.pattyn.web.ulb.be/ismip/welcome.html (12/7/2022), but all material is also found on the TC website, which is maybe better to cite.

Figure 4: I guess these are examples of the type of mesh and not the actual meshing used (it seems rather coarse to me). Mesh resolution is discussed later, but it would be informative to express the different mesh sizes used (not only in number of degrees of freedom, but also in number of x,z or x,y,z).

Line 249: This is the only mention of x,z mesh size in the paper. What are other used? Do you think the highest resolution employed is sufficient to solve the problem? This can be tested by comparing the results for different resolutions and see whether or not this converges. What is the highest mesh resolution used? Is this sufficient for the purpose of this study and how may this potentially hamper other detailed studies of ice dynamics?

Line 345: You should essentially compare your result with the analytical solution rather than the numerical solution of two other models. Having said that, I realised that the analytical solution is not given in the repository of the ISMIP-HOM results. I added the matlab file from my archives that can be used for this purpose.

Conclusions: Please refrain from a bulleted list and write a section in plain text.

References

Banwell, A.F., Willis, I.C., Macdonald, G.J. et al. Direct measurements of ice-shelf flexure caused by surface meltwater ponding and drainage. Nat Commun 10, 730 (2019). https://doi.org/10.1038/s41467-019-08522-5

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Ershadi, M. R., Drews, R., Martín, C., Eisen, O., Ritz, C., Corr, H., Christmann, J., Zeising, O., Humbert, A., and Mulvaney, R.: Polarimetric radar reveals the spatial distribution of ice fabric at domes and divides in East Antarctica, The Cryosphere, 16, 1719–1739, https://doi.org/10.5194/tc-16-1719-2022, 2022.

MacAyeal, D., Sergienko, O., Banwell, A., Macdonald, G., Willis, I., & Stevens, L. (2021). Treatment of ice-shelf evolution combining flow and flexure. Journal of Glaciology, 67(265), 885-902. doi:10.1017/jog.2021.39

Please also note the supplement to this comment:
https://egusphere.copernicus.org/preprints/2022/egusphere-2022-492/egusphere-2022-492-RC1-supplement.zip