Comment on egusphere-2022-492
Anonymous Referee #2

Referee comment on "ISMIP-HOM benchmark experiments using Underworld" by Till Sachau et al., EGUsphere, https://doi.org/10.5194/egusphere-2022-492-RC2, 2022

General comments

The paper presents an application of the Underworld software, initially developed for geodynamical applications, to solve ice flow problems using the Full Stokes formulation. Underworld uses the material point method and shows interesting potential in addressing challenges related to ice flow modelling. The paper mostly reports about benchmarking Underworld using the ISMIP-HOM benchmark experiments. Besides the benchmarking exercise, the paper provides some technical details related to the treatment of sharp boundaries and solver performance. Efforts towards better resolving physical processes with the respect to ice flow are valuable. Underworld shows potential to include complex rheologies and exposes both a mechanical and thermal solver, for both 2D and 3D configurations.

Although reporting overall good results for the selected benchmarks, the paper is missing some results and discussion about the actual and claimed new and interesting features Underworld could actually handle. These features such as incorporating anisotropy, complex rheologies or thermo-mechanical coupling, points advanced already in the abstract, would truly provide a step forward in our understanding of complex processes affecting ice flow. To turn the current paper draft into a contribution making some impact, I would be very enthusiastic about seeing actually Underworld addressing some of the challenges (e.g. as listed on Line 71) and discussing them.

I would thus suggest, besides addressing the specific comment listed hereafter, to add a couple of examples that actually demonstrate the features a 2D and 3D MPM code can provide, with particular focus on mechanical anisotropy and complex rheology, in a major revision.
Specific comments

1.10: "solution for elasto-visco-plastic materials and includes mechanical anisotropy." that's exciting! Please provide some example as this is the main motivation of using Underworld.
1.13: "Furthermore, we" -> Furthermore, we.
1.19: "ice 1h" is not an obvious concept. consider providing some additional information or making it clear that you are defining "1h".
1.24: The recent development on "complex rheologies" goes beyond the 3 articles cited here. Consider including recent work by Ranganathan and Minchew (see http://glaciers.mit.edu/publications).
1.31-32: Maybe even more important, the strong dependence of ice rheology, i.e. viscosity, on temperature...
1.59 & Eq.1: If you have both σ and P, then your σ actually stands for the deviatoric stress tensor, usually denoted as τ. If you want to consider the full (and not "absolute") stress tensor, then you should remove the pressure derivative in Eq. (1). Please correct.
Eq.4: n_ice, consider using italic text only for math variables. Here ice is not a variable thus the italic should not be used. Please correct the other math notation for consistency.
Table 2: "basal shear stress parallel x", what does parallel x stands for? Please precise.
1.71: "Some of these challenges" consider including some of these in your results (see general comment).
1.216: Basal condition section. The solution of adding a viscous layer is not the most proper implementation of basal boundary condition. Since the ice-bedrock interface is crucial, it would very interesting to see how the proposed ad-hoc boundary condition implementation performs with respect to a more serious implementation of traction boundary conditions.
1.229: CPU time consumption section. It would interesting to get slightly more information in this section, namely regarding the hardware used as the SMP system (l.237) is not the most common processor one would have. Also, it would be interesting to know how much RAM the compute server had.
1.233-234: The number of DoFs depends on the element type also.
1.242: You only report 2D scaling and performance. What about 3D? Any data available. This would be very interesting as well in order to compare.
1.255: "cp Fig. 7c", what's cp?
1.273: Section Specific results. What's the logic behind having some results in SI, while others in the article. I guess it's fine doing so, but it would be good to state about the strategy as it is not obvious as such to the reader. Also, why not having all or most figures in the main paper, potentially as appendix. This would be much more valuable.
1.277: complimentary" -> "complementary" I guess.
1.282: Experiments B. Experiment B 3D shows not a so good fit in the Figure S5 at 5km, and in Figure S6 for 5 and 10km. Please provide more information on why, or try to get the discrepancy fixed.
1.327: "Fig.9shows" -> add space.
1.353: "Underworld2" where does Underworld2 come from. Until now, you always referred to Underworld.
1.367: Section conclusion. please refrain from using bullet point list
1.378: Here as well, potentially very exciting, but nothing is shown in this paper. Consider adding material regarding these features.

Figures:
For all figures, consider:
- adding axes information
- using bigger font
- homogenising the style
- using panel names (a, b, etc) in descriptions instead of left, right
- Work on the overall style