

Geosci. Model Dev. Discuss., referee comment RC2
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Comment on gmd-2022-190

Anonymous Referee #2

Referee comment on "SUHMO: an adaptive mesh refinement SUBglacial Hydrology MOdel v1.0" by Anne M. Felden et al., Geosci. Model Dev. Discuss.,
<https://doi.org/10.5194/gmd-2022-190-RC2>, 2022

The manuscript by Felden et al. describes the newly created subglacial drainage model SUHMO. Its mathematical formulation is based on a linked-cavity inspired water-sheet drainage mechanism which has been used in many recent models. Unconventionally, it allows for melt due to dissipation to occur and thus flow localisation is possible (akin to channelisation which I use interchangeably here), as was also done in the SHAKIT model (Sommers et al., 2020). However, in an implementation such as in SHAKIT, such a flow localisation mechanism leads to unbounded localisation. In a novel approach, SUHMO stabilises this localisation with a diffusion term, which renders the equations well posed.

The numerical implementation is based around the adaptive mesh-refinement (AMR) library Chombo; the ultimate aim is to eventually couple SUHMO to the well-know BISICLES ice sheet model which is based on the same library. The manuscript presents the numerical algorithms, based on multigrid strategies, used to solve the discretised PDEs in good depth.

The manuscript then presents comparisons to results of SHAKIT from the Subglacial Hydrology Model Intercomparison Project (SHMIP). These show that the two models produce very similar results, except in a no-SHMIP test-case where channelisation occurs the two differ markedly. Last the manuscript presents a test case in which its channelisation and AMR capabilities are displayed.

This is a well written manuscript which is well suited to be published in GMD once a few changes have been implemented.

Please note that I am not an expert in AMR nor multigrid methods, thus I will not comment on those parts of the manuscript.

Major points

Note that I have quite a few major points listed here. This is merely a reflection of my interest in the model and should not be seen as a harsh critique of the manuscript. In fact the manuscript is well suited to be published without implementing these suggestions. And indeed some of the suggestions may go beyond what should be expected from a GMD paper.

Show-case channelisation capabilities

Whilst the comparison to the SHMIP results of the SHAKIT model show that SUHMO indeed can behave very similarly to that model (as is expected), it would be more informative to show where there are differences. Thus I would prefer to see SHMIP experiments where there is significant channelisation. Note that the SHMIP instructions suggest to tune to the GlaDS output of runs A3 and A5, with the latter being channelised up to mid-domain in GlaDS. The SHAKIT submission only tuned to A3 and only shows channelisation in A6 (GlaDS has channels in A4 to A6), thus it is one of the models which shows the least channelisation in the SHMIP study. Also, the shown suite-B is channelised in GlaDS but not in SUHMO & SHAKIT. (Aside, presumably in a structured grid model such as SUHMO some noise would need to be introduced, e.g. via initial conditions, to nucleate channelisation in a setup like SHMIP-A.) Also, showing a comparison to GlaDS outputs for SHMIP cases would be informative, as that is currently the canonical distributed+channelised drainage model.

In a similar vein, the purpose of SHMIP suite E was to look at effects of an overdeepening which are influenced by pressure-melting point effects, i.e. by setting $c_t > 0$. Thus it would be nice and interesting to see results of SUHMO results with pressure-melt term turned on.

All in all, I would ban the one-to-one SHAKIT-SUHMO comparisons to the appendix or supplement as it merely shows the correct implementation of the model and not its novel capabilities. Replace these with results which show the channelisation capabilities of SUHMO in action. I realise that this is probably a reasonably large undertaking, so I would not insist on it, but I do think it would make the impact of the manuscript much larger. After all, one of the coolest bits of this model, in my opinion, is the regularisation of flow localisation with the novel diffusion term.

Figures of channels

Everyone and their dog want to see figures of channel systems. On this the manuscript fails. The closest gets Fig.11 which shows the channel in this setup but very small and blue-in-blue. It would be cool to see the channel system clearly for this case but also for

SHMIP A6 and E-Suite.

AMR and channelisation

The authors mention in Section 6 that for channelisation to occur resolution needs to be good enough. It would be good to elaborate on this point some more. Does the used refinement criteria allow to always capture the channels or could some be un-noted and thus not simulated?

Also, in the small-scale experiment (Fig. 4) the channel is resolved with ca. 10 nodes across its width. How well resolved is the channel in Fig.11 for R4? Should a channel always be resolved with several grid points across its width? Or is one enough? I think it would be ok to leave these questions open for a future study but mentioned they should be in the discussion.

Regularisation and comparison to "proper" channels

It would be interesting, and I think eventually necessary, to compare the SUHMO simulated channels to more classically simulated R-channels such as in GlADS. Do they conduct the same discharge at the same pressure gradient? How do parameters translate between a classic R-channel formulation and this regularised sheet formulation?

Smaller comments

Please only use abbreviations if really needed, i.e. reducing the length considerably and reducing line-noise for the reader. Thus remove the abbreviations "GrIS", "AIS", "GMSL", "GC". I'm a bit unsure about the "AMR" in the title, albeit it should be ok for GMD.

One of the main aims of this model seems to be eventually coupled to the BISICLES ice sheet model. I think this is worth mentioning in the abstract.

One of the main reason that subglacial hydro modelling is not further along is the lack of observations. This should be mentioned in the Abstract and Introduction.

Many figures are too small to be legible. For some of them, extending them to the full page width should be enough.

It would be good to look at convergence also for the case of section 6 as that features a channel.

I feel that the SHAKIT parameters used in SHMIP lead to too much sheet flow and not enough channel flow compared to the other models in SHMIP. I don't know what the reason was to pick those parameters, maybe SAHKIT struggles with high channelisation or the parameters were just the optimal ones. Irrespective of the reason, the SUHMO-results presented, based on the SHMIP-SHAKIT parameters, end up having to use very high inputs (both in run for Fig 4 and Fig 11) to get channels.

It would be good to have a master-scrip (or master make-file) which produces all the figures in this manuscript. Maybe there is one already, but 2min of browsing the github repo did not turn up one. State this in the "code availability" section.

Line by line

9: should it read "MultiGrid" to match abbreviation?

16, 17: citation needs an "e.g."

20: that "likely" is probably IPCC speak, why not reference the latest IPCC report?

29: also cite Gilbert et al 2022 <https://doi.org/10.1029/2021GL097507>

31: write "surface-lake water"

32-34: this sentence does not work, rewrite

37: compare length to lengths and not area!

39: cite Wertman (1962) for sheets, and Walder (1986) and Kamb (1987) for cavities

67: write "The SHAKIT model..."

67: isn't it "SHaKIT"?

75: write "We propose a small but significant ..."

84: "results"

95: I find "water gap height" odd as there is no gap in the water. Maybe "gap height" or "water height" or "water thickness", "water-filled gap height"...

110: it would be nice to contrast this formulation to the more commonly used Manning or Darcy-Weisbach formulation.

119: ".. and dropped from some similar models..."

120: I find the "effective drainage-system capacity" a confusing term, something like "bed-ice gap" would be much clearer. Irrespective of the term used, it should be clearly explained and its relation to b , the "water gap height". (or as the other reviewer writes, just use the same variable without discussion)

Eq.6: this cavity-sheet formulation was first introduced by Hewitt 2011
<https://doi.org/10.3189/002214311796405951>, cite.

Eq 7: this needs an explanation. Why do is this term introduced? Presumably to avoid complete closure of the sheet?

153: "... dissipation term of the melt rate (Eq. 5)."

Eq 12: what are A , u and F ? Define.

173: missing space

Fig 1: illegible, should be full width.

202: it should be stated earlier that this system is solved. Thus far it was only ever one equation.

Fig 2: illegible, should be full width. Also note in the caption that (c) has a vastly different scale.

Fig 3: larger. Why is P_w also plotted. Is that not a simple dependence on h , and thus has essentially the same error?

242: sentence does not make sense, rewrite

272: in the spirit of SHMIP, A4-A6 should be channelising test cases.

296: these instructions are also in the supplement of de Fleurian et al., maybe better also cite that less ephemeral source.

311: The point of SHMIP-E is to see effects of overdeepenings and those effects show only with a pressure melting term. Thus removing it is a bit odd, except to have a one-to-one comparison to SHAKIT. See "Major points"

336: state what the smallest Δx is (24m). Also, to resolve channels with several grid points, probably a R_8 would be needed (1.4m). Maybe state that R_4 does not resolve channels?

Fig 9: far too small!

Fig 10: even smaller!!

370: write in this paragraph something on whether we can be sure that AMR will refine in the places it needs to, to capture all channels.

371: state that refers to an ice flow model

373: I don't think this notation has been explained. Maybe better to just write it?

377: Iken & Binschadler 1986 (Fig 6) would be the canonical example,
no?

Fig 11: I feel this is the central figure of this paper and that it could go a long way to sell SUHMO well. In this light, it needs to be better legible, and larger. The channel in the top panels needs to be visible. A scale bar would be nice.