Review of "Reorganisation of subglacial drainage processes during rapid melting of the Fennoscandian Ice Sheet"

Letter

Dear Editor,

This manuscript aims to validate or verify a sophisticated subglacial hydrology model with the presences and absence of landforms known as "murtoos" in a paleo-ice sheet setting. The basis of this is that murtoos form under specific subglacial conditions.

I personally found this paper inspiring in that it integrated numerical modeling with observational data of sedimentary structures, using glaciological and sedimentary knowledge together. Also, I found the experiments well designed, discussion detailed and paper well written, potentially making a substantial contribution.

Despite this positive assessment, there are several questions and matters that I believe that should be addressed before publication. These matters are presented below.

Hopefully the authors find the review useful.

General comments

- I found the title a bit misleading about the topic of the paper. I think the manuscript speaks to the past location of hydraulic conditions below the glacier, but I found little in the manuscript about "reorganisation of subgalacial drainage processes". Maybe "organisation of subglacial processes." Additionally, "rapid melting" does not seem like a big part of the paper, especially by reading the abstract.

- Throughout, but especially in the abstract and introduction, the authors make statements of "parameterizing and testing models of subglacial hydrology", "basal hydrology in models", or "basal hydraulic conditions." These conditions or parameterizations can cover a wide range of features describing subglacial processes, include channel size or shape, water pressure, sediment transport, water velocity, distributed or channelized drainage. I believe the authors must be more specific and deliberate in describing the specific subglacial hydraulic features they aim to examine and link these features to murtoo development and persistence.

- Related to the last point, it seems that the description of murtoo formation could be improved. At times, it seems that hydraulic processes associated with different stages of murtoo development are in contradiction. An examples are given below.

- Section 3.1.1: From my reading of this section, it seems that no diurnal forcings were used. While this makes sense in a paleo setting, I am concerned about the impact on results. For instance on the GrIS, hydraulic head can very over 150m and bed separation can be in excess of 25cm (Andrews et al., 2014). It seems like such short temporal changes in subglacial hydrology could impact the formation of murtoos and move from one murtoo sequence to another over a very short time period (stages mentioned in Introduction, Hovikoski et al., 2023). I realize that application of such variable water discharges to hydraulic models can be difficult and in many scenarios not necessary. However, it seems like it could be important in this application.

- To the best of my knowledge GlaDS uses a semicircular channel geometry that is fixed (i.e. shape of the channel does not evolve). However, it seems that a key feature of murtoo development is low

broad channels, potentially with changing channel shape. This seems to be discussed in Hovikoski et al., 2023 and in the manuscript at lines 511 to 523. Hooke et al., 1990 speaks to the effects of channel shape on subglacial hydraulics. I am aware that certain trade offs can be made between the friction factor and channel shape to end up with similar hydraulic characteristics. In some applications this may minimize the impact of the semicircular assumption. However, because sediment transport relationships are scaled to unit width of the channel, sediment deposition can be sensitive to the width of the channel floor, and thus the general shape of the channel. However, please comment on how this may impact the results. Is this such a consideration with the development of the drainage system? What are the impacts of the semi-circular and potentially fixed channel shape on the formation of murtoos?

- More out of curiosity, how do the murtoo fields persist given the retreat of the glacier and the presumptive movement of the channelized drainage area up the glacier? Might retreat have occurred too rapidly to "destroy" the murtoos?

Specific comments

- Ln 46: to the best of my knowledge Werder et al. (2013) examines hard bedded characteristics below glaciers, "subsurface material" needs clarifying. Would an alternative be sediment floored channels or canals.
- Ln 59-71: the modeling work of F. Beaud is likely relevant here, as is the manuscript Hewitt and Creyts (2018) about eskers. Consider adding.
- Ln 87: what does "more dynamic" mean also, I can imagine what "interlobate joints" are, but please clarify.
- Enumerated 1-4 in Intro: I found this useful, and closely linked to Figure 10 in Hovikoski et al. 2023. Would the authors consider applying the cartoon in this manuscript? Additionally, it was difficult for me extract in the enumerated section the model output that would be indicative of this process in murtoo development. Please clarify. Might a table with one column of subglacial hydrology model output help?
- About points 1-2, I am a little curious about the idea that there is sediment deposition at the onset of melt. It seems that the conduit could be small, thus increasing water follow could increase sediment transport capacity, rather than cause sediment deposition. Although available observations of sediment transport are from the terminus, there can often be an increase in sediment transport at this time of the season.
- Ln 120: "higher water velocity" and "development of an englacial pond." To me these processes should not happen at the same place and time. Also, please define "upper-flow-regime."
- Figure 1: Could estimated glacier flow lines be added?
- Ln 195: "modified digital elevation model"... can the section where this is described be referenced?
- Table 1: I am curious if "mean annual velocity" is really an "input" or a model result or output, given the coupling with ISSM.
- Ln 215: "Fixed cross section" or "to the bed at every node." Does this go well here? or is somehow part of experimental design?
- Ln 361: "At node 3,842": maybe make clear that these nodes are representative of their surrounding.
- Figure 3c: should "D" be written as distance? also it seems like this is the end of the melt season of one year. Would it make sense for an "average " to be represented? Also would it make sense to add A-E in the plot in C as to clarify which plots go with which points?
- Ln 505–506: why 10^0 in one line and 1 in the next?
- Ln 515: "limited cavity expansion" might this be channel floor width?

- Ln 520: "The reason... sediment supply..." My initial reaction upon reading this is that I normally do not consider a distributed drainage system able to transport large amounts of sediment, thus I am unsure about how sediment supply up glacier could impact the results here.
- Ln 524: "More broadly" good pun after speaking of broad channels... "More generally"
- Ln 544-549: I might be missing something. However, melt water input location also seems like a control. For instance, Gagliardini and Werder 2018 may speak to this.
- Ln 558-567: From reading this paragraph, the authors seem to point out the differences between GrIS and the runs here. However, I seem to miss the analysis of the causes of this difference between the two systems.
- Ln 593: "sub-lobes they bound" something funny grammatically, also I am not sure what is meant.
- Ln 606: "1-2 day... walltime?"]
- Ln 613: $\sim 0.75°C$ how much more water does this result in?
- Ln 627: "macro conditions" what are these precise conditions?
- Figure A2. what is a median discharge? Also, it seems like units are missing.