The Cryosphere Discussions

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Comment on tc-2022-180

Anonymous Referee #1

Referee comment on "The impact of surface melt rate and catchment characteristics on Greenland Ice Sheet moulin inputs" by Tim Hill and Christine F. Dow, The Cryosphere Discuss., https://doi.org/10.5194/tc-2022-180-RC1, 2022

Review comments for "Brief Communication: The Impact of Interannual Melt Supply Variability on Greenland Ice Sheet Moulin Inputs" by T. Hill and C. Dow

In this paper the authors apply their Subaerial Drainage System (SaDS) model (Hill and Dow 2021), a supraglacial meltwater routing model, to a ~20 km^2 area for four melt seasons to assess how the supraglacial drainage system and moulin discharge changes between years with high and low melt intensities. At present there is not a description of the SaDS model in the manuscript or in the supplement which prevents the readers from understanding the physics of this approach without referring to the other manuscript. Further, there are no comparisons of the model to any observations over the four years considered here, without any description of model validation it is hard to determine if the results are physically meaningful. At present the paper's main findings are unclear. I do see potential in the work presented here, however, major revisions are required to address the structural and clarity issues and further develop the ideas presented for readers to understand or have confidence in results and conclusions derived from this work.

Specific Comments

1. The manuscript currently lacks any real description of the model, a more thorough description needs to be included in the main text with supporting details in the supplement. The results and discussion mention several model parameters which are never introduced, explained or justified (e.g., sheet mass, channel mass, lake depth, and incised channel length/channel incision depth with no figures that correspond to the details stated in the results).

2. The structure of the manuscript needs some reworking. For example a majority of the paper is framed to focus on the timing of meltwater delivery to moulins and how this

evolves over the melt season, however, a majority of the discussion focuses on supraglacial lakes, introducing Figure 3 that is not included in the Results section or described in the methods, and then does not mention lakes again in the conclusions. Similarly the end of the discussion compares the SaDS model to other modeling works that are not mentioned in the introduction, much of this content should be moved to the introduction to explain why this model is being used, what makes it unique, and how it differs from other models.

3. There there are many ideas and concepts that are either not introduced and come out of nowhere or that are briefly discussed but never resolved. **(i)** The paper focuses on seasonal trends in drainage system behavior however **Section 4.1** is very brief and makes several statements without a robust discussion. There are several statements that are unsupported such as that decreasing moulin diurnal amplitude is caused by the extent of the supraglacial channel network, however, there are no figures that show supraglacial channel network evolution. What are the errors associated with your lag times and the ones presented by Muthyala et al? How does this factor in to the comparison you present? Also, this section states that the lack of a trend is because of the domain size and number of supraglacial lakes, how these two things would affect moulin discharge and diurnal amplitudes should be discussed and cited. Further, this section puts this work in the context of only one other paper Muthyala et al., 2022, and does not mention other studies (e.g., Yang and Smith 2016, Yang et al., 2018, Smith et al., 2021). It would be interesting to know how these model results relate to the wider supraglacial drainage system literature. **(ii)** Section 4.2 is missing a description of differences in the timing of meltwater delviery to moulins with catchments that either have or do not have supraglacial lakes. What were the differences that the model produced? **(iii)** There is no discussion of where the lake depth measurements are coming from, no discussion that justifies or explains why this model allows lake level to rise meters above the maximum lake surface.

4. Lack of comparison with data to show that the model is actually physically representative of ice sheet evolution. A description of how the model was validated would add credibility to the results presented in this manuscript. At present it is unclear if these results are physically meaningful.

5. Repeated use of imprecise language, some examples below:

- L4 of the abstract "the model outputs predict *important differences*…"
- L11 controls on mass loss are vague and glossed over, this important topic warrants specifics
- L16 "…can improve the efficiency", the concept of drainage system efficiency has not been introduced and the phrasing "improve efficiency" is not clear
- L16 "meltwater to be evacuated at lower pressure", lower than what?
- L27 "significantly affect"
- L113 "noticeably later", is 4 days noticeable? State 4 days instead
- L120 "significant seasonal changes"
- L164 "uncorrelated" this needs to be shown, r values and p values needed
- L147 "saturate", what does this mean? Consider rephrasing
- L151 "distributed and channelized systems" this terminology is used here to describe

the supraglacial drainage system but it typically reserved for the subglacial drainage system. Further, the components of the supraglacial drainage system are not described in the introduction (I.e., flow through channels vs interfluvial flow). This needs to be rephrased.

more specific comments below with associated line numbers:

23: extreme surface melt events and lake drainages would overwhelm an inefficient drainage system as well.

27: “damp and delay” is introduced here but never referred to again,

32: lag time between what and what?, also include a citation to Yang 2018, or say “for example”.

55: “triangular computational mesh” is not introduced and is therefore confusing. Consider flipping the order so that your model description is before the data subsection.

65-68: RAMCO melt rate with a 3 hour resolution is downsampled to 20 seconds for the SaDS model run. How does this affect your results? What is the temporal error associated with your lag times? This needs a more thorough discussion

73: Describe what a distributed water sheet is and how this relates to physical flow structures

75-76: This triangular mesh/model domain is not shown in Figure 1 as cited. A figure with the model domain needs to be included in either the manuscript or at minimum in the supplement.

86: Define what you consider a melt event early on in this section, it would make it easier to understand the text and to distinguish from a diurnal melt cycle and a multi-day melt event.

95-100: Change the order of your examples so they are chronological, also what moulin are you referring to? Moulin input values are given but no specific moulin is named.

88-89: Here you state that moulin inputs broadly track surface melt with the volume dependent upon catchment size, moulin location and melt volume, citing Figure 2, however, this figure does not show this relationship. There is no quantified or demonstrated relationship between discharge and catchment geometry.

101: Having an amplitude of 100% doesn't make sense, and comparing melting to moulin inputs is similarly confusing. Discharge isn't going to zero because of recession flow. So these two things can't be compared directly.

146: Cascading lake drainage comes out of nowhere

147-150: Lake water level does not affect the timing of hydrofracture. Consider removing this paragraph as it is incorrect.

155-161: Melting of the channel's base and walls by the flowing water is not discussed in this section. This process is particularly important for the channels draining supraglacial lakes which can incise several meters into the ice.

169: correlation < 1? This doesn't make sense

178: The other models discussed in this section need to be introduced in the paper's introduction, at present they come out of nowhere.

213: "seasonal decreasing trend in moulin diurnal amplitude", do you mean moulin inputs? This is a very important distinction that needs to be made as you do not discuss moulin water level at all.

218-219: it is not clear that the moulin inputs presented here are realistic.

Figure 1, Outline individual catchments draining each moulin. At present I cannot tell which moulin is draining which lake, or visually compare catchment sizes. There is also not a triangular mesh as cited in the text. Also include a legend. Further, there is no explanation for why only three of the lakes are labeled when in Figure 1a I can see several other lakes within the catchment's boundaries. What is the pink moulin draining? I do not see any stream flow lines leading to that moulin.

Figure 2, Add a legend indicating what colors mean. The dashed/dotted line for melt rate is hard to see. Consider either making it solid black or another color. Right now it looks gray. (e.f.) Rename axis to state that the lag time is between solar noon and peak moulin discharge. The colors are very hard to see in general, particularly for (a) and (b), I can hardly tell that there are discharges plotted for pink and yellow moulins close to zero. It is also hard to tell the difference between the teal and green colors. Include which moulins are draining lakes and which are not in the legend as well. The color choice for lakes are also confusing, do the colors correspond with the moulins that drain them? If so, state that.

Figure 3, This figure is not introduced until the discussion.

Editorial Remarks

L14: Change “This” to “The”

L88: the surface -> the ice surface

L92: "limited short-term (several day) spikes” -> several day spikes

L97: moulin inputs and moulin discharge are used interchangeably, chose one and stick with it

L97: which moulin?