The Cryosphere Discussions

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# Comment on tc-2022-180

Anonymous Referee #2

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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-RC2, 2022

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## General Comments

This is an interesting modeling paper in which the authors simulate and compare the meltwater flow routing on a specific drainage area on the Greenland Ice Sheet for four different melt seasons. This paper specifically highlights the role of supraglacial lakes in the surface water routing delays on the bare ice ablation area of the Greenland Ice Sheet. This study is particularly relevant because of the lack of discharge data measured on the ice sheet, and because of the modeling challenges caused by the constant evolution of the landscape. Therefore, it is exciting to see a modeling study attempting to improve our understanding of what controls the amplitude and timing of peak discharge in moulins.

However, there are several points I believe should be addressed:

- There is a mismatch between the title, abstract, and introduction sections and the result and discussion sections.
  - The abstract suggests that the focus of the paper is on comparing high and low melt years, but there is no section about this comparison in the discussion. A comparison appears in the results, but no clear difference is demonstrated. How are high and low melt years defined? Is the difference between high and low melt years significant? If yes, what implication does this have for moulin and subglacial drainage dynamics? What are the other findings in this paper?
  - The introduction suggests that the paper will compare the routing over different internally drained catchments during two pairs of successive melt seasons However, only two more extreme cases (one from each pair) are presented in the main text, and the analysis focuses only on the moulin drainage basins containing lakes.
  - The discussion section mainly focuses on the influence of supraglacial lakes over the damping, lag, and discharge into moulins, and not as the title suggests, how melt supply variability influences the moulin inputs.
- The method section is missing a definition of what is a high and a low melt year. For

example, 2011 and 2012 seem both high to me. Is a high melt year more related to the multiday variability than the mean melt?

- The description of the results does not always differentiate between the main field site and the moulin drainage areas. For example, Figure S5 represents the entire area, instead of the individual catchments. In addition, the field site contains three moulins with a catchment with no lake and four moulins with a catchment draining a lake, and nearly only the moulins with the lake are described and discussed. An analysis of the moulin catchments without lakes would enable a comparison with the dynamics observed in the field data from Muthyala et al. (2022).
- The paper needs a clearer statement of the main findings and how they relate to our current understanding of supraglacial drainage systems and the simplifications made in models. Try to suggest appropriate usage for the model, and how it can be applied to a different field site. Are there any findings in this paper that could improve the simplified routing models that you mentioned in Section 4.4?

I suggest reformulating the title and modifying Sections 1-3 to match the current discussion findings, and redefining the scope of the results and how they fit in the current modeling landscape of the ice sheet. Alternatively, the results and discussion could extend to all the internally drained catchments simulated in this study and compare the consecutive melt seasons with each other. After reorganization and revisions, I believe this work would be of great interest to many readers, including myself.

**Specific comments**

The catchment is described as entirely within the bare ice zone (L47-48). However, it is likely that the drainage basin is covered by snow at the beginning of the melt season. What would be the potential influence of snow on the drainage basins at the beginning of the melt season until it is fully melted away? This is not currently discussed in the paper.

In general, in the text and the figures, it is not always clear when the analysis is over the total catchment and when it is focused on a specific internally drained catchment. For example, most figures display separate timeseries for each moulin catchment, while Figure S5 seems to represent the entire study area. In addition, In the result and discussion, it is often unclear which catchment is being referred to. For example in line 97, specific numbers are given, but it does not say which moulin catchment it refers to. It would be helpful if the authors provided a logical numbering for the moulin catchment, displayed a legend on the timeseries, and referenced those catchments in the text.

Section 4.2 is very interesting. However, it is missing an analysis of the controls on lags in catchments without lakes. The authors could use the simulation on the smaller lake-free internally drained catchments to compare the results with Muthyala et al. (2022) (L140-141).

The introduction is missing a description of the physical mechanisms that are expected to

control the evolution of the system. What is the known or expected behavior of the supraglacial routing system? How does the drainage system evolve? How channelized is it? Does the drainage system get more efficient? What controls the expansion/reduction of the channels/lakes? How do the model results compare to your expectations based on the physical mechanisms?

**Line Comments**

L 15-19: Andrews et al. 2014 demonstrate that the water level in moulins did not drop as expected previously, and found that it was the connectivity of the unchannelized portion of the bed that controls the seasonal variability of ice flow.

L 43: How are high, average, and low melt years determined? Is it related to the mean discharge or the intensity of the peaks?

Figure 1: The drainage basin displayed is small. It would help to have the moulins numbered on the figure to match the timeseries on the other figures. Sometimes the black outline is not very visible.

L 67-69. in the results and discussion, only 2012 and 2015 are displayed in the main text. In addition, the pairs 2011-2011 and 2015-2016, are not compared with each other in the text.

Figure 2: The surface melt is defined as black in the caption, but it appears grey and dotted to me. There is a lot of information displayed on each subfigure. Would it be possible to plot the melt rate in a separate subfigure at the top instead of on each subfigure? The addition of Figure S5 to this graph would be nice too.

L87: Only 2012 and 2015 are displayed in the main text, but 2011, and 2016 are mentioned.

L88-89: Could you display the catchment properties for each moulin? (maybe a table with name, catchment size,  catchment melt volume, and size of the lake if present). This would help compare the variability between the different internally drained catchments of your study. Does the catchment size for each moulin vary from one year to the other, and throughout a melt year?

L89-90: Could you elaborate on “Multi-day increases in melt rate cause a 1–3 day lag in

peak moulin input…”? Where specifically on the figure do you see this?

L90-91: “… with adjustment in the extent and size of incised supraglacial channel...”. Are you referring to Figure S5?

L 92-100: It is unclear which moulin basins are referred to.

L93: Figure 2a is mentioned but 2012 is not included in the sentence

L95-97: “... frequently recurring intense melt events result in persistently high discharge into moulins with large differences between minimum discharge… “. Is the discharge really persistently high in 2012 compared to the other years? It seems to me that the discharge in 2012 drops when there is lower melt production, similar to the other years.

L 101: Did you mean “... nearly 100%...” of the mean melt?

L 103: Is the diurnal amplitude a peak-to-peak amplitude? Could you discuss how the percentage of the diurnal amplitude of the mean discharge compares to the same ratio calculated with field data? For example, in Muthyala et al., (2022) the peak-to-peak amplitude seems to be nearly two times larger than the mean discharge.

L110-111: How do you know when the lake is filled? Is there any model output that could be displayed to show the relative filling of lakes?

L114: When is the initial onset of positive temperature? There is no figure displaying the temperature timeseries.

L 117: what causes the melt out of small channels? It is unclear to me why the small channels get created at the beginning of the melt season and then melt out. I suppose I would expect an increase in channelization over the melt season, and therefore, an increase in the diurnal amplitude of discharge (L124-127). Is this a pattern observed in field measurements?

L 117-120: Consider moving this part to the discussion.

L 124: the end of the sentence "... attributable to changes in the extent of the supraglacial channel network." seems to refer also to Figure S5. However, Figure S5 only displays the years 2012 and 2015.

L 131-133: What about the lake-free moulin catchment (yellow and green situated NE of the study area? What is the size of those catchments and how do they compare with Muthyala et al.? The diurnal amplitude is not very visible for that catchment in Figure 2, due to the scale of the y-axis.

L140-141: How does the lag time compare with Muthyala et al. (2022) and other field measurements from other studies for the internally drained catchments without a lake simulated in the study? (yellow, green, and purple moulins). For those lake-free catchments, what controls the lag times?

L147. Could you elaborate on the saturation at the outlet elevation?

Section 4.3: Based on your results, when a lake is present on a drainage basin, would it be possible to calculate the discharge at the moulin based only on the lake elevation change and the lake area? Would such a correlation improve stream discharge estimation from satellite imagery?

Section 4.4: This section's purpose in the discussion is unclear to me. The comparison with other models is interesting, however, the takeaway message is unclear. Should this section maybe be in the intro or the model description?

L157-161: Is there field evidence for overflowing supraglacial streams? Is this a frequent situation in your model simulations?

L165: Is there any way to display on the figures when lakes are filled? Is this a dynamic process?

L 203-204: Only two years are presented in the figures in the main text.

Figure S1: Melt doesn't follow the same color coding as the figure in the main text. Is there a moving average in this figure? The second part of the legend might belong to Figure S2 ("Light colors show instantaneous diurnal amplitude, and bold colors show the seven-day moving average."). To what corresponds to the black line?

Figure S2 : There is not much difference between ‘light’ and ‘bold’ in the figure.

Figures S1, S2, S3, and S4 duplicate the information displayed in Figure 2.

Figure S5: This Figure only contains the years 2012 and 2015. In addition, they are not present in the main text. This would be a good addition to Figure 2.

**Technical comments**

L 159-161. Consider breaking up this sentence. "... with **a** large increase...", ...'and stored in supraglacial..."

Throughout the paper, there’s a mixed-use of kilometer and meter. Example, L 50-54.