Author Response to RC2 for “Brief communication: The Impact of Interannual Melt Supply Variability on Greenland Ice Sheet Moulin Inputs”

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Reviewer Comment	Author Response

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.

We appreciate the reviewer’s interest in our manuscript. The comments are addressed individually below, followed by a high level plan to address both reviewer’s comments (**General Changes**).

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.

We agree that the focus of the manuscript was not entirely consistent between sections. See the proposed **General Changes** related to this comment in addition to our specific responses below.

- 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?
  We did not find clear differences in the amplitude and timing of moulin inputs for all sub-catchments between years with different melt forcing. Instead, variations in melt intensity tend to lead to abrupt shifts in the magnitude and timing of moulin inputs. The same pattern was found observationally by Muthyala et al. (2022). Since we have not found a clear difference related to overall melt volume, we will instead focus on exploring the impacts of seasonally and annually varying melt volumes on the character of moulin inputs.

We will rewrite the abstract to motivate the major aspects of our work:

1. To investigate the possible (modelled) behaviour of moulin inputs, in terms of amplitude and timing, in response to different patterns of melt forcing
2. Compare SaDS to other supraglacial hydrology models
3. Suggest a framework for selecting an appropriate supraglacial drainage model that depends on the level of detail and timescale of prospective modelling studies.

- 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.
  Following from the comment above, the introduction will be rewritten to motivate the three listed themes to more fairly describe the goals of the remainder of the paper. We will also briefly describe the models we will later compare SaDS to, and will describe the key physical mechanisms modelled by SaDS. More generally, we have extended the analysis to include the moulin basins without 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.
  We will integrate these sections of the paper by adjusting the abstract and introduction as described above, and by explicitly focusing the discussion and conclusions on the questions posed in the introduction.

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).

We have developed a consistent naming and colouring scheme between moulins and the lakes which they drain, and have added the corresponding catchments to Figure 1. We will update the text to refer to specific sub-catchments when appropriate.

We have analyzed two of the small, lake-free catchments to provide a more robust comparison to the field data from Muthyala et al. (2022). This comparison will form one of the main discussion points.

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?

See the proposed **General Changes**. There, we suggest a few specific questions we will clearly answer that will make the main findings clear. Specifically, the main findings will be:

- The influence of model-induced variability in moulin inputs (i.e., changes in flow velocity, lake storage, and the extent of the supraglacial channel network that impact the amplitude and timing of moulin inputs) is the strongest in years with lower melt rates, and weakest in 2012.
- The four large catchments with supraglacial lakes have consistently lower diurnal amplitude in moulin inputs and peak moulin inputs occur later than for the three small catchments without supraglacial lakes. However, we can not fully disentangle the effects of catchment size from supraglacial lakes.
- The observational record presented by Muthyala et al. (2022) provides an important template for future field studies which, for the purpose of validating the model, should investigate streams with a range of discharge magnitudes within catchments that do and do not contain lakes.
- The appropriate supraglacial drainage model should be chosen based on a proposed modelling studies sensitivity to the amplitude and timing of moulin inputs, and the timescale in which variability in moulin inputs may impact the modelling results.

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.

We thank the reviewer for their helpful suggestions. See the proposed **General Changes** for our plan to refine the scope of the current work to reach the conclusions listed above.

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.

This is a good point, and we agree that at least part of the study site is snow-covered at the beginning of the melt season.

- Higher snow albedo than ice albedo would reduce melt rate for snow-covered elements
- Lower percolation velocities at base of snowpack compared to across bare ice (e.g., Arnold et al., 1998) would further reduce the diurnal amplitude & increase the lag time of streamflow
- Retention within the snowpack would delay meltwater transport until the snowpack melts. The previously retained runoff would be released over the duration of the final snowmelt event, resulting in a strong melt pulse in the early melt season.

We will add a discussion of these impacts to the revised manuscript and note that future development of the model could include processes emulating flow through a snowpack.

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.

We have developed a consistent naming and colouring scheme between moulins and the lakes which they drain, such that, for example, lake L3 drains through moulin M3. Catchments 1–4 will contain lakes, and catchments 5–7 will be the three smaller lake-free catchments. We will use this numbering to add a legend to the timeseries figures and to be more specific in the text which catchment(s) we are referring to.

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 reviewer raises a good point. The primary influence of supraglacial lakes appears to be to reduce the amplitude of moulin inputs and delay the timing of peak moulin inputs. Apart from these factors, the controls on moulin inputs appear similar for catchments with and without lakes. For example, we have quantified the extent to which surface melt can explain variance in moulin inputs, lag time, and moulin amplitude, and we do not find a difference in the relationship for catchments with and without lakes. We will add the corresponding content to the Results and create a new section in the Discussion to explain this more fully. We will also compare the modelled seasonal trends in amplitude and lag time to the trends reported by Muthyala et al. (2022).

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?

We will add a brief description of the physical mechanisms we attempt to capture with the SaDS model within length limitations of the current format. See also the proposed **General Changes** to refocus the Introduction to align more closely with the Results and Discussion sections. Some of the mechanisms we expect to control the drainage system are:

- Downward incision of supraglacial streams by flow-related potential energy dissipation and by shortwave radiation penetration (particularly for shallow streams). SaDS currently only represents potential energy dissipation.
- Ablation of the ice surface (in the modelling context, this specifically means ablation of 'elements') according to the local energy balance.
    - We expect that the balance between incision and ablation controls the extent of the channelized drainage system
- Rapid supraglacial lake drainage (e.g., Das et al., 2008)
- Slow overspilling of supraglacial lakes as the water level reaches the outlet level (e.g., Chudley et al., 2019)
- Snow plugs in streams and moulins (e.g., St. Germain & Moorman, 2019)
- Development of asymmetric "canyons" associated with deeply incised supraglacial streams (St. Germain & Moorman, 2019).

For specific questions:

- What is the known or expected behavior of the supraglacial routing system?
  At the basic level, the supraglacial drainage system acts to reduce peak moulin inputs and delay the peak timing. We have described this in the introduction.
- How does the drainage system evolve? How channelized is it? Does the drainage system get more efficient? Does the drainage system get more efficient?
  It is not yet fully determined how drainage efficiency evolves. Yang et al. (2018) parameterize drainage density as decreasing through the melt season (e.g., drainage efficiency decreases). Based on satellite imagery, Yang et al. (2022) suggest a linear relationship between drainage density and runoff, and suggest this relationship can be used throughout the melt season to estimate drainage density, but do not explain the physical mechanisms that permit changes in drainage density on short (~1 day) timescales. Based on previous work with the SaDS model (Hill & Dow, 2021), large channels (discharge >> 1 m^3 s^{-1}) grow larger throughout the melt season, since melt by heat dissipation along the channel bed and walls is faster than ablation of the adjacent ice surface, while small channels (discharge << 1 m^3 s^{-1}) melt out as ablation of the adjacent ice surface is dominant. The net effect is that more flow is captured by the large channels, but drainage efficiency decreases away from large channels.
- What controls the expansion/reduction of the channels/lakes?
  The evolution of channels depends on the balance between melt along channel perimeters and ablation of the adjacent ice surface (e.g., St. Germain & Moorman, 2019). The volume of water stored in lakes depends on difference between the rate of inflow and outflow (which may be due to rapid lake drainage (e.g., Das et al., 2008), rapid incision of a supraglacial spillway (e.g., Kingslake et al., 2015), or gradual overtopping (e.g., Chudley et al., 2019). SaDS includes these mechanisms except for rapid lake drainage, and they are described in the model description section with the key equations now included in an appendix
- How do the model results compare to your expectations based on the physical mechanisms?

Given the variability in surface melt rates, our model results do not clearly display how moulin inputs change with seasonal drainage evolution. This is unexpected based on the work of Yang et al. (2018) and Yang et al. (2022), as well as synthetic modelling with SaDS (Hill & Dow, 2021), but is in line with in-situ streamflow observations (Muthyala et al, 2022). We will explore this in the discussion.

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.
We see that the wording here was not as precise as it should be. Since we do not directly address the subglacial water pressure response to our modelled moulin inputs, we will reduce this discussion to a simple statement that subglacial hydrology impacts basal motion with a few key references (e.g., Bartholomew et al., 2012; Sole et al., 2013; Andrews et al., 2014).

L 43: How are high, average, and low melt years determined? Is it related to the mean discharge or the intensity of the peaks?
We will explain our definition of “low”, “average”, and “high” melt years. We define these melt years based on the total seasonal melt volume within our study site.

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.
Catchments, lakes, and moulins will be numbered, and a legend will be added to the timeseries figures to relate the timeseries curves to the lake and moulin positions. We are also adding the boundaries for the seven supraglacial sub-catchments to this figure.

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.
As part of addressing the **General Comments**, different melt seasons will be explained as being used to investigate the full spectrum of drainage system behaviour. Since 2012 and 2015 are the years with the highest and lowest total melt, we will justify our focus on these in the main 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.
We agree that there is a lot of information displayed on each subfigure. However, we believe it is important to plot the melt rate in each panel since it allows the timing of changes in surface melt and the displayed quantities (discharge, amplitude, lag, lake level) to be directly compared. We will update the caption to correctly describe the melt rate line style. We have shifted our focus away from seasonal changes in channel extent, since the consequences of channel evolution

are not the primary feature observed in moulin inputs, so we do not believe it's relevant to include Figure S5 here.

L87: Only 2012 and 2015 are displayed in the main text, but 2011, and 2016 are mentioned.
We will add a reference to the appropriate supplementary figures. Only 2012 and 2015 are displayed since they represent the highest and lowest total discharge.

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?
The SaDS model does not explicitly differentiate between individual catchments in the same way as, for example, for SRLF model. We have been able to define catchments from the modelled hydraulic potential, and we do not see changes in catchment size between years or throughout a melt year. This may be because the elements are large enough that the difference in elevation between neighbouring elements is greater than the maximum water thickness, such that flow directions are primarily determined by surface topography.

We do not have space in the main text for a table with catchment details, but we will add this to the supplement, as we agree it would be useful.

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?
We propose to focus the Results section more on the amplitude, lake level, lag time, and how this differs with catchment size and the presence of lakes to make the results more quantitative and specific than, for example, the identified sentence. In this case, we were referring to the highest discharge values observed in 2012, which occur ~2 days after the peak in surface melt rate.

L90-91: "… with adjustment in the extent and size of incised supraglacial channel...". Are you referring to Figure S5?
Yes, we are indirectly referring to Figure S5, Figure 2g, h, and Figure S4.

L 92-100: It is unclear which moulin basins are referred to.
We will add reference to the specific catchments we are referring to (L1).

L93: Figure 2a is mentioned but 2012 is not included in the sentence
We will remove the reference to Fig. 2a.

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.

We agree that this sentence was not precise. We propose to focus instead on the specific instances of large changes in moulin inputs described in L97-100.

L 101: Did you mean “... nearly 100%...” of the mean melt?
Our wording is unclear here. We mean that surface melt pauses overnight. This is in contrast to the behaviour of model inputs described in the following lines.

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.
We defined diurnal amplitude as peak-to-peak and will add this to the text. To compare to Muthyala et al. (2022), we will scale the amplitude by the mean discharge in Fig. 2 (c, d) and focus on the small, lake-free catchments.

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?
We infer that the lake has filled by comparing the lake level to the steady level at the end of the melt season and by the downstream impact on moulin inputs (Fig. 3). We will explain this in the text.

L114: When is the initial onset of positive temperature? There is no figure displaying the temperature timeseries.
This was an imprecise statement where we implicitly used temperature as a proxy for melt rate. We will make this precise by simply using melt (shown in Fig. 2) directly.

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?
See our discussion of the mechanisms controlling evolution of the drainage system. Small channels melt out by ablation of the surrounding ice surface. The initialization with many small channels is a coarse way to represent channelization in snow and the impact of rapid snowmelt.

The longest observational timeseries is that of Muthyala et al. (2022). As we find in our model outputs, Muthyala et al. (2022) don’t observe obvious seasonal trends in the diurnal amplitude (Fig. 5a) due to variations in melt rate.

L 117-120: Consider moving this part to the discussion.
Following the **General Changes**, we are no longer focusing on changes in the stream network extent.

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.
Following the **General Changes**, we are no longer focusing on changes in the stream network extent.

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.
We have scaled the y-axis of the diurnal amplitude panels of this figure by mean discharge, so that the amplitude of all moulins can be compared in a meaningful way, including compared to the results of Muthyala et al. (2022) in the case of the small, lake-free catchments. This scaling reveals that these small, lake-free catchments have consistently higher diurnal amplitude in moulin inputs than the other large catchments with lakes.

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?
These are excellent points, and we plan to address these and other questions in a revised Discussion section (see response to the final **General Comment**). From preliminary work, the lag times in the catchments without a lake are 2–4 hours, where Muthyala et al. (2022) report 1–3 hours. For a ~60 km^2 catchment with peak flow < 40 $m^3 s^{-1}$, Smith et al. (2017) report a lag time of 5.5 hours, and Smith et al. (2021) report a lag time of 6 hours. These compare well to our modelled lag time for moulins with inputs >40 $m^3 s^{-1}$ of 4–7 hours (Fig. S3). We will add these details to the main text.

L147. Could you elaborate on the saturation at the outlet elevation?
What we mean here is that the lake water level can transiently exceed the elevation of the lake outlet when inflow exceeds outflow. This means that the maximum hydrostatic pressure acting on incipient fractures on the lake bed can exceed the pressure that would be computed by assuming the lake level is exactly at the outlet elevation. We will make this clear in the text.

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?
For basins with lakes, we have computed that the correlation between lake level and downstream moulin inputs is between R^2=0.22 and R^2=0.92 ($p < 0.01$). However, the exact relationship differs between each lake basin, so any such relationship would likely need to be calibrated with model outputs or in-situ streamflow measurements for each basin.

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?
The intended purpose of this section was to provide justification for recommendations on when an expensive process-based model such as SaDS is important, and where a simpler and more efficient model (e.g., SRLF; Banwell et al., 2012) may be appropriate. However, we did not make this purpose or these recommendations clear. As part of the overall restructuring, appropriate background material from this section will be moved to the Introduction and our recommendations and justification will be clearly laid out. We suggest that the appropriate supraglacial drainage model should be chosen based on (1) the sensitivity of the proposed modelling study's results to the amplitude and timing of moulin inputs, and (2) the allowable computational cost allocated to the supraglacial model.

L157-161: Is there field evidence for overflowing supraglacial streams? Is this a frequent situation in your model simulations?
Exceptionally clean and smooth ice surrounding supraglacial streams may suggest that streams have overflowed in the current melt season. For example, see (b) and (c) https://www.antarcticglaciers.org/wp-content/uploads/2021/07/figure1_HR-scaled.jpg (credit J. Gulley) and Figure 1 from Smith et al. (2015). This is a frequent situation in our model simulations. This may be due to SaDS neglecting the contribution of shortwave radiation to melt along stream beds, or from neglecting the enhanced melt on the portion of channel walls above the waterline. Both of these processes are difficult to resolve since they should properly be a function of channel geometry, which we are forced to model as fixed to make the model numerically tractable. These limitations are discussed in detail in Hill & Dow (2021).

L165: Is there any way to display on the figures when lakes are filled? Is this a dynamic process?
For Figure 3, we could plot a vertical line or shade the region above which the lake is 'full' according to its outlet elevation. Unfortunately, we will need to remove Figure 3 given the length limitations.

L 203-204: Only two years are presented in the figures in the main text.
We will explain our reasoning for including two years (2012, 2015) in the main text in Section 3.

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?
Apologies for the inconsistency in the color coding and the inaccurate caption.

Figure S1: The solid black line shows the 24-hour moving-average melt rate. There is no moving average performed on the discharge data.

Figure S2-S3: Light colours show instantaneous quantities and bold colours show 7 day moving-average quantities.

These captions will be corrected.

Figure S2 : There is not much difference between 'light' and 'bold' in the figure.
The lineweight of the solid line will be increased to make the distinction more clear.

Figures S1, S2, S3, and S4 duplicate the information displayed in Figure 2.
We acknowledge that some of the information here is duplicated from Figure 2. However, we think it is useful to have all modelled years present in these figures to save the reader from needing to move between the supplement and main text to compare certain years.

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.
The other years (2011, 2016) will be added. Since we are shifting focus away from seasonal evolution of the channel network, we do not think it is relevant to add the content from Figure S5 to Figure 2.

Technical comments

L 159-161. Consider breaking up this sentence. "... with a large increase...", ...'and stored in supraglacial..."
We will restructure the sentence as suggested.

Throughout the paper, there's a mixed-use of kilometer and meter. Example, L 50-54.
We will translate all lake surface and catchment areas to km^2.

General changes

To address the general and specific comments above, and those of Reviewer 1, we propose to revise the manuscript as follows.

Introduction

- Reduce the discussion of the impact of meltwater supply variability on sliding velocity, since this is not directly supported by our work.
- Introduce and describe the models that are currently introduced in Section 4.4.
- The primary goals of the communication will be to:
  - Investigate the detailed modelled drainage behaviour for a catchment containing small catchments without lakes and large catchments with lakes.
  - Quantify the relationship between surface melt and the magnitude, amplitude, and timing of moulin inputs, and between supraglacial lakes and their outlet moulins.

    - Compare SaDS to a range of comparable models from the literature.
    - Define the situations where a process-resolving model may be advantageous and where such a model may not be practical.

Data and Methods

- Switch the order of Section 2.2 (Data) and 2.3 (Model) to describe the model before explaining the data used to drive the model
    - Explain key model mechanisms (e.g., balance between heat dissipation along channels walls and ablation of adjacent ice surface) in more detail in the model description section
    - Summarize the key model equations in an Appendix
- Explain that we model four years with varying melt intensity and melt season durations to capture how drainage behaviour varies with different realizations of melt forcing
- Assign consistent labels between moulins and lakes, and explicitly include these labels in the text when discussing particular catchments, moulins, or lakes

Results

- Use catchment labels to make discussion of particular features more precise
- Quantify relationships that are currently described qualitatively (e.g., computing the proportion of variance of moulin input, lag time, diurnal amplitude, and lag time that is explained by surface melt rate)
- Compare quantities of interest (moulin input, amplitude, lag time) for catchments with and without lakes and quantify the extent to which changes in lake level determine inputs to downstream moulins

Discussion and Conclusions

The Discussion and Conclusions will center around a few questions supported by our Results:

1. What seasonal trends are observed in the modelled supraglacial drainage system? How do these vary with melt forcing?
2. How do supraglacial lakes impact modelled moulin inputs?
3. How do these modelled inputs compare to observations by Muthyala et al. (2022), in particular for our smaller catchments that do not have a supraglacial lake?
4. How does the behaviour we see across years with varying melt forcing compare to what would be predicted with other models? When might it be important to use an expensive process-resolving model, and when might it be appropriate to use a simpler and less computationally expensive model?

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