The Cryosphere
Anonymous Reviewer

A comparison of supraglacial meltwater features throughout contrasting melt seasons: Southwest Greenland

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General comments:

This manuscript investigates the seasonal evolution of supraglacial meltwater features in the Russell/Leverett glacier catchment, SW Greenland, with a focus on drainage distribution and characteristics from a low (2018) and high (2019) melt year and assess its implications, including ice velocity and potential drainage response in future warmer years. Of particular interest is the attempt by the authors to include small (i.e., <0.0495 km^2) and shallow meltwater features (e.g., slush), which can be overlooked in mapping studies, however important to consider. The authors use a pre-existing method (Corr et al., 2022) for all supraglacial meltwater feature extraction and then seek to partition these features into those that drain and refreeze, with links to ice velocity events.

The main findings are that (i) surface meltwater feature characteristics and distribution differ between a high (2019) vs low (2018) melt season, with meltwater features developing earlier (May) and occurring further inland (2000 m a.s.l) in the high melt season (2019); (ii); small meltwater features (<0.0495 km^2), predominately small SGLs, are important features of the system with their drainage prevalent at lower elevations and; (iii) the drainage of features, including those that are small, can generate an ice velocity response, with inference that a sustained speed-up in ice flow may occur at this catchment in the future.

Whilst I appreciate the effort put into the development of this study and manuscript, my view is that this study is not particularly novel in terms of the methods used (well-versed in literature) or the location of the study area in SW Greenland, which has been well documented and the focus of many supraglacial hydrology studies over recent years. Additionally, whilst you present the importance of small meltwater features (<0.0495 km^2), particularly small SGLs, and appreciate why they were included in terms of your findings (as agree, they are important!), I struggle with your use of the term '*all meltwater features'.* From Figure 1, it seems your river and stream network is lacking (even with the resolution of imagery used), with only larger portions of rivers extracted, often associated with either inputting or outputting an SGL (interpreted from Figure 1). Therefore I think your use of the term *'all meltwater features'* insinuates complete supraglacial drainage network maps and analysis (including smaller, shallower features such as the river and stream network) across the Russell/Leverett catchment, which is misleading as believe this is a basic supraglacial network at best. I therefore think there needs to be increased clarity of this or further mapping to be undertaken.

I am also unsure as to the method used for partioning meltwater that 'drains' and refreezes' as it has been shown in the literature that meltwater can stay active for much longer (i.e., weeks) post surface melt cessation. I think there needs to be some further clarification as to the simplicity of the method and acknowledgement that meltwater can linger for longer post surface melt cessation. Additionally, a figure showing this occurring in imagery (from your manual interpretation) may help you here, which could be placed in your supplementary information.

In addition, the link to ice velocity and drainage/refreeze events I believe, at times, is rather subjective. I provide further comments on these issues below.

<u>Major comments:</u>

Feature extraction and terminology:

In Figure 1, you provide your mapped supraglacial meltwater features for 2018 and 2019 (only figure presenting these in the main body and supplementary information, which is a shame), however it mostly looks like only SGLs and some slush have been captured, with the caveat of some larger, wider sections of supraglacial rivers (these networks look rather fragmented and incomplete). After searching one of the images used via Copernicus Browser (2019-07-25) and comparing with other studies in this area which have captured supraglacial features, there looks to be a number of rivers and streams not captured, or fragmented, by your method.

This is a shame as you state in your *introduction 'we precisely delineate all surface meltwater features (i.e SGLs > 0.0018 km², as well as rivers and slush)'* (Line 85) and within your methodology you state: *'Our threshold values are lower than those used by Corr et al. (2022), which was a deliberate choice as we wanted to detect shallower meltwater features (including small streams and slush) than those considered in that study'* (Line 150-153). However I do not see many small, shallow streams or continuous river channels captured (perhaps a few within the slush regions at most). It is my understanding that a significant part of this paper was to map *all supraglacial meltwater features*, in particular those of small, shallow size, across the catchment to examine feature distribution, evolution and low-high melt year comparison, with an emphasis on their importance albeit their size. I therefore think there are a number of things that need to be addressed in this manuscript and a few avenues which could be taken to improve the dataset and/or clarity in this paper:

1) As stated already, it looks like you have only captured segments of some of the primary (larger) supraglacial river channels within your drainage network, mostly where they input or output an SGL. Therefore, I think you need to make this clear in your introduction and/or methodology that you only partially-capture these types of channels (i.e., primary rivers) and not smaller stream-type networks (i.e., secondary tributary networks which are shallower and transient) and explain why (method limitation?). I think to aid this, it would help to give brief definitions of these differences as per the literature (e.g., Pitcher and Smith, 2019) in your introduction and then, throughout the manuscript, make sure you refer to these features as 'rivers', rather than interchangably between 'streams' or 'rivers/streams' to make it clear (as you have in some areas of text).

2) After performing NDWI and subsequent thresholding (via Corr et al., 2022), you state you partition your features into slush and rivers via manual interpretation of geometry and colour. I think an additional figure showing these partitioned features (lakes, slush and rivers) mapped would enable the reader to visually understand and assess their differences (i.e., the distribution of individual meltwater features, the overall collective drainage network characteristics and meltwater drainage behaviour – particularly that of smaller SGLs in lower elevations which are discussed) across the two melt years. This could be completed by including multiple mapped subsets in a new figure (within the results in either *Section 3.1* or *3.2*) showing the distribution and subsequent differences in features across selected dates and/or zoom in sections for both the 2018 and 2019 melt seasons.

3) Following on from my previous comment about an additional figure, this would also help show how the network evolves seasonally across the two distinct years. A particular interest, as you discussed, is the drainage of small meltwater features (particularly at lower elevations) and how slush develops in these two years. In terms of slush, so far, I can only see your higher-elevation slush in Figure 1 (from your maximum extent). It would be therefore interesting to see how slush develops during the melt season alongside your other features.

4) You could, time- and review-dependent, try to adapt your thresholding method or perform further manual delineation to capture more of the smaller network (i.e., a more complete supraglacial river and stream network) alongside your other smaller features (SGLs) to give a more hollistic view of supraglacial meltwater, and its drainage as a whole, in this catchment. Supraglacial rivers and streams can make up a large portion of the supraglacial network, and so are important to consider alongside your captured, smaller SGLs. This is a suggestion to uphold the use of '*all meltwater features' to* elevate the paper, however, I understand that this may be a considerable undertaking.

Ice velocity:

I have no problem with the use of NASA MEaSUREs ITS_LIVE data – it is a well-used and useful data resource. However, there is a lack of acknowledgement of the error and uncertainity regarding this data and implications this may have on your inferred results. For example a lack of error envelopes for your ice velocity data presented in Figure 5 (particularly important for higher elevation, noisy data). You present an estimate of uncertainity in your Figure 3 – it would be good to do the same in Figure 5.

Secondly, the link between your drainage/refreeze events and impact on ice velocity looks highly subjective and are difficult to interpet and verify from Figure 5 as you do not separate these events by elevation (like you have done with ice velocity) – consider improving this figure.

You also refer to an ice velocity increase coinciding with a period of refreezing in July 2019 (Line 391). How do these two mechanisms work?

<u>Minor comments:</u>

Units: You interchange your use of units, from km^2 to m^2. For example, when defining small meltwater features you use km^2 (e.g., 0.0495 km^2), however when presenting your results, you refer to your meltwater features in m^2. Please choose one unit for consistency and comparison of results.

Catchment reference: You refer to the Russell/Leverett catchment throughout the manuscript and provide its outline in Figure 1. Is this catchment delineated yourself (e.g., via flow routing) or is this an already pre-defined catchment? If the former, please provide a method as to how this catchment was delineated and what datasets were used. If the latter, please cite the appropriate data source.

Specific comments:

Line 44 – *'SGLs generally form in early summer enlarge in area and depth between spring and summer as they accumulate water…'.* This sentence does not fully make sense. Maybe add an *'and'* before enlarge or *',enlarging in area…'*.

Line 60 – could include additional references to remote sensing studies here (Lu et al., 2021; Turton et al., 2021; Rawlins et al., 2023; Zhang et al., 2023).

Lu, Y., Yang, K., Lu, X., Li, Y., Gao, S., Mao, W. and Li, M.: Response of supraglacial rivers and lakes to ice flow and surface melt on the Northeast Greenland ice sheet during the 2017 melt season, J. Hydrol. 602, 126750, 2021. https://doi.org/10.1016/j.jhydrol.2021.126750

Turton, J. V., Hochreuther, P., Reimann, N., and Blau, M. T.: The distribution and evolution of supraglacial lakes on 79° N Glacier (north-eastern Greenland) and interannual climatic controls, The Cryosphere, 15, 3877–3896, https://doi.org/10.5194/tc-15-3877-2021, 2021. https://doi.org/10.5194/tc-15-3877-2021

Line 73 – *'…the drainage of meltwater features was not considered.'* Drainage how? I am assuming drainage subglacially, but could be more explicit here as some of the papers cited assess how meltwater moves or is 'supraglacially-drained' across the surface over a single/multiple melt seasons.

Line 95 *(Figure 1)* - Your figure shows maximum areal extent of meltwater features in 2018 and 2019. Is this from a particular date in the season or an amalgamation of your features from separate mapped dates across the season into one map?

Line 102 – This study area is well known for its prevalent surface hydrology features including lakes, rivers, and moulins. Could you additionally provide an upper elevation estimate from previous studies (including refs)?

Line 143 – the blue and green filter you use. What is this? A band combination? Some clarity would help.

Line 146 – Include the citation and subsequent reference for McFeeters (1996) – paper for the traditional NDWI index (using green and NIR bands).

McFEETERS, S. K. (1996) 'The use of the Normalized Difference Water Index (NDWI) in the delineation of open water features', International Journal of Remote Sensing, 17(7), pp. 1425–1432. https://doi.org/10.1080/01431169608948714.

Line 171 – how narrow were the channels that were manually added? Are they still larger, primary rivers (as commented on earlier)?

Line 260 – would be helpful to give a clarifying statement as to the purpose of ice velocity data for the study to make this clearer.

Line 285 – You refer to both linear stream and river features. Maybe just state rivers (as per my previous comments).

Line 412 – Whilst I think it is relatively clear the contrast between surface meltwater characteristics and distribution (which would be helped by an additional figure) between years, I think I would refrain from saying there is a 'clear contrast' for drainage dynamics, as this looks to be subjective.

Table S1 – From the main body it was stated that 'Images with > 50% cloud cover were omitted' (Line 122). However, in Table S1, scene IDs have been included with cloud cover >50%. Do these scene IDs need to be removed from the table? Or were these scene IDs (>50% cloud) used? If they were used, rectification in the main body is required.

Technical corrections:

Line 126 – Capitalise 'Level'

Line 131 – Missing bracket for citation

Line 133 – decide whether to capitalise (or not) the word 'bands'. Some inconsistencies.

Line 139 – you have already given the abbreviation for Normalised Difference Water Index (NDWI) on Line 89. You could therefore remove this on Line 139 if you wish (however, if retaining, please capitalise 'Normalised Difference Water Index' for consistency).

Line 217 – replace 'ocean' with lake or SGL

Line 296 – At the end of the sentence, either remove 'at' or the brackets.

In places, you have a citation and Figure number in separate brackets in immediate succession. Combine these using a semi-colon (Corr et al., 2022; Fig. 2).