**Response to reviewer 1: 'Seasonal evolution of the supraglacial drainage network at Humboldt Glacier, North Greenland, between 2016 and 2020'. Rawlins *et al.* (2023)**

We would like the reviewer for their positive and insightful comments on our manuscript, which will lead to the following improvements. Our responses for each of the comments raised and how we addressed them are given below. Reviewer comments are italicised in blue with our responses in black. Please also find attached a revised manuscript with tracked changes. When referring to page numbers in the below text, these will be with page numbers associated on the revised (tracked change) manuscript.

*This is a super well written, clear, thoroughly referenced (rare!), and interesting paper. I don't get many of these to read, so this was a delight. I do have some suggestions below for how the paper could be improved, but they are all easily done and I think will make the paper stronger. I am very familiar with the subject matter and literature here, so my eyes glaze over on the methods sections and I took them for granted.*

We thank reviewer 1 for this positive overview and for their further constructive comments which are addressed accordingly.

*Slush definition- Slush zones are a key part of these results, but the authors have not described how they were defined/mapped/identified. I'd like to see their definition of a slush zone and how they uniquely identified them in images from other supraglacial features.*

Thank you for your comment on slush zones. Slush is defined as water-saturated snow when temperatures permit melting (above 0°C) which form a large expanse of surface pooled meltwater which can become mobile as slush flows or rill-type channels. Slush zones are of great hydrologic importance during the early melt season for initial meltwater mobilisation and later on in the season as headwaters, feeding the surface drainage network below and so were not extracted/treated independently. Slush is identifiable in true colour satellite imagery as a dense, light blue zone representative of shallow, water-saturated snow: distinguishable from the surrounding white colour of snow, grey colour of bare ice and darker, turquoise blue colour of supraglacial rivers and lakes (Holmes, 1955). An example of the slush zone is now provided as an extra panel in Figure 2 (g). In NDWI images, however, slush zones are more difficult to independently extract due to their similar spectral and linear shape signatures with other supraglacial hydrological components (i.e.., narrow rivers). Clarification of this is now included in the Methodology, lines 245 – 253 (revised manuscript).

*MAR uncertainty- I do not think the authors need an ensemble of models, but I would expect to see some discussion of the fact that MAR (or any coupled or uncoupled atmos-ice model) is our least bad representation of reality. There are known issues in this sort of modelling, and errors in the model will only strengthen your conclusions by potentially reducing scatter. Figure 5, for instance, should have a MAR uncertainty plotted on it, perhaps as a confidence interval. Discussion should also be added.*

We agree with this comment and have now added some initial discussions about the use of MAR, including its development for the study of polar regions (including Greenland), its inclusion of important polar processes (e.g., SMB) and its evaluation against in-situ automatic weather station and satellite data sets (with reference to relevant literature). Further details regarding the high spatial (6 km) and temporal (daily) resolution of the MAR model version (v3.11) used is also given, as well as reference to literature where MAR data has been used in other supraglacial hydrologic studies. The inclusion of this text can be viewed in lines 201 - 211 in the revised manuscript.

We have also included uncertainty envelopes of MAR data used in original Fig. 5 (now Fig. 6 in revised manuscript), as recommended. This uncertainty is +/- 15% the MAR value calculated for the catchment (meltwater and runoff variables), as per Fettweis et al. (2020) and personal communication (Personal communication: Fettweis, 2023).

*MF uncertainty- as above, please discuss uncertainties in your MF. You have spatial errors resulting from pixel size, spatial errors from undetected sub-S2 channels, DEM resolution errors, and errors of classification that might omit/comit water area. This seems a larger omission from the paper- I (and readers) want to know where the method is good and where it is not. Since you aren't about to map a scene manually to provide true validation (although I wouldn't object to that!), I think you can propagate the variance from each of those terms based on the literature surrounding your classification methods. I think this information is essential to this paper.*

We agree with this comment and have now included a new figure (Fig. 3 in the revised manuscript) of a small mapped area of HG comparing both the automatic river detection algorithm vs manually digitised supraglacial rivers to assess performance accuracy. The results from this assessment show similarities between the overall spatial pattern of the automated and digitised networks, however small gaps are present in the automated rivers, which when quantified are 5.4% shorter than those which are manually digitised. This new section of writing and figure can be found in the Methodology, Section 3.2, lines 258 – 262 (in the revised manuscript). We believe this provides the information required for MF uncertainty in this paper.

*Drainage density and other stats- you have the data to create a vector river network and determine drainage density, stream orders, and other stats for comparison (see last point). Author Yang has published many papers on this topic and therefore I believe this should be a straightforward task that would add needed richness to this paper in terms of comparison.*

Whilst Drainage density ($D_d$) has been used previously in other publications, this stat was not originally included within the manuscript as such results were comparable with the use of the Meltwater Area Fraction (MF; a stat introduced and used by Lu et al. (2021) and Yang et al. (2021)), with behaviour of both statistics being connected (which would lead to repetition). Instead, we have now included $D_d$ statistics in Table S2 (Supplementary Information) and have attached graphs of $D_d$ and MAR-derived values (see Fig. R1: similar to that of Fig. 6 in the revised manuscript) to show their paralleled behaviour.

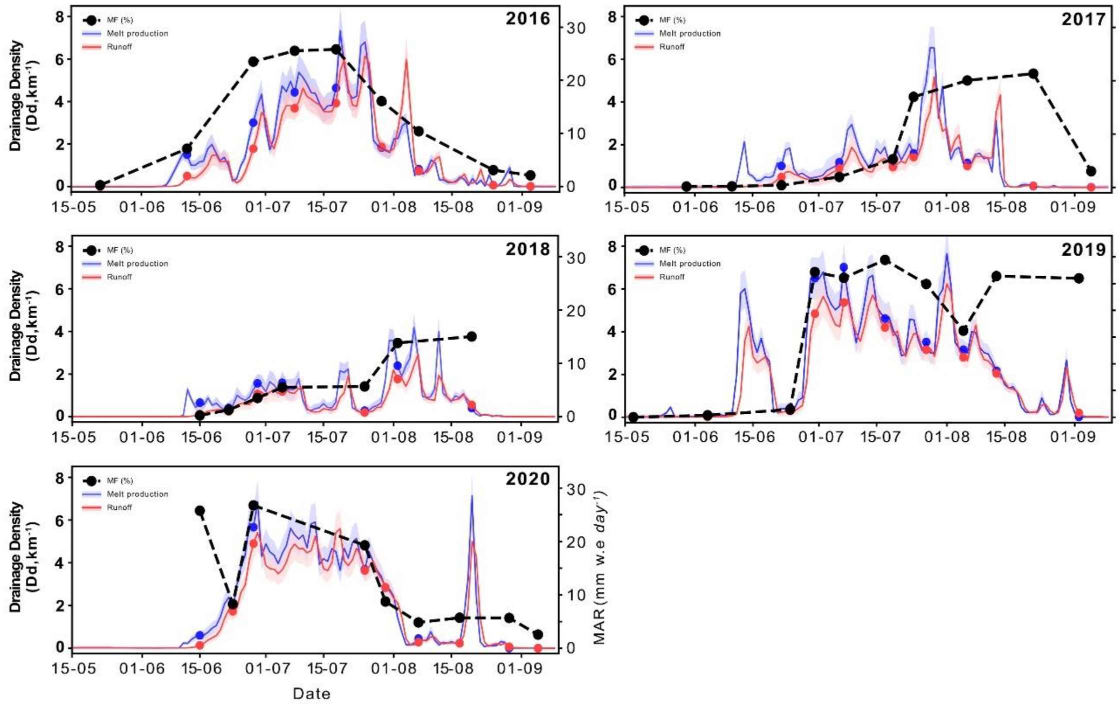


***Figure R1****: Drainage Density ($D_d$, km$^{-1}$) and MAR-derived meltwater production and runoff (mm w.e. day$^{-1}$) for each mapped study date across the study period (2016-2020) for the HG catchment, north Greenland. +/- 15% uncertainty envelopes are provided for MAR-derived values (Fettweis et al., 2020).*

In regards to other hydrologic statistics (e.g., stream order, braiding index), this is beyond the scope of this paper, which focusses on mapping the supraglacial hydrologic network (both rivers and lakes) in an unmapped location at high spatial and temporal resolution, and to do this over a number of consecutive years (for the first time) to assess the seasonal behaviour. We believe that such in-depth, targeted hydrologic statistics (e.g, drainage density, stream order) would be well placed in an additional, future paper focussing on only melt year, date or internally drained catchment of HG to enable a more thorough investigation into such metrics (such as those performed in Smith et al., 2015; 2017; Gleason et al., 2021; Muthyala et al., 2022).

*Gleason, C.J., Yang, K., Feng, D., Smith, L.C., Liu, K., Pitcher, L.H., Chu, V.W., Cooper, M.G., Overstreet, B.T., Rennermalm, A.K. and Ryan, J.C.: Hourly surface meltwater routing for a Greenlandic supraglacial catchment across hillslopes and through a dense topological channel network. The Cryosphere, 15(5), pp.2315-2331, [https://doi.org/10.5194/tc-2020-273](https://doi.org/10.5194/tc-2020-273), 2021.*

*Muthyala, R., Rennermalm, Å. K., Leidman, S. Z., Cooper, M. G., Cooley, S. W., Smith, L. C., and van As, D.: Supraglacial streamflow and meteorological drivers from southwest Greenland, The Cryosphere, 16, 2245–2263, https://doi.org/10.5194/tc-16-2245-2022, 2022.*

*Smith, L.C., Chu, V.W., Yang, K., Gleason, C.J., Pitcher, L.H., Rennermalm, A.K., Legleiter, C.J., Behar, A.E., Overstreet, B.T., Moustafa, S.E. and Tedesco, M.: Efficient meltwater drainage through supraglacial streams and rivers on the southwest Greenland ice sheet. Proceedings of the National Academy of Sciences, 112(4), pp.1001-1006, [https://doi.org/10.1073/pnas.1413024112](https://doi.org/10.1073/pnas.1413024112), 2015*

*Smith, L. C., Yang, K., Pitcher, L. H., Overstreet, B. T., Chu, V. W., Rennermalm, Å. K., et al.: Direct measurements of meltwater runoff on the Greenland Ice Sheet surface. Proceedings of the National*

*Academy of Sciences of the United States of America, 114(50), E10622–E10631. https://doi.org/10.1073/pnas.1707743114, 2017.*

*Split MF into river and lake areas- I am quite interested in this divide. This is figure S3, but for me this belongs in the main text as a very interesting expression of the supraglacial hydrology here. Some discussion should also occur.*

We agree with this comment and Figure S3 has now been moved into the main results as Fig. 7 with associated text (457 – 468, revised manuscript) and additional discussion included (629 – 647, revised manuscript), including reference to the difference in percentage composition (i.e., rivers and SGLs) of the drainage networks between the north and southwest regions of Greenland.

*Section 5.4- I am ok with this section as it is fairly hedged and well referenced, but other reviewers may not like to see such speculative conjecture.*

We thank the reviewer for their comment.

*Missing comparisons- the 2nd major omission I see (beyond uncertainty discussion noted above) is a lack of comparison to the rich literature of the SW GrIS. This is the right paper to use the discussion to first outline this bit of ice sheet (as you have done) and then explicitly compare to the SW to see what is the same and what is different- are the fractions of rivers and lakes the same? Elevations of highest melt features? Density of persistent channels? Channel lengths? Width distributions of these channels? Prevalence of slush zones/bare ice and their interaction with the network? I think you have all the data to answer those questions (and more) and I think this paper really needs it to move this beyond an interesting and well written observational study into a richer contextual understanding of this unique bit of ice. I'd like to see these differences quantified where possible (e.g. from a vector network) or discussed qualitatively and referenced where not possible (as you have nicely done throughout this paper!!)*

We have now incorporated a wider comparison of our data with studies from southwest/west Greenland throughout the discussion. This includes a comparison between the maximum elevation of the supraglacial drainage network, which is ~400 m a.s.l lower (1440 m a.s.l) at HG than in southwest Greenland (~1800 m a.s.l; Yang et al., 2021): a finding consistent with another mapping study by Lu et al. (2021) from northeast Greenland. Other comparisons are also made, including differences between the parallel-style of drainage pattern mapped in the southern sector of HG and the typical dendritic-style of drainage observed in southwest Greenland. Additionally, the composition of the drainage network differs, with supraglacial rivers contributing significantly more to the network at HG than southwest Greenland, where SGLs and associated meltwater storage is higher. This increased contribution of supraglacial rivers in the northern network is attributed to the reduced presence of available depressions for SGL development, steeper slopes promoting runoff over storage and the inclusion of slush zones within this study, which likely increases the MF and RF value. We do, however, express caution in direct comparison of metrics between regions as our study uses a lower threshold ($t_5$) and retains slush zones, which will increase river components (lines 639 – 647 in the revised manuscript). Some similarities in drainage between the two regions are also considered, including the lengthening of channels to higher elevations from the already-existing network. We thank you for your comment on the inclusion of this important aspect.