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Interactive comment on "Supraglacial meltwater routing through internally drained catchments on the Greenland Ice Sheet surface" *by* Kang Yang et al.

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Review of: Supraglacial meltwater routing through internally drained catchments on the Greenland Ice Sheet surface, submitted to The Cryosphere Discussions by Yang, K. et al. Reviewer comments.

General comments:

Supraglacial catchment hydrology controls the seasonal and daily inputs of surface meltwater to subglacial catchments, thus modulating subglacial channel evolution and, by extension, ice sheet response to surface melt. However, very little is known about the routing of water within a supraglacial catchment, and a dearth of empirical data hampers efforts to generalize methods for constructing moulin hydrographs. This paper is a meaningful and logical use of a unique in-situ measured moulin hydrograph, which is combined with traditional hydrological theory to infer the distribution of water routing within different spatial process domains in a supraglacial Internally Drained Catchment (IDC). It is largely a methods paper, but also provides insight into the relative importance and roles of the different hydrological spatial domains in routing flow, as well as how this importance varies seasonally with the evolution of the supraglacial drainage network.

The contributions of this paper to the field are:

1. Unique empirical data on moulin hydrology

2. Methodological advancements on moulin discharge derivations that emphasize the importance of considering the different hydrological processes at work within spatially distinct process domains

3. Insights into the importance of the seasonal evolution of different parts of the supraglacial drainage networks on modifying moulin hydrographs

The contributions of this paper might be enhanced in the following ways:

1. Because this paper is largely a methods paper and relies on empirical data that is available for few supraglacial catchments, it would benefit from a discussion of the choice to use the rescaled width function relative to other methods for deriving synthetic unit hydrographs. What are the practical considerations of this method, and why is it best suited for the supraglacial environment? What other morphometrics might be important in influencing water routing in IDCs, and how might the utility of this method vary spatially? Additionally, given that forward progress in constraining the hydrological processes of IDCs is limited by field data, it would be useful if the discussion section laid out a set of key priority areas for field work that would allow us to generalize this

method beyond the current catchment.

2. This paper is situated in a recent proliferation of studies attempting to generate accurate and generalizable approaches to estimating moulin hydrographs. To further emphasize the contribution of this work beyond its methodological scope, the paper would benefit from further considerations of the implications of this study relative to our understanding of the hydrology of the ice sheet (e.g. under what conditions might we expect the distribution of routing between interfluves and channels to have meaningful impacts on subglacial hydrology, how might this vary in catchments of different sizes, at different elevations, etc..).

RECOMMENDATION: This paper is well written and employs a clear and meticulous methodology with careful consideration of its limitations. I recommend publication of this work with some comments as outlined above and additional minor considerations that I outline below.

Specific comments:

Title: The title is not sufficiently descriptive to distinguish the contribution of this paper from prior contributions in this field. Further, I think that 'internally drained catchments' somewhat misrepresents the work given that the focus of this paper is derivation of the daily moulin hydrograph for a specific IDC. I strongly suggest rewording the title to emphasize that this contribution is at a more spatially, hydrologically, and geomorphologically precise scale than prior work in this area.

Abstract, page 1, line 17: Replace 'it' with specific term – accurately modelling moulin hydrographs?

Introduction

Page 2, line 9: IDCs constrain. . . suggest more specific wording, e.g. : IDC spatial and temporal characteristics and processes constrain. . .

Page 2, line 15: citations for underlying bedrock controls. I suggest citing Lampkin and

Vanderberg (2011) who did earlier work on the topic of bedrock controls on supraglacial hydrological features.

Page 2, Line 29: Clason et al. 2015 did attempt to account for some snowpack retention and runoff delay by factoring in runoff delays due to snowpack retention, although not specifically delays due to routing – would be worth mentioning.

Page 3, Line 18: specify that, in this case, the lumped spatial domain is the IDC scale.

Page 3, Line 21: is the 3 m resolution unprecedently high? ArcticDEM is 2 m resolution and has been used by Karlstrom and Yang (2016) and King et al. (2016) for flow routing in supraglacial environments. Additionally, Rippin, Pomfret and King (2015) used UAV-derived DEMs of 10 cm resolution for derivation of supraglacial channels.

3. Data sources Page 4, lines 29 – 32. For full reproducibility, please include method of degradation and spatial filtering algorithm names (e.g. mean filter, median filter, gaussian filter?).

4.3 Unit Hydrograph Page 6, Line 22: move explanation of M' to line 18, first mention of M'. In this section or in the introduction it would be useful to include a brief discussion of what other SUH methods are available (e.g. Geomorphic Instantaneous Unit Hydrograph) and why they were not employed in this case. Given that the focus of this paper is methodological, it would be useful for other researchers, particularly glaciologists without a familiarity with SUH derivations, to get a broader sense of the range of hydrological approaches that might be used in the context of this work as well as in Smith et al., (2017).

4.5 Rescaled Width Function Page 7, Line 20: can constant flow velocities be assumed for interfluve and channel zones? It seems that flow in channels is highly dependent on location within the network (Gleason et al., 2016). This is acknowledged and addressed in the limitations, but I would be interested in seeing a breakdown of the structure of the channel network in order to get a sense of the scale over which flow velocities vary.

The distribution of total (or mean) channel length by stream order, contributing area, or by channel width would be useful. This could be done as a cumulative distribution, for example, and the effect of the seasonal evolution of the drainage network could be included by showing the drainage network breakdown according to variable Ac values.

5.2 Interfluve and open-channel travel distances Page 9, Line 12: travel distances. I was confused about the travel distance comparison for some time, until it became clear to me that your Lc is in km and your Lh is in m. I suggest for the sake of clarity, put the in-text travel distances in the same units, particularly as Figure 4 is in m for both travel distances. I think it will improve the clarity and readability of this section. Overall for the travel distances section, your findings are that the interfluve travel distances are orders of magnitude shorter than the channel travel distance, and surely this is the same regardless of the channel initiation threshold you use (as per Table 1). Rather than justifying the difference between your findings for the conservative threshold and Karlstrom et al. (2014) and McGrath's et al. (2011)'s findings, I would simply state that although your findings for interfluve travel distances (in particular) vary with initiation area and are closer to prior work at the non-conservative river detection threshold, the orders of magnitude difference between channel and interfluve travel time remains effectively unchanged relative to the difference between the two process domains.

5.3 Interfluve and open-channel travel velocities As per my comment above, I would be interested in seeing some breakdown of the relative dominance of channel of different widths or orders. Assuming you have a mask of channel extents, would it be possible to generate a histogram of river widths in the study area? This would provide some context for comparison between your bulk-catchment vc and prior work.

5.5 Moulin hydrograph simulations Although the SRLF-GIMP hydrograph is different, it does not appear to be 'significantly' so. I wonder what the implications of the observable difference are, and whether these implications are significant at scales that affect subglacial channel evolution. Some discussion of the conditions under which this difference in hydrograph simulations might be accentuated would be useful (e.g. small vs. large basins, etc. . .). Or, perhaps including the volume of water would be useful for context, rather than just the RWFUH. Amplified by the total volume of water collected in this catchment, how significant does this offset become in a physical sense?

6.1 Surface runoff delays on the Greenland Ice Sheet Page 12, Line 28: is the MAR runoff delay a delay due to runoff routing, or a delay in the production of runoff due to melt storage in the snowpack?

Page 13, Line 6: This is interesting.

6.2 Seasonal evolution of the supraglacial drainage network Page 13, Line 25 – 27: Could these variations in water pressure be due to an evolving sub-glacial network that is better able to transport peak diurnal flow in August? How could we disambiguate these processes?

Page 14 – line 11: Do you not have in-channel measurements of width and depth with which to derive R? R should be in units of meters – in which case your R value seems very low (manning's n is not dimensionless, although it is often represented that way). Also, is the slope value of the catchment surface, or the channel slope? It should be channel slope if you are using the manning's equation for open channel flow.

6.3 Is interfluve meltwater dominated by overland flow or subsurface flow? This is a nice discussion of the mechanisms dominating interfluvial water routing.

6.4 Limitations. This section provides a good overview of the limitations of the RWF method. However, I would also like to see some mention of the morphometrics that are not addressed by the RWF, such as drainage network complexity (e.g. the distribution of streams of different orders), and channel and interfluve slope.

Appendix I: R should have units of m (defined as area [L^2] over perimeter [L]). Again, I am not clear on how a constant R of 0.035 m and thus a depth of 0.05 m is used in this case. Is this meant to be catchment-averaged? For the SRLF, which is distributed, one would expect R and depth to change with every pixel, no? Some clarification of these assumptions is needed.

Figure 3: according to the text, the WV-1 image was acquired on 18 July, and the UAV image on 20-22 July, therefore the images are not concurrent?

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