Distribution and characteristics of supraglacial channels on mountain glaciers in Valais, Switzerland. Holly Wytiahlowsky et al. 2nd review for TC by Ian Willis

Thank you for the vast number of improvements to the paper following the suggestions by myself but also the other two reviewers. I noticed that many of our comments were similar.

The paper is greatly improved and is closer to being ready to publish in my view. I've been through the paper carefully and have a few remaining general comments and a few more specific detailed comments and questions.

The science is good, and the results are interesting, but my comments and suggested edits are to encourage you to work on articulating the results and implications of your work more carefully, precisely and logically than you do, with the ultimate goal that more people will read it and it will have a better impact. The Discussion was the main part of the original paper that needed improving and you've done a good job in doing so. But it remains the section that'll most benefit from more work.

<u>General points</u>

1. Throughout your paper, it would be clearer (and you could lose a lot of repetition), if you did not continuously tell us that your channels are 'large' or '> 0.5 m wide'. Tell us in your methods that you can only resolve channels above this size and that hereafter you refer to these simply as 'channels'. Then you can delete all subsequent references to '> 0.5 m' or 'large', as we know that when you use the term 'channels' it is an abbreviation for 'large channels > 0.5 m'.

2. You use the word 'morphology' and 'morphometry' with respect to channels throughout the paper and it's not clear what you think the difference between these two is. Can you better define these two terms when you first introduce them and then use the correct word thereafter? Or do you see them as the same thing, in which case just use one term consistently.

3. There are places in the paper where you're comparing your work to 'ice sheets' but really you're just comparing with the Greenland Ice Sheet. I think you should alter all such sections to refer to the GrIS only and not give the impression that there are vast surface drainage networks on the Antarctic Ice Sheet!

4. Similar to above, there are places in the discussion and conclusions where you refer generically to 'mountain glaciers' or 'valley glaciers'. You need to decide whether you think your results for the 85 Valais glaciers are universally applicable and can be generalised. Parts of your discussion suggest you do not think this and work is needed to apply your methods to other areas of the world. I would agree with this. In which case you should always refer to 'Valais glaciers' and not imply that your findings are necessarily applicable everywhere.

5. I would encourage you to proofread your work more than you do and have your other authors look over it, to spot and correct grammatical errors. Unfortunately, there were a lot of these, as some of the detailed line by line comments below show.

<u>Detailed line by line comments</u>

14. we map 1890 channels (to keep tenses consistent).

35. repetition of word 'rapidly'

48 could say ' with potential to impact the suspended…"

54-5. Better English would be "…which has implications for subglacial water pressure, the onset of subglacial channelisation and, in turn, ice motion."

72. Better to say "…to have a larger debris cover…" or "…to have a larger coverage of debris".

81/82. "…high concentrations of channels correlate with …" or "high concentrations of channels appear to be correlated with…"

91. Discharge is a rate so should say "discharge is a strong control…" [or "volume flow rates are…"]

104. '…from glaciers…" plural!

105-6. "… determining the extent to which surface hydrological characteristics (e.g., channel, channel transport pathways) are uniform between" would be less ambiguous.

120. "…comparable with Switzerland's as a whole" [Add the apostrophe - it is not comparable with the size of Switzerland!]

121. "…and varying crevasse densities…"

130. "found to contain" => 'containing'.

175. "has been found to be" => "is".

There are loads of examples of the above throughout your paper. Do a search for all the words 'found' and see if you can get rid of all the extra words.

191 remove ref to 'Canton' as you've already established that Valais is a canton.

205. delete 'width' or 'wide'.

217 'was assigned a code based…"

218 'The type of channel terminus.."

232 "…mapping had been repeated…"

233 "small enough for us to conclude that the original mapping provided a…"

234 – add "…and total channel length" to the end of the sentence.

234-5 "Both sets of mapping also clearly identified how the channels terminate. The primary source of uncertainty here, stems from knowing when to stop mapping up-channel."

239. "found to contain" => "that contained". Also, shouldn't you replace "85" with "the" as the number of glaciers with channels is reported as a result on line 280?

248 "had been used"

260. Need a colon after 'three classes'.

263-275. There is a mix of present and past tense throughout this paragraph.

279 '…glaciers that had an area…" would be less ambiguous.

280 delete 'were found to'

283-4. delete 'were found to'

302-3. "and inclusive of the higher one"

306-314. "Glaciers without large channels (>0.5 m) are more likely to terminate at higher elevations (mean minimum elevation: 2936 m) compared to glaciers with channels (mean minimum elevation: 2797 m), which are often characterised by longer valley glacier tongues. Where glaciers support channels, they are more likely to have a higher maximum elevation (mean max elevation: 3637 m) than glaciers without large channels (mean max elevation: 3555 m). Where channels >0.5 m are present, there is a mean drainage density of 2.4 km/km2 and a maximum of 15.2 km/km2. The latter was found on the Oberer Theodulgletscher, which is situated on a low slope plateau and has the lowest glacier slope angle in the dataset (13°) (Fig. 3c, Fig. 4a). To summarise, glaciers containing channels are larger, have lower mean slopes, and have a larger portion of their area at lower elevations compared to glaciers without large channels (>0.5 m)." [149 words]

could be improved and shortened to:

"Compared to glaciers without channels, glaciers with channels are more likely to have longer tongues that terminate at lower elevations (mean minimum elevation = 2797 m vs. 2936 m) and have higher maximum elevations (mean max elevation = 3637 m vs. 3555 m). Glaciers with channels have drainage densities ranging between 2.4 km/km^2 and 15.2 km/km^2. The latter was found on Oberer Theodulgletscher, which has the lowest glacier slope angle in the dataset (13°) (Fig. 3c, Fig. 4a)." [78 words].

This is just one example of where a verbose writing style could be made more succinct.

317. should say 'top right'. In the Figure, is it possible to remove the white 'gap' in the top right part of (a)?

326. Grammatical problems. This would be better: "Few segments exceed 1,600 m, as the ablation areas of most glaciers are smaller than this."

328 "~~observed~~"

340-3. This sentence still needs work. It's not quite right.

345-6. Wouldn't this be better for this entire sentence: "Qualitative observations suggest that channel distribution and morphology are controlled by glacier structure and topography."

350 'low' not 'lower'

353. This title should come above the previous paragraph as that previous paragraph is exactly on this topic!

354. This sentence does not capture what this section is about. You're not only investigating links between channel characteristics but also the glacier controls on the channel

characteristics. Suggest you adjust the section heading and this sentence so that they match what is being done here.

359. I'd say 'shallow slopes' as 'lower slopes' could imply slopes at a lower elevation (i.e. opposite of upper slopes).

362. "lowest slope angles" => 'shallowest slopes"

366 I assume this should say 'ice' not 'glaciers'

372. 'higher-order channel' not '…channels'

377 'each of which is" singular!

394-5. Correct the grammar here.

399. I think Principal Component Analysis should strictly be capitalised (as you've done on lines 424-5).

404 delete "identified to be"

435. You need at least a semicolon between "variance" and "instead"

446-7. What do you mean "are likely to be" You know whether they ae or not. Do you mean "tend to be" here?

451 Comma before 'which'

454. I'd put a comma after 'meltwater and before 'which'. End the sentence after 'channels' start a new sentence "Conversely, crevasses that have closed…"

478 and Figure 7. Do you mean 'inception' or do you mean 'interception'? The latter would seem to make a lot more sense to me. "Inception" refers to the beginning or starting point of something, while "interception" means to stop or capture something that is moving or being passed. You say 'intercepted' on line 481 which seems correct.

486-7 should say "location on a high elevation plateau". You can't say 'higher' as you don't explicitly state what you're comparing it with. Be careful of your use of comparative adjectives.

493-4. I'd delete this last sentence as it confuses things. You've already described the balance of glacier surface melt vs channel melt.

574 "compared to' => "and".

578 "seasonal variation in ice velocity" [or "summer speed up in ice velocity"].

614 "observed to occur" => 'occurring'.

614 delete 'We find that'

616 Delete 'Our observations find that" [it should say "We find that" or "Our observations show that", but these and all similar phrases used throughout your paper are redundant].

613-630. This discussion on the relationships between certain channel variables on the Valais glaciers (this study), vs. those on high Arctic glaciers reported by St Germain and Moorman and those on glaciers reported by Gulley et al (2009) [location not stated] is impossible for me to follow. I've read it through several times and cannot follow the logic. I'm not convinced the statements are logically connected. I'd encourage a rewrite of this whole paragraph. There is a confusion about what the evidence is supporting the statements. Is everything just based on correlation? This is not the same as causation of course. We need better distinction between correlation and causation and the latter should be linked to physical processes. Line 614 states that slope affects sinuosity which implies causation. You say that wider and more incised channels are more sinuous but where is the evidence for this? You don't measure width or incision. You say that such channels are likely to carry a higher discharge, but what is the evidence / logic / process base of this statement? You suggest it's because St G & M "attribute" higher sinuosity to higher discharge. But on what basis did they do that? All this from lines 614-619 seems poorly reasoned.

Then you state that St G & M find a positive association between channel slope and sinuosity for glaciers in the Arctic. But this is not observed for the temperate glaciers in your study. So, state what is observed. From Fig 5 it's a moderate -ve correlation, right? OK, so we have a discrepancy which needs explaining. Then you state that steeper channel slopes increase channel incision and ref Gulley et al. You should tell us that that study was also for glaciers in the Arctic. On what basis did Gulley et al reach that conclusion? Was it also correlation analysis like you've done? Then you refer to a positive relationship in your study between incision and sinuosity. But where is the evidence for this? Incision is not one of the variables you define in your correlation matrix. So this is just anecdotal evidence, correct? I don't think you can make any meaningful statements about relationships involving incision when you don't show any evidence for incision. On line 624 you state "These channels are likely to continue to evolve inter-annually due to their incised depth." But where is the evidence or what is the process base for this? And how is a statement about what may or may not happen in the future relevant to the discussion here, which is about explaining the present day relationships between channel variables? Then you state "Given this…the relationship between slope and sinuosity represents the conditions under which large channels can form (i.e., flatter, less crevassed regions) rather than the direct impact that slope has on sinuosity." But what do you mean by this? I can't work out how you would logically deduce that from the previous statements.

651. What do you mean by 'appearance' here? Can you just loose that word as the subsequent discussion seems to be about sinuosity only.

652-654. The statement here "Channels that have a proximal debris source and those that run directly through debris cover tend to be more sinuous than channels on clean ice (Fig. 5c)" contradicts the statement in the results on lines 365-8 where you say "We find no noticeable difference in sinuosity between channels on bare ice and those on debris-covered glaciers (Fig. 5c). However, channels proximal to debris …are more likely to be highly sinuous than channels on bare ice or continuous debris cover". Which statement is correct?

654-6. I cannot reconcile this sentence with what is shown in Fig 4d. The sentence states that Fig 4d shows channels on clean glaciers but the non-sinuous channel in Fig 4d is on the same glacier as the sinuous channel. Are you talking about the two sides of the glacier tongue here?

658-9. This sentence isn't quite right. It is not the less sinuous channels that are funnelled through areas of bare ice. It is the water that would be funnelled. Or you could say the channels become straighter as they pass through the clean ice area. I don't see what your explanation for this finding is. Is it to do with the debris cover or is it just to do with the slope? If the clean ice zones of debris-covered glaciers have steeper slopes, then would this create

the straighter channels? Or is it from the paragraph 613-30 that you're ruling out a slope control on sinuosity?

659-666. This reads like a literature review of previous work. Can you better explain how this work is relevant to your results? Can the processes that are implied with reference to the previous work explain any of your findings relating to the slopes and sinuosity relationships on glaciers or parts of glaciers with different amounts of debris?

666-668. This sentence doesn't seem relevant here. It reads as though it should go in the introduction of a different paper justifying why it'd be useful to assess the effect of debris within supraglacial channels on channel morphometry (which you don't do in this paper). Or it could go in a future work section of this paper.

668-671 doesn't seem relevant at all – I'd personally delete this.

672-5. You say 'further insight' but further insight into what exactly? How is this sentence relevant to your work?

675-677. Could the sentence on lines 666-668 be merged with this and better articulated if you want to end this section with recommendations for future work that stem from the discussion about controls on channel morphometry?

714 You need to say "Previous research on surface channel morphology has…" [or some such]

714. Just say 'ice sheets' not 'ice sheet settings'.

717. Need a full stop or semi-colon after 'environments'.

718. Grammar! Should say 'which are commonly observed". Also, why not just say "observed on ice sheets"?

718-720. You say 'some glaciers' but is this all but the large glaciers? This would seem logical given what you then say. By 'less interconnected' do you mean 'less dendritic'? You don't been less anastomosing I assume, which is what 'parallel networks' implies. It's just a question of scale as to whether drainage systems can be described as dendritic?

723. What are 'flow-stripes'? These have not been mentioned previously so you can't introduce them here in the discussion.

724 I'd say "both for Valais glaciers and for ice sheets" [note you could say 'Valais glaciers" throughout most parts of your paper to remove a few words and make the sentences flow faster].

726-7 I'd say "between ice sheets and Valais glaciers, for example debris may…formation on the latter". Then delete the 'For example' on line 727. You say 'channel formation' here but do you mean that? Or do you mean channel morphology [or morphometry]?

729. You refer to Rippin et al here but surely you should refer to your work first (and then bring in others' work if it supports your argument)? Otherwise, this is just a literature review.

730 You mean 'surface channels' not 'surface melt' here. Your paper is not about melt.

731 delete 'are observed to'

735. If you want a reference for the notion that lakes temporarily store water you could refer to this: https://tc.copernicus.org/articles/8/1149/2014/tc-8-1149-2014.html

736. And if you want one for the notion that lakes may refreeze you could use this: https://www.frontiersin.org/journals/earth-science/articles/10.3389/feart.2017.00058/full

But actually, if you were to delete lines 734-740 I think your paper would be improved as it remains more focussed on your Valais glaciers.

744. What do you mean by 'will develop'? Delete?

746 'will depend on the rates of'

747 I'd say 'associated' not 'subsequent' as higher melt will cause ELA to increase but also through the albedo feedback ELA increase will cause higher melt rates.

751 should you say 'and a reduction in drainage density'? Not 'or'. Because the example you give of drainage reconfiguration would reduce drainage density.

756 need a comma after '…evolution'

757-8. Poor phrasing – you could end the sentence "…future studies should repeat our work in such regions" [or something along those lines]. Actually, your statement isn't quite correct as you do compare your findings to those of others in Arctic settings (St G & M; Gulley et al) although that paragraph did need improving.

760. Say 'on Valais glaciers'. Your previous sentence correctly noted that you can't necessarily extrapolate from the channels you delineate in your study to all mountain glaciers.

796 'found to contain' => containing'

812. You could clarify that by terminating englacially you mean ending in a crevasse or moulin.

814 you refer to channels terminating supraglacially or englacially here. By supraglacially I assume you mean those that run off the glacier? Why not make that clear in the sentence above too? So, the sentence above would read:

"…have 80% of its channels run directly off the glacier (terminate supraglacially) while 20% would end in a crevasse or moulin (terminate englacially)." Would that make sense? It seems a little odd to refer to a channel that flows off the glacier as terminating supraglacially. Would 'proglacially' be better?

816. Refer to your Figure 7 at the end of this sentence. Delete the word 'observed' in the next.

816. Correct the English. Should say "differ from those in typical ice sheet…" [note plural therefore 'differs' not 'differ'].

818-20. Your final sentence is poorly articulated and could be stronger. This would be better, but you should decide.

"Compared to the GrIS, drainage networks on Valais glaciers are less developed due to smaller drainage areas and limited distance for channels to merge. Additionally, the down-

glacier narrowing of the Valais glaciers further restricts the potential size of their drainage networks."