Anonymous reviewer

The latest round of revisions by Wytiahlowsky and others has resulted in an improved manuscript however, several of my previous concerns were not addressed or not sufficiently addressed by the authors. I have expounded upon my previous comments to help clarify my concerns. My original comments (black, italicized), the authors response (blue), and my new comments (black) are included below. The few other concerns I have are also detailed below.

We appreciate the reviewer's positive assessment of the revised manuscript and thank them for their constructive feedback. In this version, we have made every effort to thoroughly address the reviewers' remaining concerns, and we hope that this is clearly reflected in the updated manuscript.

Concerns

L44-46: Here Pitcher and Smith 2019 is cited as stating that channelized meltwater flow occurs on some glaciers and not others. This isn't an accurate representation of the 2019 review paper that instead argues for a full inventory of supraglacial channels to be mapped but does not present conclusions or findings that channels are absent on some glaciers and present on others.

This citation was used in reference to the spatial distribution of channels not being known; however, we acknowledge that this wording may imply that the citation directly discusses why the distribution of channels may vary between glaciers. We have now reworded this sentence to clarify that this citation is used because it explicitly states that the lack of information on channel distribution is a key research gap that needs to be addressed.

(1) Citations were not added to support statement that most alpine glacier channels have widths smaller than satellite imagery resolution

> *L56-57: Here the authors state that remote sensing techniques have not been applied to mountain environments because of the small channel sizes there, but this is not supported adequately, how big are the channels typically found on mountain glaciers? This should be stated and references given. Currently only satellite resolutions are given which does not mean much if the size of the streams are not given as well.*

You do not need to provide a definitive, universal value for channel size, but you should state the range of sizes that have been observed, such as from glaciers that have been widely published on in Norway, Switzerland (Ferguson 1973), Alaska/Canada (Dozier 1974), Iceland , etc. Even though the statement is reasonable, stating something is "likely" to be true is insufficient without the necessary rationale. If you can't support statements with a citation then the logical argument needs to be presented.

We have modified this sentence to note that supraglacial channels on mountain glaciers tend to be less than a metre wide and have added relevant citations that include some measurements of channel width. We now cite Knighton (1972, 1981, 1985) and Ferguson (1973), whose papers include width measurements for a range of channels.

(2) Measured drainage density values were not added to the Discussion text.

L404: state the value for drainage density here.

I still think a range of drainage densities observed should be stated in this section. For example, what constitutes a “high drainage density” or “low drainage density” in your area? Ranges for these vague statements should be given to aid readers in comparing their observations to yours for this region of Switzerland. Values from your dataset aren’t misleading if they are properly stated with the caveats you mention above.

While this section focuses on our conceptual schematic, we have now included some example drainage density values in the Discussion based on additional analysis carried out in response to comments from another reviewer. Specifically, we performed a cluster analysis and an additional Principal Component Analysis, which helped group our study glaciers based on their characteristics and provided further support for our conceptual schematic. Although we have added summary statistics, including drainage density values, for each glacier type in the Results section (see final paragraph of Section 4.4) and included select examples in the Discussion, we note that these values should be interpreted with caution. Drainage density can vary significantly depending on image resolution and mapping method (for example, thresholds for minimum channel width), and therefore the values are not easily comparable across studies unless identical methodologies are used.

(4)

L484: If there are sediment laden beds there, this should be said so explicitly and cited.

My suggestion results from a gap in the logic of the paragraph. If no previous studies have identified subglacial sediments or rational for why they would be likely (which should be included if this exists), then a qualifier such as “if subglacial till is present, then …” should be included. The phrasing implies you know there are extensive subglacial sediments.

We have now added ‘If subglacial till is present…’ to the beginning of this sentence to help clarify that we are proposing a hypothesis rather than discussing direct observations.

Additional Comments

Throughout - Remove extra space between all #s and the % symbol. The space between the numbers and the % is in accordance with the journal style guidelines, which follow the SI brochure’s guidelines of ‘a space separates the number and the symbol %’.

L184 this is not a complete sentence. Amended – we have rewritten the sentence to say ‘Examples of supraglacial channels are shown on Glacier de Moiry (a-b) and Allalingletscher (c-d).’

L284- it appears that there is a space between each number and the % that should not be there, unsure if this is a weird compiling error or included in the submission but it should be fixed at some point. The space between the numbers and the % is in accordance with the journal style guidelines, which follow the SI brochure’s guidelines of ‘a space separates the number and the symbol %’.

L377: change “from mid-July 2020” to “acquired in” and add the specific date range in July

2020.
In addressing this comment, we revisited the Swiss geoportal and noticed an error regarding the acquisition date stated in the paper. We have since discovered that the flight lines that make up the swisstopo orthophoto from 2020 were acquired on several dates in August 2020 (5th, 7th, 8th, 15th, 21st & 27th), with one small area being covered on the 4th of September. As there is overlap between all these flight lines, it is challenging to definitively determine which part of the orthophoto comes from which flight line.

Overall, this helps to address an earlier comment regarding the use of imagery from earlier in the melt season, when channels are not fully developed (July). We have now corrected the manuscript, and any mention of mid-July has also been removed throughout.

L442-443: The sentence now reads "Overall, we find that at the average Valais glacier, 80% of channels run directly off the glacier, while the remaining 20% terminate in moulins or crevasses". Previously the text stated that 72% of the mapped highest order channels were routed englacially or sub glacially with 25% running off the glacier. This point should still be included within the manuscript as the most important channels in the context of supraglacial hydrology are the highest-order channels.

Amended – These figures have been added back into the manuscript. We chose to remove them because they are for all mapped non-tributary channels rather than per glacier, and this figure may be confusing because it predominantly contains channels from a few large glaciers that contain a very high portion of englacially terminating channels. We have now provided extra contextual information to try to avoid such confusion.

L529-530: here the authors state "**we** suggest that supraglacial drainage networks may expand to higher elevations due to rising equilibrium lines (Leeson et al., 2015)". The "we" should be changed in this sentence as the authors work does not directly assess future supraglacial drainage evolution. Amended - We have modified this sentence to state that 'previous research suggests…' instead of 'we'.

Review by Ian Willis

General Comments

I have commented positively on this work in my previous reviews and those points still stand. The paper presents a highly original data set, much of it obtained from meticulous manual digitising of tens of orthophotos. The descriptive statistics of the channel and glacier characteristics and their relationships (analysed using correlation and PCA) are all well done. It's good to see the improvements that have been made to the manuscript since my last review. For all these reasons I do think this work deserves to be published.

In my last review, I showed how the Discussion section needed the most work and it's good to see that in the latest version of the paper many changes have been made to the Discussion. I'm sorry to say, though, that I still don't think the paper is quite ready to publish because the Discussion and Conclusions still need some work. A fundamental problem is that many of the statements made in the Discussion and Conclusion do not clearly follow on from the data presented.

I think a major problem I'm having is that the Results focus on good robust quantitative

analysis of glacier and channel characteristics and their relationships (4.1, most of 4.2, 4.3 and 4.4) with a short weaker section on ‘qualitative observations’ towards the end of section 4.2 (6 lines of text and Fig 4) but the Discussion and Conclusions focus a lot on those ‘qualitative observations’ and don’t draw out some of the interesting things from the quantitative work.

Given the importance of these ‘qualitative observations’ I think they should be defined and described better and more thoroughly. Looking at lines 295-301, the ’qualitative observations’ ostensibly show examples of how ‘channel distribution and morphology’ are controlled by ‘glacier structure and topography’. These terms are poorly defined. Channel distribution is rather a vague term and not precisely defined but I take it to mean where they are located on a glacier vs where they are not]. Channel morphology is defined on line 49 as “channel shape and structure” which is slightly confusing as when I think of channel shape I think of the shape of a channel cross section. ‘Planform shape’ would be a better description as this is what is meant (i.e. whether channels are straight or meandering (sinuous). Channel structure is never defined. What is this? ‘Glacier structure’ features twice in this paragraph and nowhere else in the paper and is never defined. It seems to refer to patterns of crevasses, which is not what I’d call ‘glacier structure’. ‘Glacier topography’ is not defined but I think this is probably clear to most readers, i.e. the pattern of surface elevation and its derivatives (e.g. slope).

Despite it being suggested that both ‘channel distribution and morphology’ are controlled by both ‘glacier structure and topography’, we’re just given one example of how ‘channel distribution’ is controlled by ‘channel topography’ (Fig 4b), which is a channel occurring ‘along the interface between debris-covered and bare ice’. We’re also given an example (Fig 4c) of how ‘glacier structure’ influences ‘channel morphology’ which is a straight channel following a ‘trace or shallow’ crevasse. Finally, we’re given another example of how ‘glacier topography’ influences ‘channel morphology’ (Fig 4e), which is a sinuous channel at low elevations on a flat part of the

glacier towards it’s terminus. [We’re also told that such channels tend to occur on ‘large glaciers’, which is not defined by ‘glacier structure and topography’ but is anecdotally thrown in here].

I’m sorry to labour the point here but this paragraph is weak and yet a lot seems to hang on it in terms of your Discussion and Conclusions. How to improve it? First, you’d need to very precisely define the terms. Second, the reader would need to have an idea of how representative these 3 examples are of all the glaciers that you’ve looked at. Otherwise, how do we know that you’re not just ‘cherry picking’? Personally, I’d recommend removing this section as it is. Given that you have done all the robust quantitative work, I’d strongly recommend you base your Discussion and Conclusions on that evidence and perhaps show these examples in Fig 4 (and more if you like) of glaciers that show the typical behaviour that you see from the analysis of your large sample. Your quantitative work cannot tell us anything about how ‘channel distribution’ relates to ‘glacier structure or topography’ but it can tell us how ‘channel length’, ‘drainage density’, ‘sinuosity’ are related (or not) to the glacier variables of ‘area’, ‘slope’ and ‘elevation’. Note you cannot tell us anything about how ‘glacier structure’ [by which I assume you mean presence and orientation of shallow crevasses] influences channel characteristics as you do not have this information about crevasses in your large data set. What you can tell us about is that ‘crevasse extent’ influences ‘drainage density’ as that’s shown in Fig 5h.

You'll see in the line by line comments, when you get to the Discussion and Conclusions that I'm pointing out all the instances where I do not see evidence to support the statements you make. I would recommend a fairly root and branch edit of the Discussion and Conclusions so that your statements more firmly follow on from the robust evidence you have.

I think your correlation matrix and your PCA show some very interesting findings, only some of which you draw out. For example, your first PC shows that the greatest variability in your data set concerns glacier area, glacier elevation and channel maximum elevation. The way these variables are related (+ve / -ve), which is also shown in the correlation matrix, is interesting and could be interpreted. I think I give a possible interpretation in the line-by-line comments below. Similarly, your second PCA shows the 2nd greatest variability in your data set is to do with drainage density, mean glacier slope and mean glacier elevation. Again, the way the variables are related in their contribution to PC2 (and in the correlation matrix) is really interesting and supports the main conclusion that you wish to make (and which you've depicted in your conceptual model). Fig 5h also supports this. As far as I can tell you have no evidence that 'glacier area' may affect drainage density (r = -0.1) although you do have evidence that glacier area may affect sinuosity (r = +0.29). These points based on your evidence need articulating clearly.

Another thing you'll see form the line by line comments is that you need to be careful to separate out correlation (which you have evidence for) from causation (which is your interpretation). Be careful and consistent throughout your paper on this point. I think I've given examples below on how you can change things or where you should.

I hope my comments are helpful. As I've said before, they are designed to improve the paper so that it's intelligible and people will want to read it, understand it, and hopefully reference it.

We thank the reviewer for their continued efforts to help strengthen our manuscript. Hopefully it is clear that we have made a substantial effort to address the majority of their suggestions in full. The primary instance where we do not fully address the reviewers' suggestions relates to qualitative results. This is because we believe there to be value in these observations, but we do agree that it may be more useful to tone these down and focus more on our statistical analysis, which is what we have done in this revision. The only minor comments that we have not addressed relate to choice of terminology and a suggested figure edit. We have summarised the key changes below and responded to line-by-line comments. When a common theme emerges among comments in a section, we respond at the end of that section to avoid repetition.

The primary changes made during this revision include the addition of new analysis. Notably, we now include a cluster analysis to provide further insight into how glacier properties vary within our dataset. This has helped provide support for our conceptual schematic, as each cluster is typically characterised by different drainage densities and channel termini locations. We also renamed the glacier types in our conceptual schematic to reflect the properties of the glaciers in each cluster.

We have rewritten parts of the discussion to focus more on the data presented in the results section. This included removing much of the discussion surrounding individual glaciers and replacing it with discussion of our cluster analysis, as this uses our large dataset and helps to

better substantiate our interpretations. Changes were also made to the channel morphology section to focus more on our own data rather than the research of others.

We also edited the Valais and GrIS section to provide a clearer comparison between both environments. It was suggested that it would be useful for us to provide more of a quantitative comparison; however, unfortunately, there is not much directly comparable data. For example, due to the differences in mapping resolution, it is not useful to directly compare drainage density values (e.g. studies using coarser resolution imagery/measurements will be biased towards lower drainage densities and vice versa). We would have liked to compare bifurcation ratios, but we were unable to automate the calculation of stream order due to the complexities (e.g., frequent bifurcations) of our mapped channels. Hence, this section is written in a more speculative manner to reflect the greater uncertainty surrounding our interpretations.

Lastly, the conclusion has also been rewritten to focus more on our interpretations of the data presented in the results section.

Line by line comments

Introduction

45. suggest "…why surface meltwater becomes channelised on some glaciers but not others…" Amended.

55-7. correct to "…as most channels on mountain glaciers are likely much smaller than those on the GrIS and therefore fall below the resolution of even the highest-resolution freely available satellite platforms…" Amended.

58-59. Better to say: "…comparable to those on mountain glaciers. Mountain glaciers are characterised…" [because 'the latter' strictly refers to "the channels on mountain glaciers"] Amended.

70-72. "Where channels occur, they are often reactivated annually" repeats lines 67-8. And "…deeply incised channels suggested to be a product of high discharge.." is similar to lines 64-5 as high meltwater production => high discharge. Amended – we have removed the repetition of annual reactivation and discharge.

79-81. Better to say: "However, much of what we know about supraglacial channels was established from observations of a small number of individual glaciers, especially those that are cold or polythermal (e.g., Knighton, 80 1972, 1981, 1985; Gleason et al., 2016; St Germain and Moorman, 2019). Amended.

91. I'd say "glacier surface characteristics" Amended.

92. Can you briefly summarise what the 'qualitative observations" are? Although if you follow my advice in my general comments this may be removed. Amended – we have briefly elaborated on this. We should add that we still see value in adding some discussion of qualitative observations and note that this is not uncommon in the discipline.

Study location

100 Swiss canton [not capitalised here as not a specific canton, e.g. Valais Canton] Amended.

101 I'd delete the 2nd 'area' so "… a maximum of 77.3 km2…" Amended.

118. delete 'right'? Isn't G Aletsch just in the centre? Amended.

Methods

154-5. I'd say "This is because they are likely too small to form channels large enough to be detected in our imagery, and because many of the small glaciers listed in the Swiss Glacier Inventory (SGI2016) do not meet the criteria for classification as glaciers (Leigh et al., 2019). Amended – we have followed your suggestion but kept 'unlikely' instead of 'do not' to acknowledge the uncertainty.

174 "…main channels were mapped…" Amended.

178-179. confusing to have 'terminus' for channels and for glacier. Suggest use 'snout' for glacier terminus throughout paper. [Or you could use terminus for glacier and terminal for channel]. Also, later you talk about a channel running off (terminus or periphery). Would it better to refer to that here. So you could alter your list here to say: The type of terminus was assigned to each channel, which was one of: running off the glacier snout, or off the glacier side, or terminating in a moulin, crevasse, or lake, or adjoining another channel, or disappearing beyond the image resolution (i.e.., the terminus was not visible and could not be inferred confidently).

Note I've changed 'periphery' to 'side' here as 'periphery' to me would include the front (i.e. snout). If you like these suggested changes, check your entire paper and make the relevant changes.

We retained 'terminus' because it is an internationally-recognised and widely used term in the glaciological literature. The word "snout" (meaning the projecting nose and mouth of an animal, especially a mammal) is sometimes used but may confuse non-English speakers. However, the reviewer's point is well made, and we have gone through every mention of 'terminus' in the manuscript and made sure that it is clear whether we are referring to the channel or glacier terminus.

184. "Supraglacial channels on Glacier de Moiry and (c-d) on Allalingletscher…" Amended.

186. Should assessment be plural? Also, put in brackets the initials of the 'individual'. I assume (HW). The error assessment is not plural as it was a singular assessment. To clear up any potential confusion about our mention of 'on two occasions' we have reworded the following sentence to clarify that we re-mapped Rhonegletscher once after our original Mapping. The initials of the mapper are provided in the CRediT statement.

Tell us approx. what the time period was. E.g. "…was conducted over an approximately 6 month period."Amended – We have checked the file creation and export dates and can confirm that mapping took place from the 15th of June to the 18th of December 2023 (6 months and 3 days). We have added your suggested text, as it does reflect the duration of our mapping.

191. "…of each channel length and glacier's drainage density…" The sentence states that the error margin is small enough to conclude that we provide a good representation of each glacier's drainage density. We feel it would be contradictory to add 'channel length' here, because the following sentence goes on to acknowledge that most of our uncertainty comes from channel length. While the overall difference in drainage density values between our original and repeat mapping is small, the error for individual channel length may differ. Hence, we do not add 'channel length' in this sentence because we do not have the same confidence in those values as we do with drainage density. Therefore, we consider it better to refer to them both separately, as we currently do in the manuscript.

192. Could delete 'here' Amended.

195-6. This is unclear to me. Do you mean you mapped the up-glacier channel limit to where you were confident the channel existed? Note past tense 'were'. Amended – Yes, that is what we meant. We have now edited the text.

199. Helpful to reiterate "..the 85 glaciers…" Amended.

204. Regarding segment length, wasn't this derived from the orthophotos not the DEM as implied here? Regarding straight line distance, is this in 2D plan (so from the orthophotos) or in 3D (so from the orthophoto and DEM)? Amended – We have modified the text to state that the segment length is the geodesic length and calculated using ArcGIS tools that do not use a user-inputted DEM, and straight-line distance does use a DEM because it is in 3D and uses the minimum and maximum channel elevation values from the DEM.

209 change 'which' to 'and' Amended

201 could delete 'record' Amended.

199-219. There's confusion I think between these paragraphs about how you calculate elevation and slope. In the first para you say the DEM was used to calculate both. In the 2nd you say that slope was calculated for the snow free area so calculated from the DEM. But what about elevation variables? Did you also calculate that for the snow free part? Amended – The first paragraph has been reworded so that it is clear that we extracted channel elevation values from the DEM and use these to calculate other metrics such as channel slope and straight-line distance. This should hopefully prevent any confusion as we've separately mentioned how we calculated channel and glacier slope. We have also rewritten the 2nd paragraph to more clearly state which data comes from where. Notably, it is clearer that the elevation values are from the 2015 glacier inventory data, and we do not separately recalculate elevation values for the snow-free portion. We used elevation data for the full glacier, as this allows us to characterise the glacier in its entirety, which is more difficult to do when just using the elevation of the snow-free area at a time-stamp.

226-27. given what you said earlier you could reorder these and say "drainage density, glacier area, aspect, minimum elevation, mean elevation, maximum elevation, and mean

slope of the snow-free area." Amended – we have removed the mention of 'glacier' from this list and reordered it so the snow-free area and mean slope are mentioned together.

228-233. Could be abbreviated and improved to say: "A one-way ANOVA was performed to test the significance of the relationship between the three debris-cover classes and sinuosity. In addition, a Principal Component Analysis (PCA) was conducted to examine relationships among variables and identify the main drivers of variance in the dataset, with the data normalised to enhance pattern detection." Amended.

Results

243 I'd change 'on' to 'of' and say 'km2, with a maximum…" Amended.

264. It would be helpful to indicate where these glaciers in Fig 4 are on Fig 1. This suggestion is well made but would overcomplicate Fig. 1 as we already colour-code glaciers in the figure and have letters showing the location of panels. Additionally, now we have shifted our focus away from a few specific glaciers.

286. change 'terminus' to 'snout'? See earlier comment. Change throughout if you agree.

289. change 'periphery' to 'side'? See earlier comment. Change throughout if you agree.

We have kept this as terminus (see our response to your comment about line 178 – 179.

292. What do you mean here? what is 'the average glacier'? Also, have you defined 'terminating proglacially already? Is this the same as having water running off the glacier snout or off the glacier side? Amended – we have provided additional clarification in this sentence. We refer to the proportion of channels that terminate englacially versus run directly off the terminus at each glacier are averaged across the dataset. This value includes channels that run off the glacier side/periphery and at the glacier terminus, which is clarified earlier in that paragraph when we refer to terminal segments.

305. 'variables to test for…" Amended.

306. 'affect' implies definite causation, but of course you're doing correlation (not causation). You could say " 'may affect' or 'are related to' here. Amended.

312-13. "The 'debris' class generally contains more sinuous channels than…" is more correct Amended.

341. You can't say 'controls' here as this implies causation which you don't know from correlation analysis. From here and for the rest of our paper you'll need to be careful with this. You'll need to be clear when you're sticking to the facts (correlation) and when you're making inferences from them about cause-effect or processes. You could say "'associations between' or 'possible controls' here. Amended.

345. 'control' No Amended.

355. What does " high channel sinuosity can in part be explained by multiple weak correlations" mean? I'd just delete this. Amended – we have made this clearer.

358. ‘controlled’ No Amended.

361. ‘relationships’ [plural] Amended.

361-2. did you use all the channel and glacier variables in your PCA? If so state that here. Amended – yes, we used the same channel and glacier variables included in our correlation matrix (Figure 6), which is the same as those listed in section 3.3. We have now also modified section 3.3 in the methods to make this clear.

362-367. Capitalize ‘Principal Component’ when referring to a specific PC (1, 2 , 3 etc). Or just abbreviate to PC Amended.

366. Tell us what % PC1 and PC2 explained individually (not just together).
Amended – we have now given the individual percentages for PC1 & 2.

Discussion

Section 5.1

377. I assume you want to say “Previous work has suggested that the presence of visible channels is primarily controlled by…” ? Because you do not measure ‘meltwater supply’ in your paper. Or is this interpretation based on your results? It’d be best to start each discussion point (so 5.1, 5.2, etc) with explicit reference to your findings, then your interpretation of those findings (make it clear where results end and interpretation begins) and you could also discuss your findings / interpretation in the context of previous work.
Amended: see response 2.

Section 5.1 - This subsection is headed “Controls on the spatial distribution of channels” . This is a little unclear as a title, especially as you haven’t really shown results on this topic. Your paper is not about why channels form in some places and not others on a glacier.
Amended: see response 1.

382. Your statement “glacier area controls much of the variability within the dataset (Table A1)” is correct as glacier area dominates PC1. You could refer to PC1 after Table A1 to clarify this. Amended – this section has been rewritten to focus on our results.

383-4. Your statement “… albeit with large variation in drainage density.” Is rather thrown away here. Drainage density dominates PC2. So why not explicitly say that. Amended – see response 3.

384. When you say “This variation is in part attributed to glacier slope…” what exactly do you mean? I can see that PC2 is dominated by drainage density (+ve) and glacier slope (-ve). Is this what you’re talking about? Refer to the evidence for your statements. Note glacier mean elevation (-ve) also contributes to PC2. Why not mention this? What this means is that a high source of variability in your data set comes from these three variables contributing to PC2. Glaciers with high drainage density tend to have low slopes and are situated at low elevations. Use your results to discuss them. Amended – see response 3.

384-5. Your statement "…together with ice flow velocity, governs the crevassed area of a glacier" is either from previous work or it's your interpretation of your results. You do not analyse ice flow velocity. Nor do you show the relationship between glacier slope and crevassed area. You need to more clearly discuss your results and explain what your evidence shows and how you interpret it. Amended – see response 3.

388-92 'Channel formation is also governed by glacier hypsometry…' is a little confusing as 'hypsometry' is not one of the variables you quantified and investigated. Similarly, you talk about "glaciers containing a larger proportion of their area at lower elevations', which I agree is to do with hypsometry, but again, you don't measure or report this. What I can see is that the 3rd most important variable contributing to PC2 is glacier mean elevation, and I can see from the Table A1 and the Fig 6 correlation matrix that drainage density is inversely correlated with glacier mean elevation, so lower elevation glaciers have higher drainage densities. Refer carefully to your data and evidence and make statements that you can support. Then interpret. The last two sentences of this para don't really contribute meaningfully to the discussion. Amended: see responses 2 to 4.

393. The word 'hypsometry'. Again, this is not something you explicitly focussed on in our paper so I'd remove reference to it. However, here you're focussing on explaining variation in drainage density (so we're with PC2 still) and you could also draw on evidence from the correlation matrix. It is glacier slope and glacier mean elevation that correlate with drainage density and contribute to PC2.

394. "The lowest drainage densities are predicted to occur on smaller cirque glacier…" You cannot say this based on your work. First, the word 'predict' suggests you've developed a model (e.g. regression) and are using it for prediction, which is not the case. But nor did you show that low drainage densities are correlated with small glacier size. In fact, the correlation between these two variables is only -0.1 and non-significant so you need to play down the role of glacier area. Lowest drainage densities are associated with glaciers with steep slopes and high average elevations (PC2 and correlation matrix). Perhaps they're not necessarily the cirque glaciers, just steep, high elevation glaciers – they could be valley glaciers. Base your statements on the evidence. Then you could go on to infer the processes involved in explaining the correlations,
i.e. your interpretation. Make it obvious to the reader in your writing when you're moving from results to interpretation. Amended: see responses 2 to 4.

398-400. As above, you've not shown direct evidence for this statement. You have evidence that large drainage densities are on gently sloping glaciers at low mean elevations. Why are you talking about steep slopes and crevasses here? Amended: see responses 2 to 4.

400-402. Again, you must use your results as the basis of your discussion. You have evidence that large glaciers extend to lower elevations and have channels that don't extend to very high elevations (PC1 and correlation matrix). I cannot see evidence for a link between glacier area and drainage density. The opposite in fact as these have a low correlation. You have evidence that glaciers with high drainage densities have low slopes and have a low mean elevation. Amended: see responses 2 to 4.

404-408. The two sentences here are a contradiction to your general finding based on the statistical analysis of high drainage densities for glaciers with low mean elevation. You'd be

better to discuss things based on your findings! Amended: see responses 2 to 4.

413. Channel inception in Fig A should read interception – I think I pointed out this mistake in an earlier review. Amended.

425. As I say above, I don't think glacier size can be discussed in relation to your conceptual model that is supposed to be based on your evidence. You could talk about steep, high elevation glaciers here but not 'small'. Categorising them as 'cirque' is an interpretation I assume? Amended – we have renamed 7A to 'Steep, high elevation glacier' and avoid assuming that all glaciers that fall into this category are cirques.

428. 'valley glaciers are larger' Again, valley glaciers is an interpretation. Your evidence doesn't allow you to equate 7B glaciers with size. Your evidence suggests these are less steep with lower mean elevations cf. glaciers in 7A. Amended: see response 4.

435-436. Again, link to your evidence. Avoid talking about 'area'. Here you're talking about very shallow gradient glaciers with very low mean elevation. These have the highest drainage densities. And they have the lowest incidence of crevassing (Fig 5h). Amended: see

441. 'connectivity'? What does this refer to? Amended – this paragraph was rewritten and no longer includes this sentence.

442. "…based on the locations of our mapped channel termini". Up to this phrase, this sentence sounded like a summary of your previous paragraph and conceptual model shown in Fig 7. This phrase throws a spanner in the works as you have not yet discussed possible links between locations of mapped channel termini and lag times between melt and discharge. I've read on and it appears as though you're going to talk about this wrt 2 case study glaciers. I suggest rewriting this sentence to introduce the work you'll present in this paragraph. Amended.

442-3. As I mentioned before, what exactly does this mean? How do you define 'average glacier'? Amended – we have reworded this to clarify that we are referring to the average proportions of channel termination locations (e.g., englacial or running directly off the terminus), calculated by averaging the values from all individual glaciers.

444. "… the largest glacier, Grosser Aletschgletscher (type B in Fig. 7)" OK, so your largest glacier is type B not C! This adds to my advice that you should not refer to glacier area as a control on drainage density (for which you don't have evidence). Amended – we no longer focus on glacier area as a control on drainage density.

451-2. where are the 'trace crevasses' in Fig 8? They are not labelled as such. Amended – this figure was removed as we have shifted the focus away from qualitative observations.

440-456. This paragraph is a little rambling and unfocussed. State at the outset what you're aiming to achieve here. It looks like you want to show us how different types of glacier (low drainage density to high drainage density - types A to C in Fig 7) have channel segments that

terminate in different ways. Correct? One way to have done that would have been to cluster your glaciers into the three types (based on their statistical attributes - either the raw

variables or the PCs) and then looked at the number of channel termination types in each of the 3 clusters. You'd hypothesize that your steep, high elevation, low drainage density glaciers (type A) would have most channel termini ending in crevasses. Type C would have most ending by flowing off the snout or side. And type B would be somewhere in between. That would have provided you with the evidence you need to support all your statements relating to crevasses affecting channel / drainage characteristics. But you're not doing that.

Instead, you're picking a single case study example of Type B and Type C and telling us about their channel termini characteristics. For completeness why not do the same for a Type A glacier? Explain at the outset that this is what you're doing in this paragraph. In fact, would it be best to do all this BEFORE you present your conceptual model because in your description of the 3 types of glaciers you mentioned crevasses without really showing us any evidence that crevasses were relevant. Amended: see response 2.

460. You refer to ' meltwater overtops the crevasse' . Does this make it a trace crevasse then? Amended – this figure was removed as we have shifted the focus away from qualitative observations.

464. You refer to Oberer Theodulgletscher and Grosser Aletschgletscher but as I said above it'd be helpful to add an example of a type A glacier wouldn't it? Note the proper nouns (names of glaciers here) do not need to be prefixed by 'the'. Amended – we now focus on our cluster analysis rather than individual glaciers.

473. As I said before, you don't measure 'hypsometry' but you do show the role of glacier mean elevation so I'd refer to that here. Amended: see response 2.

472-3. I'd agree with the statement: "Hence, categorising glaciers based on their slope and mean elevation is beneficial because it provides insight into the anticipated drainage density of a glacier" because this is based on your evidence from your correlation matrix and PC2. Amended: see response 2.

474-5. This statement about things providing insight into "channel pathways (i.e., sub-/englacially or proglacially terminating), and whether a higher amount of surface-to-bed meltwater transfer is likely" is a bit clumsy and is less well supported by your evidence but see my suggested way forward above wrt cluster analysis..Amended: see response 2.

Response to comments on section 5.1:

We have made some key changes to this section to address all the comments above:

1. **Section name -** The name of this subsection has been changed to 'The influence of glacier characteristics on supraglacial channel networks' to better reflect the focus on the impact that glacier slope and elevation have on glacier drainage density and channel termini locations.
2. **Principal Component Analysis & cluster analysis** – Following the suggestions from the reviewer, we have now performed a cluster analysis to group glaciers based on their properties. This data is also now visualised using a PCA biplot in Figure 7. We find that the clusters presented in Figure 7 support our interpretations as they show an increase in drainage density with a decrease in slope and glacier elevation. Channel termini locations also differ between the glacier types identified in our cluster analysis, which

helps strengthen our interpretations. We have now added this analysis into our methods, results, and use it to strengthen our discussion. We thank the reviewer for this suggested analysis.

3. **Structure** – We have reconfigured the structure of section 5.1 to mention data that forms the basis of our conceptual schematic before its introduction. The section now discusses the results of our correlation matrix and initial PCA first, clearly outlining that drainage density is primarily influenced by slope and elevation. We then introduce our data on channel termini locations and how our cluster analysis can explain inter-glacier variations in meltwater pathways based on glacier slope and elevation. After this, we introduce our conceptual schematic as our interpretations are supported by the data presented in the previous two paragraphs. The final part of this section uses our conceptual schematic to speculate how different glacier types may produce different hydrographs in response to a surface melt event.
4. **Conceptual schematic –** we have changed the names of each type of glacier on the conceptual schematic to better reflect what our data shows. For example, Type A in our schematic now refers to a 'steep, high elevation glacier' rather than a 'cirque', and we have removed the mention of glacier size in order to better focus on what our data clearly shows.
   We also now focus on using our data to support the interpretations made in the schematic. While we previously referred to specific glaciers for each type, we have removed this information, even though these glaciers are still classified as the same type using our cluster analysis. This is to avoid focusing on specific glaciers and instead simply use our cluster analysis to provide support for our interpretations.

Section 5.2

479 "…slope affects sinuosity". Clarify you're talking about channel slope. And avoid the word 'affects' as this implies causation whereas you just show correlation. Amended.

480. As well as Fig 5a you could refer to Fig 6 as this is supported by your correlation work. It's also interesting that this -ve association between channel slope and sinuosity remains apparent in PC5. Amended – we have cited Figure 6 and also Table A1 given that this provides additional evidence of this relationship.

481. After stating the correlation between channel slope and sinuosity, you could interpret it and discuss processes. It's what you'd expect isn't it? Steeper slopes → lower sinuosity. On steep gradients, water has high energy and tends to take the most direct downslope path. This reduces the development of bends, keeping channels relatively straight. Gentler slopes → higher sinuosity. On low gradients, flow velocity and stream power are lower. Water has less ability to cut straight downslope and instead meanders laterally, forming more sinuous channels. We agree. After we mention the correlation between slope and sinuosity, we now also cite fluvial literature which further supports the logic of our observations.

482-3. Fig 4e doesn't provide all the evidence to support the statement. It just provides examples of two sinuous channels on clean ice. Are there other channels not shown that are straight and on dirtier ice? I'd be tempted to delete this sentence. We have removed this sentence to avoid focusing on specific glaciers, but the examples shown in 4e are indeed the most sinuous channels in our dataset, which we include as an example.

483-5. The statement spanning these lines could also explain the sinuosity of at least one of the channels shown in Fig 4e as that channel seems to be sourced on debris. So this all seems a little weak. We now acknowledge that we find differences in channel sinuosity depending on how extensive the debris cover is surrounding the channel. We suggest this could be due to sediment transport affecting channel sinuosity, as prior research has suggested this may be the case (e.g. Rhoads and Welford, 1991; Boyd et al., 2024).

486-500. I don't really see what you're trying to explain here. Channel slope controls stream power. Surely this promotes straighter channels. So your finding of more sinuous channels on gentler slopes makes perfect physical sense to me. Like you say, discharge also controls stream power so if discharge is higher through gentler slopes, then I suppose that could override the slope control, promoting straighter channels on gentler slopes and more meandering channels on steeper slopes. But you do not find this! Nor do you have any discharge data! So why try to explain it? Are you trying to explain Fergusson's and StG and M's findings, which would seem to buck what makes more physical sense? Haven't they already done that in their papers? Is it your job to do it here? I suppose you could just briefly explain that your findings are different to those from the Arctic glacier but explain briefly why the earlier work provides evidence which is contrary to what you might expect. But be brief. Amended - We have rewritten this section to shift the focus towards our data/observations and have since added in fluvial citations that provide good support for our findings. We still briefly acknowledge the differences from St. Germain & Moorman's findings, but do not focus on explaining these differences.

Section 5.3

503-5. Split the sentence to be clear. So say: "Previous research on supraglacial channel morphometry has focused predominantly on the GrIS (e.g., Smith et 503 al., 2015; Karlstrom and Yang, 2016; Yang and Smith, 2016; Yang et al., 2016, 2021, 2022). We find some similarities between the drainage patterns observed on Valais glaciers, and those on the GrIS." Amended.

505-6. I don't think you should resort to just picking out this one glacier in 4a. Your work has not focussed on how dendritic drainage patterns are. Can you not compare some of the quantitative channel and glacier characteristics and relationships between Valais and the GrIS, e.g. drainage density or sinuosity and their correlations with channel / glacier attributes? Much of the research that looks at the morphometry of channels on the GrIS focuses on channel network properties (i.e., stream order and bifurcation ratios) (e.g., Yang et al., 2016). It is not possible for us to quantitatively compare these values to our dataset because we were not able to reliably automate the calculation of stream order from our channel centerlines. We also cannot directly compare our drainage density values to the GrIS due to the use of different resolution imagery, nor are we aware of any papers that have summary statistics for sinuosity, although many papers mention it in passing. Hence, any comparison between both environments will have to be more qualitative, but we still think there is value in this and have tried to refine this section to focus more on the data presented in the discussion.

507-8. "…some glaciers in Valais display parallel, weakly interconnected channel networks, likely due to insufficient distance for meltwater to converge into a single channel" Seems a bit anecdotal. Do you have strong evidence that this is prevalent on Valais glaciers? Doesn't the GrIS also display this in places? We have rewritten this paragraph to better explain that channel networks across Valais exhibit a range of drainage patterns,

i.e., some glaciers contain much more dendritic networks, while others are less interconnected. Now we more clearly outline that a range of drainage patterns are found on the GrIS. However, we suggest that controls on drainage types (i.e., dendritic vs parallel) on the GrIS may not fully explain the drainage patterns found on Valais glaciers due to the difference in area and high crevasse density. This is done in a speculative manner and does not suggest that we have more data than we do.

509 "…these networks…". Which networks are you referring to here? The parallel weakly interconnected ones? So Yang et al 2016 find these follow Horton's laws on the GrIS? Why not calculate them for your drainage networks? Then you could properly compare Valais glaciers with GrIS. So far, you've not convincingly told the reader based on evidence whether and how the supraglacial hydrology differs between Valais glaciers and the GrIS. We previously intended to calculate stream order and bifurcation ratios for our dataset, but this has not been possible to automate because the polyline network often bifurcates and re-merges, which doesn't align with the simple, branching structure that stream ordering tools are designed for. Small overlaps between segments and issues during raster conversion also broke flow continuity, leading to unreliable results.

511. You say 'trace crevasses exhibit a strong control on meltwater routing on Valais glaciers'. I do not believe you can conclude this from the evidence you've presented. The only mention of 'trace crevasses' in your results is on p18 wrt Oberer Theodulgletscher when you say "it is not known whether meltwater enters englacially or is routed on the glacier surface through trace crevasses (e.g., Fig. 8). Fig 8 makes no mention of 'trace crevasses' explicitly. Amended – we have removed mention of trace crevasses.

512. I'd delete ref to Antarctic ice sheet – see the subheading title! Amended.

514. should say 'Valais glaciers and the GrIS…' Amended.

516. I'm still unsure what the "average Valais glacier" is. Amended - This was removed when this paragraph was rewritten. Any mention of the "average Valais glacier" earlier in the text has been rewritten to provide further clarification on what we were referring to.

520 "appears to affect…" The language in this paragraph has been modified to acknowledge uncertainty.

520-1. Where did you show debris cover affects channel distribution? And what do you mean by 'distribution'? The only place I can think of is Line 295 onwards "Qualitative observations suggest that channel distribution and morphology are controlled by glacier structure and topography. For example, channels often occur along the interface between debris-covered and bare ice (e.g., Fig. 4b), particularly adjacent to medial moraines, where channels are confined to a topographic depression, commonly occurring at the confluence between two tributaries." This is only one example you've shown and I bet you could find at least one example of a channel on the GrIS flowing adjacent to a medial moraine. I don't think you have enough evidence to say anything meaningful here about the similarities or differences between Valais glaciers and the GrIS in terms of the effects of debris on channel 'distribution'. What about morphology? Any studies of sinuosity and role of debris on GrIS? We have rewritten this paragraph to acknowledge more uncertainty with regard to these interpretations. The mention of channel distribution in the first sentence of this paragraph is in reference to the discussion of how moraines may affect the transport of meltwater and affect where larger channels are observed. We also refer to

the distribution of areas with high channel density when discussing roughness later in the paragraph. Unfortunately, we are not aware of any studies on the GrIS that could meaningfully strengthen this section, hence the more speculative nature of our discussion.

522-4. This sentence seems misplaced as it's for a glacier in Svalbard. Suggest delete. We have kept the reference in but rewritten this section. We have kept this citation as it is useful to acknowledge that debris may affect channel density, regardless of where that research was conducted.

524. What do you mean by "scale" here? And are you comparing Valais glaciers with the GrIS? Amended - We mean the extent of debris cover and have since rewritten this paragraph to clarify its meaning.

526. At the end of this para I don't have a clear sense of the similarities and / or differences between Valais glaciers and the GrIS in terms of the role of debris on supraglacial channels. This paragraph has been rewritten to more clearly emphasise the similarities between the data we have which is comparable with the GrIS, which has hopefully strengthened it. However, as few studies have investigated the impact of debris on channel distribution and morphology, this section has to remain fairly speculative. For example, we acknowledge that the extent of debris coverage varies between the two environments and then focus on discussing how debris may affect channel distribution and morphology when it is abundant.

Section 5.4

530. 'may' => 'are likely to continue to' Amended

534 'large enough' => 'sufficient' Amended

537-9. Seems a shame that you can't add anything to this based on your work. What would you expect from Fig 5c? Figure 5c is discussed on lines 343 to 348 and 627 to 631. We could further speculate about the relationship between debris and sinuosity, but given that most suggestions have favoured removing speculation, we do not deem this to be a fitting addition.

540-47. All this is not about the future evolution of channel systems. You need a separate section, or you need to reframe this section and provide a new heading. If you're talking about future work, you should discuss the possible imitations on your work of using July imagery rather than later season imagery. Amended - We have split this paragraph to keep these lines separate and have changed the subheading to acknowledge that this section also discusses research gaps.

Conclusion

550. I'd say 'From a sample of 285 glaciers…" Amended.

551-2. Here you talk about variability in glacier drainage density. This relates to PC2. Before this you could report the PC1 finding of high glacier area variability with large glacier area correlated with low minimum glacier elevation and low maximum channel elevation. And the possible reasons / implications of this. Of course, you'd need to have this as a discussion

point earlier, as I suggested you could. This section has been rewritten in line with the reviewer's suggestions below. We do still mention glacier area briefly, but we focus more heavily on what the clear controls on glacier drainage density are (i.e., glacier elevation and slope).

553. As well as ref to Fig 7 I'd use (or add) your correlation matrix Fig 6 here. The rewrite of this section doesn't include references, as these are not commonplace to include in the conclusion. We do, however, provide references to figures in our results and discussion, which now better support the statements in the conclusion.

553-554. " The presence of channels is primarily dictated by a sufficiently supply of meltwater (i.e., large enough glacier area)" Note sufficiently => sufficient. But more importantly, this can't be a direct conclusion of your work as you do not measure melt water supply in your study. In your conclusions, explain what you actually find and then explain what your interpretation is. A large glacier area is not necessarily synonymous with a large supply of meltwater as you seem to be suggesting here. I assume this conclusion relates to your first result on lines 237-8 "Glaciers with channels (n = 85) have a larger mean area than glaciers without channels (n = 200) (mean area = 5 237 km2 vs. 0.6 km2) and all glaciers larger than 5.6 km2 contain channels
> 0.5 m wide (Table 1, Fig. 3a)." If so would it be useful to remind us of this or refer to the relevant Fig? Amended – the mention of meltwater supply has been removed.

554-555. "…and an uninterrupted distance for meltwater to coalesce (i.e., absence of crevasses)" Where did you show us that the 85 glaciers had fewer crevasses on them than the 200 glaciers that did not have channels, as you are suggesting here? This point refers to our finding of higher drainage densities on less crevassed glaciers (Fig. 5h) and on lower relief slopes (Fig. 6), which are assumed to be less crevassed. We see how our original wording may have been confusing and now just mention the controls on drainage density rather than presence.

555-57. I can't see evidence for this sentence. You're suggesting that there are thresholds of glacier slope and glacier area beyond which channels don't form. Where is the evidence for this? Fig 5b does not show this. You also suggest that glacier slope and glacier size provide a limit on channel length. Again, where is the evidence for this? Fig 5b shows the relationship between channel slope and channel length of your sample. There is nothing about 'limits' here. This point is no longer a primary focus in the revised section. However, we note that Fig. 5b shows an absence of long channels on steep slopes and no channels above a certain slope, which we interpret as a constraint likely related to crevasse density. While it may not be the only control, glacier area also places an upper bound on channel length. The revised text no longer implies the existence of hard thresholds.

557. "…strong structural controls on channel distribution exist." It seems really odd to be talking about channel distribution as that is not really what your paper looks at. For the glaciers with channels on them, your paper focuses mostly on the relationships between channel and glacier characteristics, not about the presence or absence of channels in particular places. Amended – the conclusion now focuses more on the relationships between channel and glacier characteristics.

557-8. "For example, trace crevasses have been observed to act as preferential meltwater pathways, resulting in channels forming perpendicular to ice flow." Where have they been observed? I think you give just two examples in your study (Fig 4c and Fig 8) and this point

is mentioned almost in passing. It is hardly a major conclusion of your work. On line 452 you state: "Observations have shown that trace crevasses may act as a preferential meltwater pathway, often resulting in channels forming perpendicular to ice flow (e.g., Chen et al., 2024). " So this is a conclusion of another paper! This is something we commonly observed whilst mapping, which is why it was initially mentioned. In this revision, we have removed mention of it in an effort to shift the focus more towards our quantitative results.

559. “Channels also commonly form parallel to medial and lateral moraines due to topographic confinement.” Again, is this really a major conclusion of your analysis? Where do you show this? where is the evidence that this is widespread? As mentioned above, this statement is based on our observations during the mapping process. We have since toned down the mention of qualitative observations per the reviewer’s suggestion.

560. You refer to Fig 5a here but wouldn't Fig 3f be better? What is your definition of low? Can you say that x% are < some threshold? Amended – we now just mention that there is a negative association between sinuosity and slope.

560-61. “….highly sinuous channels are present, particularly on moderately debris-covered ice and lower-relief glacier termini.” Again, where is the evidence.? See my comments on your section 5.2. Amended – we’ve removed mention of glacier termini here.

566-575. You may wish to reword or refocus this and the entire conclusion after thinking more about the Discussion section. Amended – this section has been revised.

Response to comments on the conclusion:
We have rewritten the conclusion section to better summarise our revised discussion. Hopefully, it is evident that the conclusion is now based on our interpretation of the data presented in the results section, and focuses less on qualitative observations. In this new conclusion, we do not include references as it is not commonplace, but references are present when the points in the conclusion are discussed in the previous section.