

Overview

This is a novel paper involving the generation of a unique and valuable data set on surface stream characteristics for 85 glaciers in Valais, Switzerland from open access 0.15 m resolution SwissTopo orthophotos and DEM. The lead author is to be congratulated for manually digitising the 1890 streams, although it is a shame this couldn't have been automated. Automation was attempted, based on previous methods applied to the Greenland Ice Sheet, but these were found not to work here. Having created the data set, the paper investigates statistical relationships (correlation, PCA) between channel variables (segment length, channel slope, sinuosity, minimum elevation, maximum elevation and elevation range) and several glacier variables (drainage density, glacier area, mean slope of the snow-free area, aspect, glacier minimum elevation, glacier mean elevation and glacier maximum elevation). Differences in certain channel characteristics between clean and debris covered glaciers are investigated, as are differences between the way the channels terminate (moulins, crevasses, running off the terminus or edge of the glacier, etc). The results are shown in a set of nicely produced figures and tables, and examples of different types of streams are shown in Fig 4 (although I'd like to have seen an example of a stream which terminates in a lake, although this type of termination only makes up 1% of the total).

I think the justification for the work is adequately provided in the Intro, although I'd add the importance of the supraglacial stream network, and particularly for whether the water enters moulins or crevasses or not, for understanding subglacial drainage evolution, water pressures, and basal motion to this.

The data sets and methods are described well, although I'd like to hear more about precisely what automated methods were attempted and why they failed. I also note that the orthophotos were collected in mid-July 2020. Can this melt season be put into some perspective? Was it a high accumulation winter previously? What was the weather doing in the spring and early summer? So what were the snow / ice conditions in mid-July this year compared to other years? What are the implications of using orthophotos from this time? I imagine results would be very different if they'd been collected later in the summer during very high melt conditions? Does the timing of the orthophotos explain why you only found 85 (out of 285) glaciers with streams on them? This seems quite a low number to me.

The results are clearly presented overall, and the statistical analysis seems generally robust, and the results sensibly interpreted. The PCA doesn't add very much, and I wonder whether the authors had considered collapsing potential independent glacier variables (glacier area, mean slope of the snow-free area, aspect, glacier minimum elevation, glacier mean elevation and glacier maximum elevation) using PCA and then investigating the correlations between the PCAs and potentially dependent channel variables (segment length, sinuosity, drainage density)? This would appear justified given the significant correlations between all the variables (Fig 6), and the desire to try to explain the variability in channel characteristics.

I think the weakest part of the paper is the Discussion, which is not sufficiently focussed on the results presented, occasionally confuses results vs previous work, and appears a little long-winded and speculative in places. I think there are some interesting points to come out of the results and some legitimate comparisons that could be made with previous similar work on the

Greenland Ice Sheet and other glaciers in the Arctic or which are debris covered. It's just that these need to be more streamlined and succinctly articulated. The Conclusions would then be stronger, and the paper would have more impact.

I provide more comments on all these points in the details below, together with recommendations for where grammar could be improved, clarity could be enhanced, or where I have queries.

I have one more general query which is why did the authors decide to use the English names for all the glaciers? Would it not be more appropriate to use the local Swiss names (which are in German or French)?

I think the work should be published if the authors are able to address my comments and suggestions.

Detailed line by line comments

13. I'd say '~ 2000' [as <2000 could be anything between 0 and 1999].

12-14. Seems odd as worded. Would this be better: "Here we use high-resolution (0.15 m) orthophotos across a sample of 285 glaciers in Valais Canton, Switzerland, to identify 85 that contain supraglacial channels. For these 85 glaciers, we delineate ~ 2000 supraglacial channels (> 0.5 m wide) and investigate their distribution and characteristics."

15-16. What are 'lower relief slopes'? Should this be 'lower angle slopes'? This phrase is used several times throughout the paper.

21. Should be "...where all channels terminate englacially..."

23-24. You could delete "the majority of channels reach the terminus supraglacially and" as you already said that on lines 18-19.

43. Suggest "channels has implications..."

44-45 Suggest '...through and under glaciers, with potential to impact suspended sediment...'

48-50. The distinction between channels vs channel absence is a bit artificial here as the former is typical on an ice surface in the ablation area whereas the latter will be confined to higher elevations. Can you distinguish between importance of channels vs absence in ablation areas as this controls delivery of water to bed which influences subglacial water pressures and basal motion (e.g., Banwell, A., Hewitt, I., Willis, I. and Arnold, N., 2016. Moulin density controls drainage development beneath the Greenland ice sheet. *Journal of Geophysical Research: Earth Surface*, 121(12), pp.2248-2269). Channels vs absence on firn at higher elevations reflects melt rates vs infiltration capacity, and I agree this has implications for partitioning of refreezing vs runoff.

52-53. '...glacier systems...' is vague. If you elucidate importance for proglacial water quality, glacier dynamics, and mass balance above, you could refer to these things again here. But are you going to address the impacts in this paper? If not, I suggest delete this last clause.

64-65. Suggest "...larger ice sheets also apply..."

67-8. Suggest "...about supraglacial channel distribution in mountainous environments, but previous research has helped to establish some fundamentals (e.g., Knighton..."

75 'present' => 'presence'

76 'influences' [i.e. singular as refers to 'presence']

76-80. These two sentences are repetitive. Suggest combine to make the point about the controls of discharge and slope just once. 'increased slope' should say 'high slope'.

80. 'discharge rates' is wrong as discharge is a rate [discharge is the volumetric flow rate of a stream].

86. Suggest changing 'systems' => 'glaciers'.

132 'records an historical'

122-137. To what extent is all this info on climate and glacier area change relevant? Can you delete it all (or much of it)?

146 Need a comma here "small amounts of water, or incised channels where..."

141-147. You say you applied automated methods [i.e. plural] and refer to Yang et al 2019. Does this reference detail all the different automated methods you applied? But then you only mention the first method you used and refer to Yang and Smith. This seems odd. Why did you single out just this one method to talk about if you applied others? Clarify here how many methods you applied, what they were, and what the problems with all of them were.

148. when you say 'multispectral methods' do you mean 'automated methods' [as referred to on line 141]?

149. You mention your data set here "high resolution cloud-free orthophoto imagery" but was this the data you first attempted to detect channels on automatically as mentioned above? State above what data you were working with.

150-52. Suggest "hence 6% of glaciers were still snow-covered down to their termini and were omitted from further analyses as the presence or absence of channels could not be detected."

I assume by this statement that you included glaciers that were still largely snow-covered, as long as they had some exposed ice on them?

150-7. You need to reorder this material. First state how many glaciers you start with, then how many you remove because they are too small, then how many of those you remove because they are still completely snow covered.

167-8. How easy was it to distinguish how the streams terminated?

Fig 2. The stream in C looks like it used to terminate in the moulin identified but that a new moulin on a crevasse has opened up above it.

256-7. You say 'When only considering terminal segments...' but you used the term 'channels terminate in a range of settings' on line 254. So what do you mean by 'terminal segments'? You mean ignoring those that join another channel or disappear below map resolution?

Are there segments that disappear below map resolution but then look as though they reappear again down glacier? How common is this? What are the implications for your results?

261 'singular' => 'single'

261-2. I don't understand what you mean by 'Thus, when the percentage of channels terminating in each position are extracted as an average value from each glacier...'

'are' should read 'is' as its singular as it refers to 'the percentage'. But even with this grammatical change I don't think the statement makes sense, does it?

274-5. You could cut words (and improve style) here and just say "Here, we investigate links between different supraglacial channel characteristics. Previous studies..." [You refer to Fig 5 at the end of the relevant sentence below so no need to refer to it up front]

279-80. Is this accurate? I think I'd remove the word 'clear' [as the boundary looks a bit fuzzy to me] and I'd say a sinuosity of 1.3 [eyeballing the figure suggests you have 8 values > 1.2 but only 4 > 1.3 for slopes > 20 degrees].

280-281. Do you need the word 'segment' here? You just said channel length on line 277.

281. You say 'which often have a lower density of crevasses' but there's no evidence for this in Fig 5b that is referred to. Is this interpretation – in which case this could be moved to the Discussion section. Or do you have evidence for this, in which case refer to it here.

282-283. You don't need to refer to the slope-sinuosity relationship in Fig 5a again here as you've just dealt with that. Just stick to telling us what the upper boundary for the slope-length relationship is. For example, you could say that except for one outlier, channels >500 m long are confined to slope < 20 degrees.

290 Consider "...along with..." => "...as do..."

300. What do you mean by this sentence? '...less evident' than what? '...lower number of data points' than what? Haven't you just been referring to the influence of a glacier characteristic (slope) on channel characteristics (length & sinuosity)?

302-305. I think these statements about drainage density vs minimum or maximum glacier elevation and ref to Fig 5f and g are spurious. What you say is based on just 4 data points, which is not an adequate sample. I'd just point out no obvious relationships between drainage densities and either min or max elevation.

306. Do you mean 'interception' not 'inception' here?

316. Should say 'Fig 5e' here.

340. What do you mean by 'variables such as drainage density'? This is not clear. What is drainage density an example of? Should you not just list all the variables that are not closely

related to just one other variable? Note you're saying that drainage density is not obviously related to a single causal variable, which was my interpretation of the bivariate plots 5f and g above.

341. The word 'singular' is used incorrectly here. You could say "... not closely related to just one other variable. Overall, our PCA analysis reveals no single main driver of variance.."

354. I think 'restricting' should be changed to 'determining' or 'affecting' or 'controlling' as the first part of your sentence is just establishing a general relationship not the direction of that relationship.

354-6. This sentence is not quite grammatically correct as it should be '...can either intercept...or route...'. I'm not quite sure what you're saying here. Are you saying that shallow crevasses may simply route the surface water along them, contributing to the supraglacial drainage system and maintaining channel length? Whereas deep crevasses may intercept surface water and deliver it to the englacial drainage system, thereby reducing surface channel length?

358. I think 'surface' is redundant here.

358. I think you should introduce Fig 7 at the start of the next paragraph and introduce it fully. Is it depicting the influence of slope more than elevation? Or at least as well as elevation?

361-371. You refer to 'valley glaciers' and 'Upper Theodul Glacier' in this paragraph but you don't systematically take us through the increasing drainage densities going from left to right in your Fig 7. I think it'd be helpful to describe the drainage density component to Fig 7 more systematically and thoroughly, perhaps with more ref to your case study e.g.s shown in Fig 4.

360. Can you say 'Alpine settings' rather than just 'the study area' to make your conceptual model more generic?

362 'higher' => high. [you say 'small' not 'smaller so should say 'high' not 'higher']. I'd not use comparative adjectives through this paragraph unless it's obvious what your comparison is with.

370. It will not just be glaciers extending to lower elevations that will require channel incision rates to increase. It'll be the likes of Upper Theodul Glacier too won't it?

385 'or a slightly delayed peak' [peak; singular]

400-1 suggest 'main stem channel segments'

407 Delete 'compared to 0 % at the Aletsch glacier' as you've just said that.

409-10. "...but rather may act as part of the channel network and are mapped as individual segments as they may not be continuous."

The second part seems to contradict the first part. Surely a channel network must be continuous, doesn't it? Whether you can see it all or not is another matter. Can you clarify the point you're making here?

411-12. What do you mean “We attribute the difference in drainage pathways...”? Is this the difference in drainage density between Aletsch and Upper Theodul Glacier? Things are getting a bit hard to follow here.

414-428. This is all rather speculative and rather long-winded. Also, it seems odd to be talking about specific glaciers again having introduced your conceptual model (Fig 7). Can't you continue to talk in the generic way wrt Fig 7, having given examples of the 3 types of glaciers depicted in the previous paragraph? Can you summarise much more succinctly and based on evidence where possible, the impacts of the different surface stream densities, on hydrographs, basal motion, and proglacial hydrochemistry?

Fig 8. I'm not convinced Fig 8 adds to the paper as it's just one example of a particular phenomena that's not especially groundbreakingly novel.

435-453. This whole paragraph is very speculative. It contains 4 instances of the word 'likely' and 2 of the word 'may'. I don't think this deserves 18 lines of prose.

441. I find the term 'higher relief slopes' odd. Is this used widely in the fluvial geomorphology literature that I don't know about? Why not just say 'steeper slopes'? If you agree, can you check all instances of this term in the paper and change accordingly?

442. '...this figure'. What figure are you referring to here? The 20 degrees? I think this sentence needs writing more precisely. Does your PCA allow you to add evidence to the statement I think you're making here?

454 -464. It's difficult to work out from this paragraph, which statements are based on the new evidence presented in this paper, and which are based on previous research. Ideally these discussion paragraphs should clearly state the former and then bring in the latter to show the extent to which previous work supports or contradicts the findings from the new work presented.

For example, where is the evidence for the first sentence? The only thing I recall wrt debris-covered vs clean glacier is Fig 5c which shows no difference in the sinuosity between debris-covered and clean glaciers in Valais.

465-478. As above. Potentially some interesting points in here but the discussion must be related to the results you show.

481-499. Again, I do not think enough in this paragraph stems from the work presented in the results. It's too speculative. Can you just compare your results with the results of similar work (a lot by Lawrence Smith, Kang Yang and coworkers) on the GrIS? By all means offer a sensible reason for any differences, but avoid all the lengthy speculation.

500-512. OK This para is better and does what I suggested above. I don't think the last sentence follows on from the rest of the paragraph. Instead, I'd weave that info and the refs into a point in your introduction, justifying that the study of surface streams and where they terminate is important for subglacial water pressures, subglacial drainage evolution, and basal motion.

514-529. I think this para is basically fine – it's speculative but then it must be as it's about the future.

532. Should say "...dataset on..."

536. Delete 'existing'. I'd say "low slopes".

537 suggest change 'mass' => 'area' as that is what you measure. Could delete 'We find that'

539 'low ice surface slopes' YES!

543-5. This sentence is not quite grammatically correct. "...the percentage of channels...revealing that...80% of channels" do one thing and 20% do something else doesn't make sense. It is not the percentage of channels that reveals it. I think this whole sentence needs rewriting (also of =>off). As I mentioned earlier wrt lines 261-2, I don't follow what you mean by 'averaged by glacier'. Whether you simply calculate the % of different types of channel irrespective of glacier and quote those, or whether you calculate the % of different types of channel for each glacier, and then average all the percentages for the different channel types, and quote those doesn't matter. You get the same result. Unless I've misunderstood something.

546-7. What exactly do you mean by "The variation in where channels are located"? Are you talking about elevation on the glacier, whether they're on clean ice or debris, close to or far from medial moraines, steep slopes or shallow slopes, or what?

548-9. The phrase 'with different glacier geometries likely predictive of glacier drainage density and channel pathways' is vague. You've not mentioned glacier geometry so far in the paper so what are you referring to? And 'pathways' has been mentioned 4 times but again not very clearly defined. You say glacier geometry is likely predictive of glacier drainage density and channel pathway and refer to Fig 7. But if I look at your evidence in Fig 5e-h it's not clear that anything shown really controls drainage density, is it? Your correlation matrix in Fig 6 shows highest correlations between glacier slope, glacier mean elevation and drainage density so glaciers with low slopes and low mean elevation have the biggest drainage densities. Anyway, I think the paper would be strengthened if you based your conclusions on the evidence that you present in the results section and avoid weak speculative statements.