# Comments to ESSD-2022-369

## General comments

The study by Fountain et al. is presenting the results of a new glacier inventory for the contiguous United States /without Alaska) as mapped from manual digitizing of orthorectified digital aerial imagery. Independent of my comments below, I want to congratulate the authors to this long overdue update and acknowledge the great effort that is visible here. I have a number of more general comments to a) the terminology, b) the 'layout of the 'paper' and c) the datasets as well as some more specific ones.

> ***We thank the reviewer for his attention to detail and thorough review of our manuscript. We have made a number of changes and improvements.***

Starting with a), I am not very happy with mixing glaciers and perennial snowfields. First, snow fields should not be included in a glacier inventory and second, I think the definition applied here for 'perennial snowfields' is ambiguous. Of course, glaciers can be described as perennial snow (L82), as they originate from snow that survives the melting season over several years, but I think this is not the same as 'perennial snow fields' that are just composed of snow and firn and should thus not be included in a glacier inventory. Things get a bit complicated when ice patches (not moving glacier ice) - that might be completely covered by seasonal snow - are to be included but seasonal snow has to be excluded.

> ***We appreciate the reviewer's consideration regarding glaciers versus perennial snowfields. We feel it important to include the snowfields for their importance to high alpine ecology. In fact, we believe all inventories should include perennial snowfields as they contribute to a comprehensive inventory of perennial ice and snow. We are very clear in the manuscript the separation between the two. We do not mix them. Our criteria to distinguish them are clear and given the time series of imagery available on Google Earth, we are confident about our classification. Also, the other two reviewers did not object to inclusion of snowfields.***

Given that seasonal and perennial snowfields are abundant in this region, that their separation is nearly impossible in many cases, and that the transition of a glacier to an ice patch is gradual, I suggest using a definition that is better suited for this environment. Leigh et al. (2019) have tried to sort this out with a scoring system that can be applied when very high-resolution images are available. I suggest testing it here and re-evaluate the assignment. Currently, a large number of the here assigned 'perennial snowfields' are actually glaciers, e.g. they show bare ice, deformed debris bands, lateral moraines and could be found 'above' units classified as glaciers (and in a few cases its also the other way round, some avalanche deposits in valley floors are classified as glaciers). One example is shown in Figure A10. I think there is no need to assign the class 'Perennial snowfield' to (the two parts of) Freemont glacier. This is still a usual glacier that is actually connected in its lower part (under a thick medial moraine) to the neighbouring Sacagawea Glacier.

> ***Thank you for making us aware of Leigh et al. (2019), it is a very informative paper, and it has been cited in the revised paper. We were gratified that the paper supported our contention of the detail and accuracy of using high resolution orthorectified***

***imagery for compiling a glacier inventory and the importance of having multiple people viewing each feature.***

***Our region is not particularly unique, most, if not all regions, exhibit abundant seasonal and perennial snowfields. They are inherent in glacier environments. But it is true that the transition from glacier to ice patch/perennial snowfield is gradual and ambiguity exists between very small glaciers and ice patches/snowfields.***

***We were intrigued with Leigh's et al., scoring system to identify glaciers. However, we do not see the utility given the effort. A lengthy and time-consuming reanalysis using an experimental and non-standard procedure of over 2500 features requiring identification and tabulation of 7 criteria for each is beyond the scope of this study. Furthermore, it would result in reclassification of < 5% of the features. We agree, however, that our inventory would be a good test for this procedure in a future study.***

***It is not clear to us what that reclassification adds to our understanding of glacier cover given the extra effort involved. That a tiny glacier is counted as a perennial snowfield or vice versa, might affect the total number of features somewhat but not the total glacier area, which is dominated by the larger glaciers. One justification provided by Leigh et al. (2019) for the scoring system is to identify which small features should be marked for review. Given the pace of climate warming all features should be reviewed with new imagery.***

***We disagree with the comment, "*****Currently, a large number of the here assigned 'perennial snowfields' are actually glaciers, e.g. they show bare ice, deformed debris bands, lateral moraines and could be found 'above' units classified as glaciers (and in a few cases its also the other way round, some avalanche deposits in valley floors are classified as glaciers)." As we stated in the Methods, we do not distinguish between ice patches and perennial snowfields and refer to all as perennial snowfields. So bare ice can be present. Deformed debris bands may are probably the legacy of past movement, if there are no crevasses ((no crevasses are present)). Isolated lateral and terminal moraines are geological features indicating the past presence of a glacier.**

**Regarding Figure A10, the two Fremont glaciers may be connected to Sacagawea Glacier as you suggest. Or they are perhaps narrowly separated under the medial moraine. But there is no clear evidence either way so we consider them separate features.**

I fully acknowledge the difficulties in performing such an assignment and that in many cases a clear assignment might even be impossible, but currently the number of real glaciers that would be removed from the sample when users exclude the perennial snowfield class is rather high and thus worth revisiting.

***We disagree as mentioned above, that a signification number of real would be removed.***

Moreover, in some regions it seems that perennial snowfields (and even glaciers according to Leigh et al. 2019) have not been mapped.

> ***We disagree with this contention. We utilized three independent inventories, one manual, one based on an automated glacier identification procedure, and a third that merely identified the presence of perennial ice or snow, to compile our inventory and we are confident that it is comprehensive.***

Once this is done, please add example images for the various cases in a multi-panel figure so that readers have a chance to follow the decisions. Maybe also a short note on the class 'Buried Ice': I would not use it. Include it with the glacier outline when it looks like glacier ice under debris-cover and leave it when not. None of the dataset users will do the reassignment, but all are aware and will understand that other interpretations might exist. So please decide as an analyst where to place the glacier outline and leave it with this.

> ***We agree that 'Buried Ice' is a problematic category. The observable evidence certainly suggests the presence of subsurface ice. But there is no suggestion of movement, hence it is what we might call 'dead' ice.***
>
> ***We received an email from Wilfried Haeberli regarding our report not long after it was first online. In the email he included,***
>
> ***'Please also note that the term "buried ice" is used in permafrost science as a technical term for surface ice embedded within, or on top of, perennially frozen ground. It could be helpful to clearly state that your inventory uses this term in a different sense: terms like "dead ice", "remains of former glaciers" or the like are more common in corresponding cases.'***
>
> ***We have modified the report to include that distinction of definition.***

Regarding point b), I also have the impression that the current draft reads more like an internal progress report rather than a paper. There is no problem with being short and to the point, but for example a discussion is completely missing, the information included in the attribute table is not presented, glacier characteristics to be included in a glacier inventory (e.g. minimum, mean, maximum and median elevation, or mean slope and aspect) are neither calculated nor presented and visualized and lots of information is listed in the Appendix without providing a good access (e.g. showing the image footprints) or mapping examples from the various regions with outline overlays to see the decisions taken (also in difficult cases). The text provided in the Appendix comes thus across as rather theoretical descriptors of image conditions and would in this form have a better place in the Supplemental Material. Some of the images in the Appendix, however, should be transferred to the main part and used to illustrate the methods. Please show outline overlays and annotate the images to guide the readers through the decisions made.

> ***Agreed. The text has been modified.***

The digitizing of the new dataset has in general an excellent quality and is a clear improvement over the currently available datasets. However, as mentioned above, the assignment of 'this is a glacier' and 'this a perennial snowfield' seems a bit arbitrary and inconsistent at times. Moreover, some glaciers (and/or perennial snow fields) are seemingly missing.

***We have responded to these comments earlier.***

I have compiled a few examples at the end of this review for illustration and suggest revisiting the assignment of all perennial snowfields to really have all glaciers included in the glacier class.

***Addressed below, after the image captions***.

Please add an item Class_nr with 1 for glaciers and 2 for PS.

***We believe this to be unnecessary, given that databases can be easily searched for words. However, if the editors would like such a change it will be implemented.***

I would also encourage the authors to calculate topographic information for each glacier entity, provide the data in the attribute table of the data file and add some selected illustrations of the dataset characteristics to the text (e.g. maps, scatterplots, bar charts, tables). A shape file providing image footprints (to see which outlines have been derived from which image) would be a most welcome asset.

***The intent of this report was to submit updated glacier area to the Glacier Land Ice Monitoring from Space (GLIMS) database for inclusion in the next Randolph Glacier Inventory. Inclusion of the topographic variables were not necessary and we do not believe it important to this report. Neither of the other two reviewers suggested this inclusion. However, if the editors disagree, we will add the topographic data.***

**Specific comments**

L1: conterminous or (first n missing) or contiguous (as in L9)?

***Changed***

L26/27: What are the criteria to cite these publications? Not all of them are about stream flow.

***Yes they do. Dussaillant et al, addresses glacier loss to stream flow in South America, Fountain and Tangborn address streamflow variations caused by glacial runoff, and Moore et al addresses a broader North American perspective on the influence of glaciers on runoff.***

L27/29 (and elsewhere): When referring to contemporary glaciers, I would use glacier instead of glacial (see Cogley et al. 2011)

***Changed***

L62/64: I suggest not naming it a report when it should be a paper, maybe use this study.

***Changed***

L67: Please give this part an individual subsection 2.1 (and Uncertainties in L132 to 2.2)

***Added***

L82: How was the 0.01 $km^2$ size threshold applied before the digitizing?

***Changed***

L81-87: I suggest applying the classification system suggested by Leigh et al. (2019) to get a better handle on what is a perennial snowfield and what can be named a glacier.

***We disagree as explained earlier***

L90: Shaded reliefs are often ambiguous. I suggest using a flow-direction grid to separate glacier complexes into individual entities.

***In the few cases in which we used shaded relief they were very clear. I can imagine cases where that is not true. Fortunately, there were not present in our terrain.***

L103: In fact, this IS a huge common problem.

***Reworded***

L112 (and elsewhere): Please number all sections in the Supplemental Material and refer here also to this number.

***Changed***

L117: 'once part of the glacier': Couldn't this be checked against the previous inventory?

***The imagery used in this area was quite snowy and we cannot make a definitive interpretation.***

L132: Please give Uncertainties and individual subsection (2.2)

***Done.***

L142: digitizing

***Changed***

L148-170: As mentioned in the general comments, can you please illustrate with a Figure how these datasets (SFI and NLCF) look like and how the merging was done?

***We did not see this mentioned in the general comments. But we did a simple overlay of these data sets, first, the SFI over our initial inventory, then the NLCD over the revised initial inventory. In each chase where the outlines did not overlap, we examined/reexamined each feature.***

L172: Please add an analysis of glacier characteristics as derived from a DEM

***Added***

L190: I suggest moving this table to the Supplemental Material and showing in the text only a figure (bar or pie chart). And remove the 'Buried ice' class. Either include or exclude it.

***We prefer to retain it in the main body of the text.***

L205: I think also Table 2 has a better home in the supplemental Material. This is background information, there is little that can be learned from it.

***Agreed***

L210: Please add a Discussion section

***Done***

L262: Can you explain here why some of these are perennial snowfields while others are glaciers. It is not entirely clear, in particular not for the large ones.

Figures A3, A6 and A9 miss outline overlays. Where is Figure A8?

***Figures A2 and A3 show topographic conditions used to distinguish glaciers/perennial snowfields from rock glaciers. Outlines would interfere with the perspective of field conditions***

***Figure A6 I illustrating what we perceive as buried ice. Outlines would complicate an already complex image, and one that also has a number of lines and arrows.***

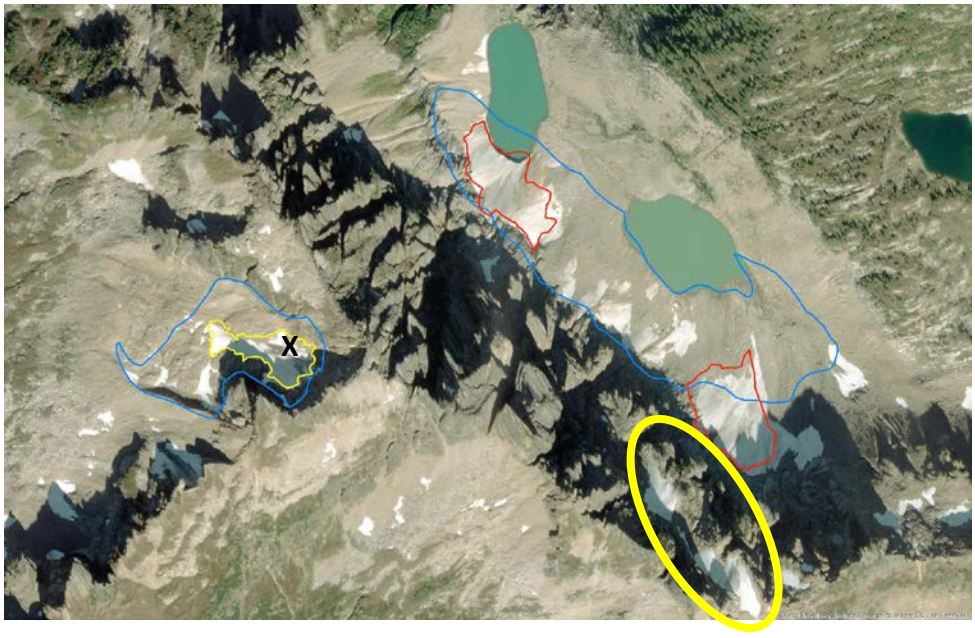
***Figure A9, like A2 and A3, shows field conditions. Adding an outline would bias the viewer to our interpretation. The absence of an outline better shows the transitional nature from ice to debris-covered ice, to debris.***

***Miscounted figures there is no Figure A8***

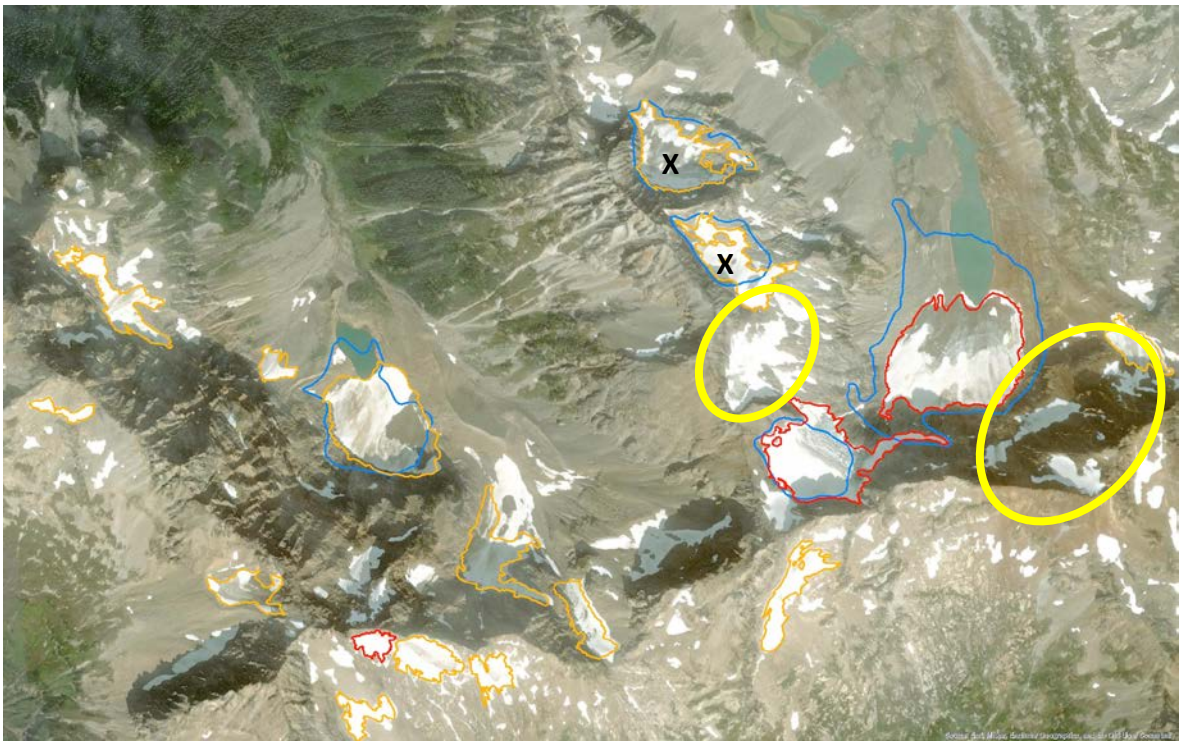
Leigh et al. (2019): https://doi.org/10.1017/jog.2019.50

***Regarding the images and comments below, please remember that our inventory is based on three prior efforts, our own reanalysis, the SFI, and the NLCD. Perhaps the NLCD is the most important one to consider here. That inventory utilized LandSat imagery, 15 m spatial scale every three years from 2001 to 2016 to map surfaces features across the entire USA. Among other landscape features, they identified perennial snow and ice. If we initially missed the features identified in the examples below, and if they were present in the NLCD (or the SFI), we would have examined them for inclusion. That they are not in our inventory indicates to us that they are not perennial. We infer that the comments below are based on one-time imagery. Considering buried ice, we see no signature of buried ice. The suggestion that some features are glaciers not snowfields, we don't see crevasses so they are not moving; the debris bands are relict indicators of past movement. However, if we had locations for the examples below, we would have been happy to examine them further.***

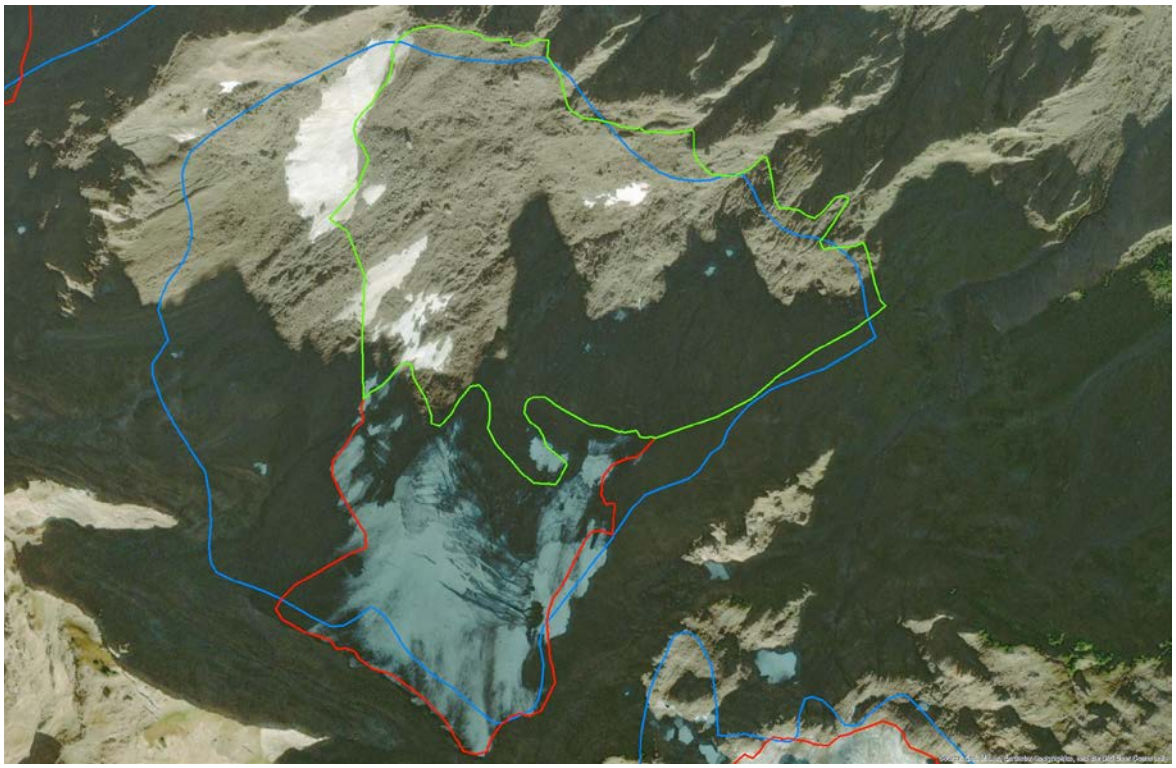
Image examples (World Imagery layer of the ESRI Basemap)

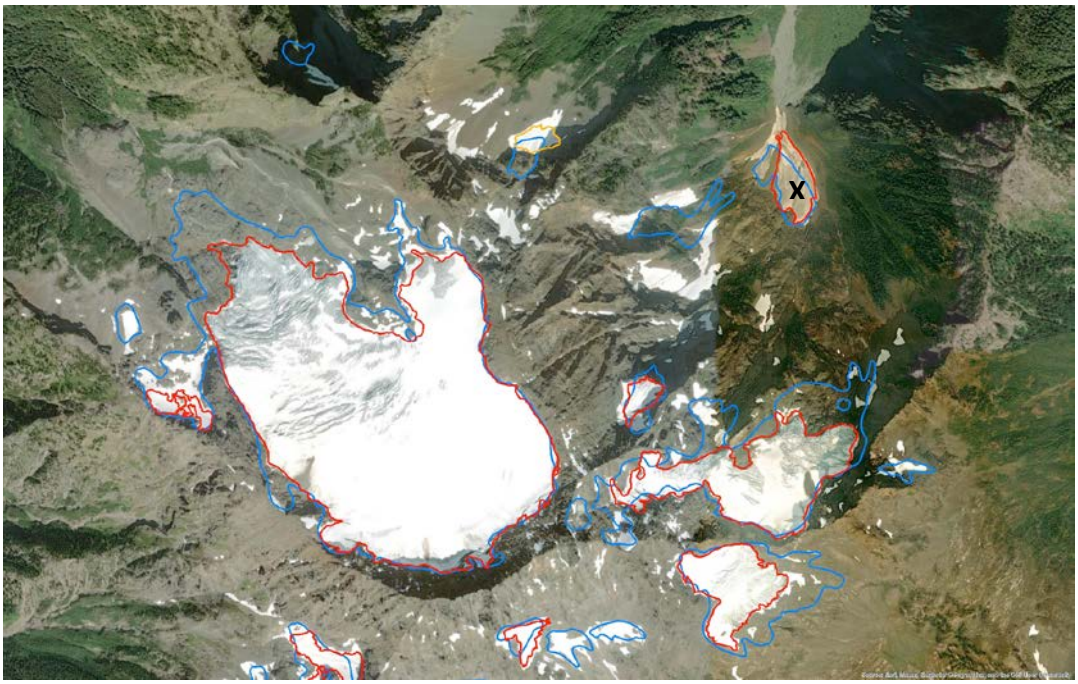



Red: glaciers, yellow/orange: perennial snowfields, green: burried ice, blue: RGI6
x: this is also a glacier. Circle: these should be included, at least as perennial snowfields.
Background image: ESRI

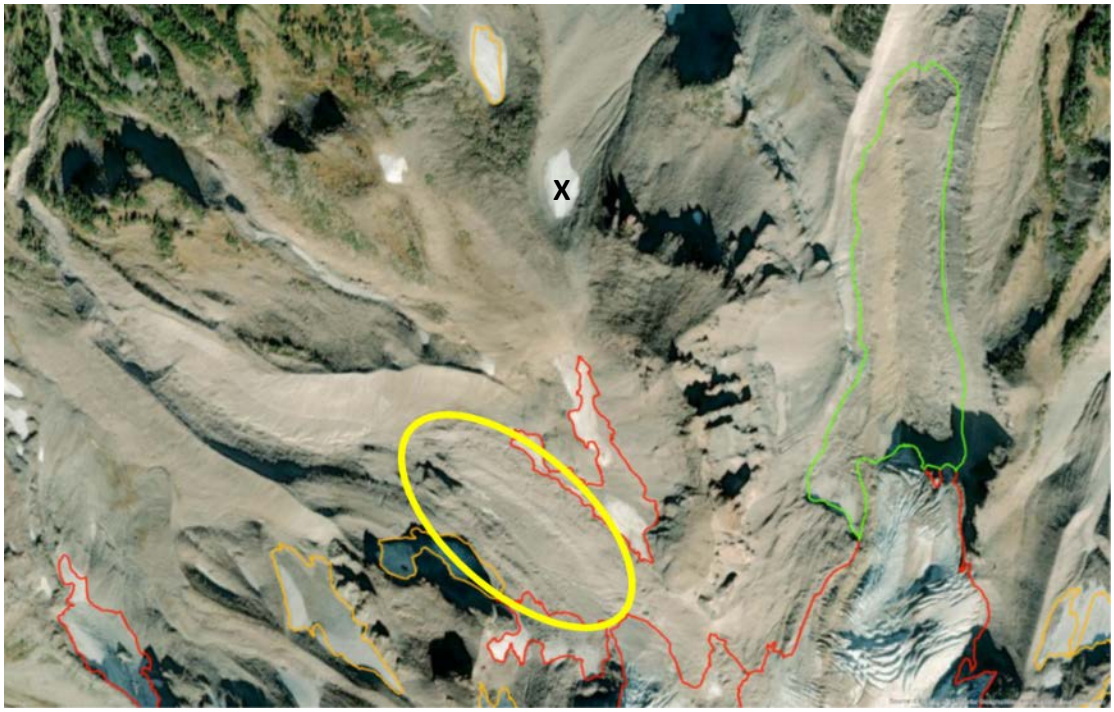


x: glaciers rather than perennial snowfields, Circles: Missing. Background image: ESRI.

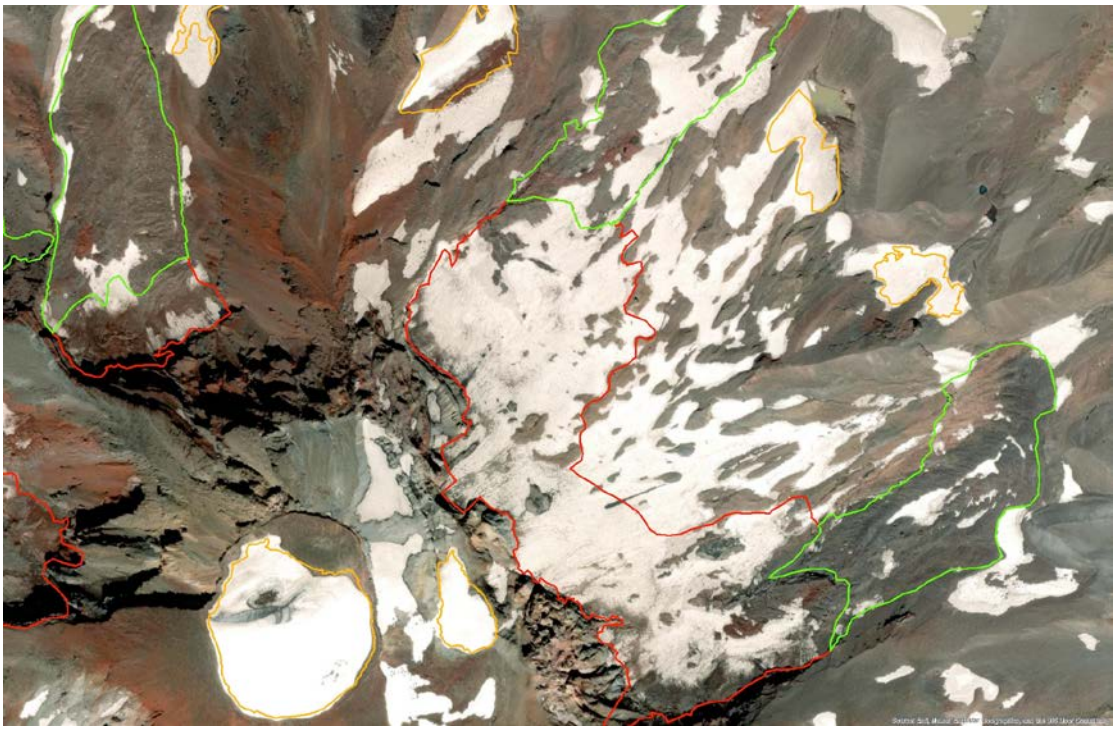

I would not include the green part. Background image: ESRI.



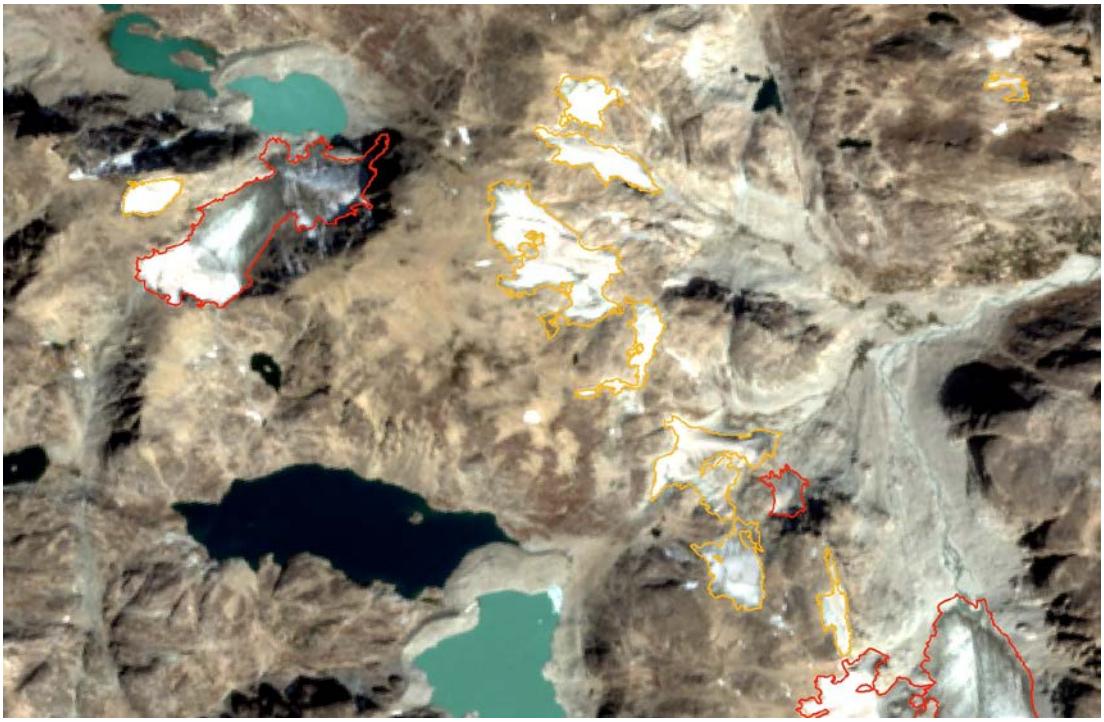

This is an avalanche deposit rather than a glacier. Maybe not even a perennial snowfield?
Background image: ESRI.



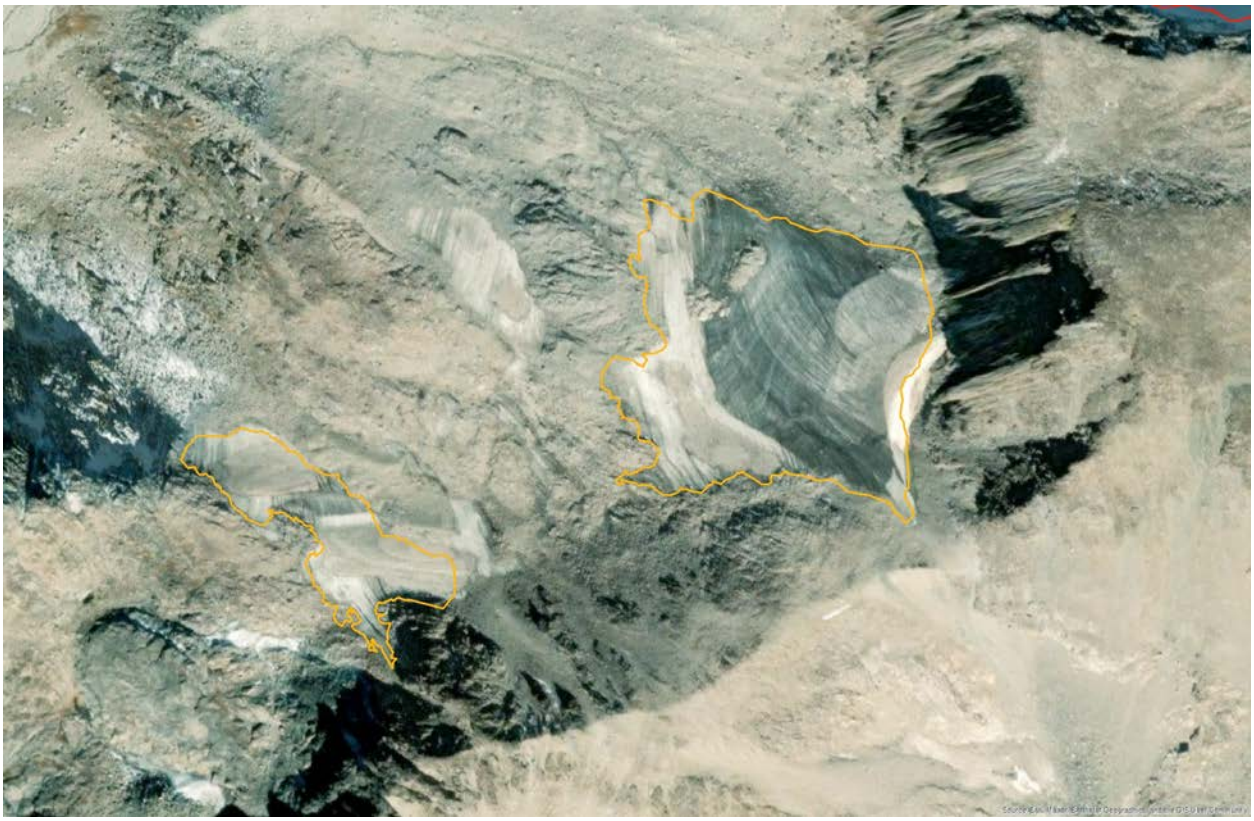

Where is the debris covered part (yellow circle), why is this (x) not a perennial snowfield.
Background image: ESRI.



The orange outlines should be glaciers rather than perennial snowfields. x looks like a rock glacier. Background image: ESRI.



The orange outlines (larger polygons) should be glaciers rather than perennial snowfields. Background image: Copernicus Sentinel-2 2020



The orange outlines should be glaciers rather than perennial snowfields. Background image: ESRI.