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Earth System Science Data Discussions

Interactive comment on "Glacier shrinkage in the Alps continues unabated as revealed by a new glacier inventory from Sentinel-2" *by* Frank Paul et al.

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The manuscript "Glacier shrinkage in the Alps continues unabated as revealed by a new glacier inventory from Sentinel-2" by Paul et al. presents a new glacier inventory that optimizes several criteria including consistency, a tight time-span of source data acquisition, precision, and complete coverage over the Alps. The authors provide a thorough and well written manuscript that I found easy and enjoyable to read. One unique element of this work is the lead author also authored an earlier study that derived a similar product from Landsat imagery acquired in 2003. I was surprised that, even with this degree of consistency, this new inventory was only marginally compati-

ble for a comparison. This seems largely due to the inclusion of "new" glacierized area that was not previously mapped, yet the authors walk this back some in the discussion admitting that some "glaciers" might really be perennial snow and firn patches. Since other scientists will likely base their work on this inventory, I think it is most fitting that the expert authors here make decisions and interpretations that they are confident with. Below are mostly minor comments with some concerns regarding analysis subdivided by political boundaries, results that reflect the highly variable 'number of glaciers' and the buffer method error analysis.

Abstract

L23-24 "...national inventories have been used as a guide to compile a consistent update." How do several inventories generated from different countries by different analysists enable consistency?

L23-27 It is odd that you develop the guiding datasets first and then explain methods to map glaciers from raw data. It's not perfectly clear what fraction of the new inventory is in fact new.

L24-25 You shouldn't have sentences beginning with "However" and "Whereas" back to back.

L28-29 Is there a topographic result you can add to the abstract? This is the only sentence in the abstract referencing topographic information, and it doesn't explain why this is relevant to the study.

L57 Following the logic from L47-48 shouldn't this be $\pm$3%?

L59 Change "has" to "was"

L63 Change "representing" to "represents"

L72 "...in part to be compliant with the analysis in earlier inventors." Do you mean communicative? What are the other parts?

L90 What does “commissioning phase” mean?

L94 “. . .and distribute the raw outlines to the national experts for edition of wrongly classified regions” This sounds smart to use local knowledge, but to me it does not fit the description “consistent”. To me a consistent method would be done by one person or one automated routine.

L96-97 “As a guide for the interpretation the analysts used the latest high-resolution inventory in each country” What does this mean exactly? Is the time stamp then some mix of 2015 and the range spanning the imagery used for the national inventories?

Study Region

L121 “With a total area of about 2000 kmˆ2 in 2003” You say 2100 kmˆ2 on L30 in the Abstract.

L121-122 Please add a citation for “about 1 m w.e. . . . 2 Gt of ice per year.”

L126 “and the mean elevation is around 3000 m a.s.l., a unique value compared to other regions of the RGI.” In which direction?

L130 “. . .many glaciers – large and small – become invisible under increasing amounts of debris” “Invisible” is imprecise language, “indistinguishable from optical data” is better.

L132 “. . .mapping their extent is increasingly challenging” Is this the same glaciers becoming more challenging or new glaciers becoming challenging?

Datasets

L149-150 “only the required bands, no longer possible” I don’t understand this.

L161-164 I really like this level of detail you provide. Here you make clearer what “commissioning phase” means (question to L90).

L193 Change “using” to “to use”

L194-195 “. . .due to the locally poor geolocation of the S2 scenes . . . the location of the ice divides was [change to: were] partly manually adjusted” Are you saying you moved correctly geolocated flow divided to agree with an erroneously geolocated S2 image? Please be clear what this implies about your new dataset (including the magnitude of these adjustments) and how you motivated your choices.

Methods

L201-207 This is confusing to follow.

L208 “We followed the recommendation to select the threshold in a way that good mapping results in regions with shadow are achieved.” Where is this recommendation? Can you please add the threshold values used to Table 1 and cite that here?

L213 You mention several times “misclassified rock in shadow” which I believe means the dark rock becomes darker but is then classified as glacier, I’m confused by this.

L222 “contrast stretched” Is this just referring to how you assigned display colors? Probably unneeded information if so.

L235 “All pre-processed scenes were provided in their original geometry for correction” This doesn’t make sense to me. What is the geometry of a pre-processed satellite image?

L238 Dark bare ice (that you reference in the sentence before) is also an omission error

L239 And shadowed rock classified as glacier is also a commission error. Meaning, you’re not wrong but it’s slightly odd to not give these aforementioned quantities the same classification.

L240 I know this is a glacier definition interpretation question, but I really cannot imagine a 0.01 kmˆ2 “glacier” internally deforming. The argument for including these patches is weak, in my opinion.

L246 “(see Paul et al. 2016)” do you mean “following Paul et al.”?

L253 Regarding sub meter resolution data to inform debris cover delineation, I agree this can be very helpful, but I think it can also be less helpful. In some instances it is simply not clear, even if you were standing in the field, in these cases I think the high resolution images give us analysts a false sense of confidence. I would even argue that in some cases a lower 10-15 m resolution helps flow features stand out which is probably a better guide to finding the glacier margin than images that can resolve individual clasts. You make a similar counter argument to mine later at L321-323.

L254 “we illustrate the strong glacier shrinkage from 1998” Strong relative to what? And I believe all citations so far have been to the 2003 former outlines, please add a citation for these 1998 outlines.

L265 “changes. . .are important.” Hard to constrain importance, I would say “notable” or “visible”

L270-284 The relevance of these two paragraphs is not clear to me. What information does your reader need from this to understand your study? I think it can be said much more concisely.

L289 Can you please let us know how common these shadow errors were? In kmˆ2 preferably but also qualitative terms could be okay. I think it is useful information for others who will use this work as a guide for their own glacier inventories.

L293 Do you mean “[Italian] alps”? also I don’t think “i.e.” is correct if you list the full set of 3.

L295 If you go into sub-region detail it would be helpful to have these regions labeled in Figure 1 and possibly summarized in a table.

L300-304 I think this is an appropriate place to mention rock glaciers and either cite others regarding their definition/interpretation or use these data and possibly change since 2003 to make your own inference on this classification. Were you sufficiently

convinced what you show in Figure 4c is in fact glacier? You defer to the previous inventory, but you clearly demonstrate a level of expertise in this subject and I think the readers will appreciate a more decisive call on these small, difficult glaciers.

L317 I think something like “completely ablated” is more precise than “disappeared” but maybe only stylistic.

L325-326 “This glacier has thus strongly grown since 2003 due to a new interpretation. . .” This is incorrect language, change to “the interpreted glacier area strongly grew”

L336-339 I agree with your statement that political boundaries are meaningless in a scientific context, yet you go on to present your results per country. I understand that the source of some degree of your results are from national inventories, but my sense was this article is a pure research stitching together of these datasets. What is your motivation to partition your results by country?

L341 I don’t think “digital” is needed.

L360-362 Please provide the specific rational as to why a glacier specific comparison was not possible between glaciers that met the “point in polygon” check. One thing that makes this article so unique is that the 2003 inventory was made by you. This is the interesting point of unique consistency that you bring with this study but here it seems like you deflect from this. Has your personal definition of a glacier changed so much since the earlier inventory? There is a strange human element to this line of work/this study, which you later spend considerable effort attempting to constrain, yet this change in interpretation/definition of a glacier between the 2003 inventory and this one, with the same lead author, is surprising and interesting to me.

L382 “. . .we applied the buffer method. . .” Please add a citation for this

L390 I don’t understand how it is computationally expensive to buffer the debris-covered areas (a smaller area than total glacier area) while it is computationally feasible

to buffer all areas. I have applied buffers to all glaciers and debris cover on Earth on a typical laptop without outstanding computational demand. Is there a step or condition that causes the high computational cost?

L391-392 I think Figure 4d is a good example of where this assumed realistic uncertainty estimate of ± 2 pixels is not applicable. You say this depends on the degree of debris coverage which I agree with, could you apply a different buffer as a function of debris-covered area? Maybe it could help keep your above referenced computational cost low if only considering the very debris-covered glaciers.

L396-397 Please watch your significant figures, the sum your report is slightly off. Further, do you have confidence in your results in Austria to 0.01 km^2?

L399-402 I do not see the value in 'number of glaciers' based results. I am not convinced a different research group repeating your study will fine the same number of glaciers. If you disagree with this argument, I would at least suggest a minimum area of 1 km^2 to promote some degree of repeatability.

L415 "glaciers smaller than 1 km^2 can be found at all elevations" I see what you are trying to say but this statement is incorrect.

L415-416 "indicating that their mean elevation [remove: does] only slightly depend [depends] on climate factors" This doesn't make sense to me. I think you are trying to obliquely address the question: why aren't some of these small glaciers bigger? I think there might be a statement you can make here but as it is I don't think there is supporting evidence.

L17 "arrange around a climatically driven mean elevation which is around 3000 m a.s.l." Why not compute the mean and add a fit mean line to Figure 6a? "...the largest glaciers are not those with the highest elevation range..." Yes, I actually think they are and your next statement contradict your previous statement "...and for the majority of glaciers the elevation range increases with glacier size" One very steep, small glacier

is an outlier, not relation breaking evidence.

L422 "This is typical for regions dominated by mountain and valley glaciers as these follow the given topography" This statement needs a citation and an example of regions where glaciers (or ice sheets) do not follow the given topography.

L423-424 "an exception from the rule" What rule? I would call it an outlier

L428 Can you please motivate your use of median here versus mean at L415.

L428 "largely driven by temperature, precipitation and radiation" Since you don't specify glacier size this is in contradiction to L415-416.

L428 Wouldn't topography be an important factor here?

L429 "temperature is rather similar at the same elevation over large regions" Needs citation

L431 Remove "amounts"

L434-435 Why are glaciers larger than 0.5 km^2 les impacted by local topographic conditions?

L435 "...median elevations (around 2400 m a.s.l.)" L418 says 3000 m a.s.l.

L438 "b" not labeled in Figure 7

L439 "On average, glaciers...have median elevations that are about 400 m higher" Is this a mean of medians? I'm a little lost how you choose distribution middle metrics.

L440 "However, the scatter is high" It's hard to understand a "result" that is then walked back some qualitative amount. Can you draw on statistical tests to qualitatively inform signal form noise?

L445: I am again missing the scientific argument for presenting result per country.

L456 "For a selection of 2873 glaciers present in both inventories..." According to this,

the number of glaciers in 2003 was 65% of the number of glaciers now. I find this more concerning than a result. I am inclined to assume this new inventory is overly generous with a “glacier” classification and I would strongly encourage the authors to double check their confidence on what they are calling glaciers.

L460-461 Per country results should probably be in a table if you report some here.

L462 “Reveals [should be: a] small shift” Can you please say more about this translation error, it doesn’t look linear(?) is it elsewhere? Should this be corrected?

L466-468 As stated above I’m concerned there is not a way to make a per glacier area change plot. In my opinion, the new outlines (yellow) in Figure 10 have a lot of unrealistic area: too narrow, too small, not following a flow pattern. For the glaciers that do intersect 2003 it is clear the outlines are of very high quality, but I think the 2003 interpretation of what is a glacier is in some cases better.

L48 “with a limited meaning on the basis of individual glaciers” These differences that disable a per glacier change analysis aggregate to the whole, I’m not sure how you can consider changes of the whole Alps or per country and not be able to consider individual glaciers.

L480 “-15%” This value starts at -13.2% earlier in the manuscript, was bumped up to 15% at L459 and now is “even higher”. For the results section I think it’s best to present a consistent and confident value.

L493 “a detailed analysis” Where is this analysis? Or do you mean the overlay Figure only?

L495 “When excluding P1” what if P1 is the most trained expert?

L505 “digitized glacier extents increased by several per cent after consultation of very high-resolution satellite images” Is there a way this information could be added to Table 3?

L510-513 “If such regions have to be included. . .can be discussed. . .including these features in a glacier inventory or not is a (personal) methodological decision” This belongs in the discussion section.

L522-524 Check English here.

L528 re-state acquisition gap dates.

L530 5 years of elevation change are within the uncertainty range? I would expect there to be a clear signal.

Discussion

L535 missing citation here

L536-537 Probably belongs in results section

L538-539 “However, for consistency with earlier inventories they have been included” Figure 10 makes it clear this is not true, consistency with earlier inventories would exclude non-glacier area. I think it’s concerning that the authors walk back what is considered a glacier here in the discussion, in my opinion, we need this set of experts to make these (hard) decisions so the rest of the community can uses this product with confidence. L540 “precipitation amounts have a limited impact” I think this a contradiction to L431.

L543-544 I don’t think Figure 7 supports these claims.

L546 “Widespread glacier thinning” L530 suggests no thinning

L546-547 confusing wording

L548 Confusing English in this sentence

L551-552 “merged their IDs. . .combined extent” This is unclear

L558-559 As stated above, interpretation/definition errors don’t disappear at a wider scale.

L565 Snow covering 20% to 30%, where did these numbers come from, I don't recall anything in the methods.

L571 "change rates of identical size classes are compared" Do you mean hypsometry?

L573 "revealed a large variability in the interpretation of debris-coved glaciers" Did it? I'm not sure if this was quantified.

Conclusions

L609 "DEM quality and co-registration" were these mentioned in the text?

Tables and figures

Table 3

Am I reading correctly that STD derived for n=4? Is glacier ID 4 two glaciers in the inventory? This sounds like an interesting result that most participants called in one. Is this a unique case, or common?

Figure 3

The blue is a little misleading, possibly better as 4 sets of colored lines It's a little hard to tell what is error and what is true.

Figure 4

Are blue in a) and green in b) the same? Why different colors?

Figure 9 and 10

Many of the small glaciers identified in these figures do not look like glaciers to me.

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