

Re-review of the study by Tielidze and Wheate

General comments

The revised paper by Tielidze and Wheate is rather different than the one before and in my opinion it has greatly improved. The authors have removed unnecessary contents and speculative statements and focused on the presentation of the results they have achieved. This makes the entire study more comprehensive and to the point. Apart from several minor points that I have listed in the specific comments, I have now only one major remaining issue, the limited science that is presented. With its current focus on data presentation the study would have been more appropriate for journals such as ESSD that do not require new exciting scientific progress. As this is maybe difficult to achieve at this stage I would like to make a few suggestions for adding some more science. I assume that most of the requested material has already been produced so I consider all these changes as minor.

A) Many of the tables presenting data of individual glaciers have been moved to the supplement. This is fine. On the other hand the paper itself contains aggregate figures (Fig. 4, 5, 6, 8, 10) of glacier statistics and changes that do not reveal any numbers. As these are also not listed in the supplement, the related values should be added in tabular form to the paper (Figs. 5 and 6d) and in the supplement (Figs. 4, 6abc, 8, 10).

B) The analysis is currently restricted to the presentation of area changes (Figs. 4 and 6) and some selected glacier statistics in the form of bar charts and plots (Figs. 5, 7 and 8). Overlay of glacier outlines is visualized in the supplement (Figs. 1, 2, 14). To put some 'meat to the bone' I would like to see some further plots and analysis of the data. Suggestions include (see also Specific comments):

- a) Glacier aspect vs. mean elevation, maybe with colour-coded dots distinguishing between the northern and southern macro slope (as Fig. 8c)
- b) A map showing the spatial distribution of mean elevation (using colour-coded circles) for all glaciers larger than a certain threshold (maybe $> 1 \text{ km}^2$).
- c) A map, plot or table showing the change in mid-point or mean elevation from the 1960s inventory to the most recent one. Plotting this against the change in minimum elevation could be very interesting as well.
- d) A scatter plot showing glacier size vs. minimum and maximum elevation (dots in different colours and/or small symbols).
- e) A scatter plot showing glacier size vs. relative change in area, maybe colour-coded for different regions and symbol coded for the two periods 1960-1986 and 1986-2014.
- f) A scatter plot showing length changes vs. original length (this could end up in the supplement if results show a limited correlation).

C) The discussion section is currently looking at area change rates and differences to the RGI / GLIMS databases. This is fine but it should be extended, also considering the new plots suggested above. I thus suggest introducing three or four subheadings: 5.1 Glacier inventory parameters, 5.2 Glacier changes, 5.3 Comparison to GLIMS and the RGI, 5.4 Accuracy considerations (this can also be part of 5.2). The discussion should then focus on commenting on and evaluating the results rather than repeating the data. This might include interesting local differences, the large-scale variability and comparison to other studies, at best from the Alps that have at least similar characteristics (east-west and north-south gradients, similar mean elevation and glacier types).

Such an extended discussion would help to markedly shift the contents from a data report to a scientific paper with new insights. In this case it should clearly be in TC rather than ESSD. I hope the authors agree with this and can implement the suggested improvements.

Specific comments

P1

L19: aspect and height; what about slope?

L19-22: Simplify sentences, they have too many commas.

L23: The area results for the three inventories are fine but what about adding some further key characteristics and changes, e.g. mean size and elevation for the southern/northern slope, change in mean elevation from 1960 to 2014, and aspect dependence of elevation (if present)? See also General comments.

L24: 'The new glacier inventory will be ...'

L30: Bliss et al. 2014 is maybe more a global scale hydrological study rather than a global sea-level study. Maybe move this one upward and add here Radic and Hock 2013 and/or Huss and Hock 2015?

L40: 'with ten thousands of people'?

P2

L1 I fully agree with you that this should be changed but it is just a matter of an email to Bruce Raup and than it is done. It is thus a rather short-lived statement and the reader might wonder why you have not already addressed this issue. It is much better to write here positively that the former wrong assignment of the greater Caucasus to one country has now been amended and split into three of them (R/G/A).

L6: This also sounds like complaining. In fact, nobody volunteered to write something so it is not covered (as many other regions). The GLIMS book never intended to be spatially complete as it lives from their contributors. So maybe remove this statement or write more precisely: 'As nobody volunteered to write a section about the Glaciers in the Caucasus for the GLIMS book (Kargel et al. 2014), the region is missing in this compilation.' or something similar.

L7/8: To avoid brackets, maybe write 'Our inventory has 6.5% less glacier area than ... and 7.3% more than ...'

L10: I suggest writing: 'Caucasus region based on manual delineation of glaciers from multi-temporal satellite images, and ...'

P3

L6-9: This sounds a bit like mass balance observations are also providing temperature and precipitation time series. Please add one more sentence to clarify.

L14: 'photographs covering the time period 1875-1906 ...'

L28: with a total area of 563.7 ...

L37: maybe add: 'indicating a contrasting slow-down / increase of the loss rate on the northern/southern slopes.'

P4

L25: And for glaciers without a melt water stream or a very lateral location of it?

L33: interval of 20 m from

L36: 'georectified' you mean orthorectified (with a DEM) or geocoded?

P5

L1: not for deriving the mean slope? This is a very good indicator for mean ice thickness.

L5: Table formatting is maybe not required but I would align all heading row text centre, all cell body text (columns 2, 3, 5) left and cell body numbers right. As the path-row is visually difficult to extract from the given scene ID, I suggest adding a further column Path-Row (with entries only for Landsat and maybe ASTER).

L7: Actually both, the buffer method and the multiple digitizing only provide uncertainty (or precision), error (or accuracy) can only be determined by a comparison to appropriate reference data. So I suggest merging sections 3.2 and 3.3 to one section 'Uncertainty assessment' and start with a sentence saying that you have determined uncertainty with two independent methods. Than start with the buffer method (as it is the more simple one) before you describe the multiple digitizing.

When you also want to include the accuracy assessment performed with the Garmin GPS, name this section 'Uncertainty and accuracy assessment'. Then introduce the latter and also present results of it as these are currently missing. I see black dots in Fig. 2 c/d but it is not described in the caption what they mean (please add). Regarding Fig. 2, please make the a b c d panel marks much larger (factor 4) than they are now. Also be consistent with the syntax: Either use (a) (b) as in Figs. 1 and 8 or just a b as here.

L17/18: Maybe write: 'To determine the precision of the digitizing, we manually digitized fifteen differently sized glaciers independently five times in the western ...'? (it is not really the error that is determined by the method but the variability of the interpretation. So roughly this is the analysts precision.

L28/9: 'covered heavily by debris'

P6

L6: It is difficult to see anything on Fig 2c. I suggest replacing it with another close-up view.

L9: As mentioned above, please merge this section with 3.2.

L16/17: You might consider to also referring here to your own results shown in Figs. 2a and b. They clearly reveal a $\pm 1/2$ pixel buffer for clean ice and a ± 1 or 2 pixel buffer for debris-covered ice.

L20: 30 m (with a space in-between)

P7

L6: I suggest showing a close-up of the debris-covered part.

P8

Tables 2 and 3: I think these two tables can be safely merged.

Figure 4: I suggest adding minor tick marks on the y-axis (step 0.1) and repeat them on the opposite site

L15: experienced the highest relative glacier area loss

L17/18: This might be correct but it comes a bit of a sudden and is difficult to verify without knowing further details. So maybe move it to the discussion and add some details about the cited study there. The problem is that you cite here a study that has been published before this study but you link the results of this study to it. So I wonder how the cited study could have known the results presented here?

L21: I would not introduce a subheading 4.1.1 when there is no 4.1.2. Maybe rename 4.1 to 'Glacier changes for the entire study region' and 4.1.2 to '4.2 Glacier changes in the ... massif?'

P9

L24 (Fig. 5): I think this figure is fine in general but I would change a few things: remove the 'Mean area ...' text line, add some minor tick marks for both y-axes (left and right), use more distinct colours (or shades of grey?) for the bars and triangles (green is difficult to distinguish from cyan), and in particular change the colour of the 1960 triangle to something else (black?). As it is very difficult to extract any numbers from the graph, please also provide a table listing all numbers (can be in an Appendix).

L30: resulting from the disintegration of ... (retreat is change in terminus position).

L34: As Fig. 6 is only an aggregate figure, would it be possible to add a scatter plot showing the individual values, maybe symbol coded for the two periods (1960-1986 and 1986-2014) and colour coded for northern / southern slopes? This would also depict the local variability.

P10

L2: Please add the equidistance of the elevation bands used. Currently it looks like 250 m? In this case please use 50 m to avoid the blocky appearance of the graph.

L9 (Fig. 7): Can you please add some minor tick marks on both axes. With 50 m elevation bins please also use major gridlines for the y-axis.

L9: Please consider adding a scatter plot (as Fig. 7b) showing glacier size vs. minimum and maximum elevation (colour coded in the same plot).

P11

L3 (Fig. 8): Please use capital letters for the cardinal directions (N, NE, E, etc.)

L3: Please add a scatter plot (as Fig. 8b) showing aspect vs. mean or mid-point elevation of glaciers

L3: If there is some interesting variability, please show a map with colour-coded circles representing glacier mean (or mid-point) elevation for all glaciers larger 0.5 or 1 km².

L5: When analysing length changes, wouldn't it be more sensible to sort glaciers for length classes? I ask because there is often a certain relationship between initial glacier length and length change. You can check this by creating a scatter plot initial length vs. (absolute) length change. If there is a relation, I suggest showing also this plot.

L6/7: 'length change': I think you mean 'retreat rates' here?

L28: Discussion section: The two topics presented in the discussion section are fine. However, I think ones the additional plots are shown some further discussion on the achieved results should be presented. This should also add some science (or give some 'meat to the bone') to this data-driven contribution.

L36: than from 1957-2000

L37ff: Interpretation of shrinkage rates: as mentioned in my previous review, I would really restrict the higher loss rates in regions with smaller glaciers to their size and nothing else (please add the related scatterplot as suggested above). All other representations require knowledge about changes that you do not have. I repeat: Glaciers are where they are because climate is at it is. So climatic conditions itself do not have any impact on area change rates. What you need to show for your statements is that climate CHANGE was different in different regions and elevations. For the eastern Caucasus this means that climate has dried (less precipitation) at the elevation of glaciers whereas at the same time the larger accumulation areas of the glaciers in the central Caucasus have received more precipitation. Similarly, to get increased glacier loss at lower elevations you must show that temperatures have increased more at these elevations than higher up. As no proof is given for any of these trends, you cannot claim that these are the reasons.

P12

L21/2: I assume these differences have a sign? Can you please add which ones are larger and smaller?

L26 (Fig. 10): I think there is not much to see when absolute area differences are plotted like this. Better use a plot style like in Fig. 6 with bars and positive/negative differences. Maybe these display even better when presented as relative rather than absolute differences.

P13

L8/9: Is this shown somewhere (map overestimation of snowfields and the related correction with Corona images)? I suggest adding this, as it would have some relevance beyond this study. Increasing the consistency in the interpretation of glacier outlines is still a major issue for glacier inventories so a practical example would be very helpful.

L20/1: 0.7% is quite strong but it is only half of the rate in the Alps. For this not further elaborated statement I would maybe add a citation from one of the global scale studies presenting volume changes per RGI region until 2100.