Authors reply to Dr. Rakesh Bhambri Referee #2

"Strong acceleration of glacier area loss in the Greater Caucasus over the past two decades"

by L. G. Tielidze, et al.
The Cryosphere Discuss.,
https://doi.org/10.5194/tc-2021-312, in review, 2021

Dear Dr. Rakesh Bhambri,
First of all, we thank you for your careful reading of the paper and for the constructive review. In the following pages, we provide point-by-point responses following every comment.
All corrections and changes we did in the text are marked in green.
Best regards,
Levan Tielidze on behalf of all co-authors

Summary

This study presented a new glacier inventory for two time periods (2000, 2020) covering the entire Greater Caucasus (Georgia, Russia, and Azerbaijan) using satellite imagery (Landsat, Sentinel, SPOT) and reported significant area loss in the study area. The manuscript is very well written and nicely structured. I have given some minor suggestions for improvement. The Caucasus region has several debris-covered glaciers and therefore this study mapped these glaciers manually. I could not see results/numbers on debris-covered glacier changes in the manuscript. There is a need to present changes in debris-covered ice in the results section and comparison with other regions in the discussion. Also, in the introduction, there is a need to highlight gap areas in previous glacier inventories and their changes and how the present study is going to fill these gaps.

Thank you for positive feedback.

We agree that the change in debris cover extent is an interesting research topic, but did not specifically include it in this paper. The main reason being that we think it is a further topic of separate research. We already have 14 figures now and more than 20 pages. Adding debris cover at the required level of detail would add several more figures, increase further the length of the text and blur the focus of the study. We would thus strongly prefer keeping the investigation of debris cover extent and evolution for a separate study (e.g. see Tielidze et al., 2020b). However, we still included debris-covered glacier to test the mapping process and the results are given in methodology section.

With regard to highlighting gaps in previous inventories. We note that previous inventories are quite comprehensive from this region (e.g. see Tielidze 2016; and Tielidze and Wheate, 2018) with the exception of RGIv6. To highlight this issue we moved an appropriate paragraph from "2.2 Previous studies" section to the end of the Introduction: "The year 2000 inventory presented here was compiled following the demand for creating glacier outlines closer to the year 2000 and improving the quality of existing datasets in the widely used RGIv6 for a next version of the RGI. It could be

created as satellite images with the required quality were available from Landsat 5 and 7." This issue is also further extended in chapter 2.2. and discussed in chapter 6.1.

Please see P2-3 L71-76

General comments:

L21: By 2020, glacier surface area had decreased to 1060.9±33.6 km2. After this sentence, you can present results in % which have given at line 24. You can shift this sentence here.

Agreed. We changed the structure of some sentences here and now it reads:

"Glacier margins were mapped manually and reveal that in 2000 the mountain range contained 2186 glaciers with a total glacier area of 1381.5±58.2 km^2. By 2020, the area had decreased to 1060.9±33.6 km^2 a reduction of 23.2±3.8% (320.6±45.9 km^2) or -1.16% yr^{-1} over the last twenty years in the Greater Caucasus."

Please see P1 L21-22

L24, 28, 289, 290-292: -1.16% yr. Present results in single-digit after the point (-1.2% yr). Please carefully check the entire manuscript. At some places, it is single-digit, and at some places in double-digit.

For the relative annual area change rates we always use two decimal digits as a small difference can be valuable in a sub-regional comparison (e.g. northern vs southern slopes).

L31: Two glaciers. Please mention here the name of glaciers.

Done. (Djankuat and Garabashi glaciers)

L46: Johansen et al., 2018. Please use any English reference. There is so much published literature on this.

Done. We cited two different papers:

Huss, M., Bookhagen, B., Huggel, C., Jacobsen, D., Bradley, R., Clague, J., Vuille, M., Buytaert, W., Cayan, D., Greenwood, G., Mark, B., Milner, A., Weingartner, R. and Winder, M.: Toward mountains without permanent snow and ice. Earth's Future, 5: 418-435. https://doi.org/10.1002/2016EF000514, 2017.

Pfeffer, W. T., Arendt, A. A., Bliss, A., Bolch, T., Cogley, J. G., Gardner, A. S., Hagen, J., Hock, R., Kaser, G., Kienholz, C., Miles, E. S., Moholdt, G., Mölg, N., Paul, F., Radic V., Rastner, P., Raup, B. H., Rich, J., Sharp, M. J., and The Randolph Consortium: The Randolph Glacier Inventory: a globally complete inventory of glaciers, J. Glaciol., 60, 537–552, https://doi.org/10.3189/2014JoG13J176, 2014.

L52: complete detachment? Glacier or rock? Please correct.

Corrected as follows: “complete detachment of ice and rock, glacier surging, glacier lake outburst floods”

L57-65: I would suggest to highlight gap areas in previous glacier inventories and their change and linking with your study objectives. You have given this gap area at 110 to 127. Please shift these sentences here and modify the text.

We partly agree and moved this paragraph at the end of the Introduction: “The year 2000 inventory presented here was compiled following the demand for creating glacier outlines closer to the year 2000 and improving the quality of existing datasets in the widely used RGIv6 for a next version of the RGI. It could be created as satellite images with the required quality were available from Landsat 5 and 7. The year 2020 inventory was created to also test the improved quality of the 10 m resolution Sentinel-2 data and compare results against even higher resolution data from SPOT6/7 and Google Earth.” We did not move the rest of the paragraphs in “2.2 Previous studies” section as we think they are more appropriate for this section.

L69: GLIMS and RGI ver6?

Yes, thank you. Corrected.

L154: ‘Topographic details’ such as aspect, slope, and elevation….

Done.

L176, 190….: Generally, the glaciology community use the term glacier outline for glacier boundary. Your study used the term contours for glacier boundary at many places and in some places, your study also used outline (L210). Readers may be confused with this term as normally contour represent a line on a map that joins points of equal height or depth. I would suggest to use glacier outline or glacier boundary term instead of glacier contours.

Done. Corrected as an “outline” everywhere.

L190: half-pixel buffer size. You can refer here to Bolch et al. 2010. They have given reason for the selection of half-pixel buffer size.

Could be cited, but in the next sentence we say: “The selected buffer size for Landsat scenes is based on a recent study from Caucasus region (Tielidze et al., 2020b) while the Sentinel buffer was selected based on a study from European Alps (Paul et al., 2020).”

L312: Figure 10. What is the source of the 1960s-1980s data? Please mention this in the caption.

Corrected as follows: Data for 1960 and 1986 was taken from Tielidze and Wheate (2018).

L365, 369: You can show the location of these stations (Terskol and Mestia meteorological stations) in Figure 1.

Done. Please see the new Figure 1.

L367: Negative trend or decreasing trend?

Done. corrected as “decreasing”.

L385: since the 1980s (10 W/m2 over 10 years). How computed this value? or provide a reference here.

This value was calculated by Toropov et al. (2019) which is also cited at the end of the second sentence.

L390: Two different pollution events (5/05/2009 and 23/03/2018) are…. provide a reference here.

An appropriate references have been provided:

Kutuzov, S., Shahgedanova, M., Mikhalenko, V., Ginot, P., Lavrentiev, I., and Kemp, S.: High-resolution provenance of desert dust deposited on Mt. Elbrus, Caucasus in 2009–2012 using snow pit and firn core records, The Cryosphere, 7, 1481–1498, https://doi.org/10.5194/tc-7-1481-2013, 2013.

Dumont, M., Tuzet, F., Gascoin, S., Picard, G., Kutuzov, S., Lafaysse, M., Cluzet, B., Nheili, R., and Painter, T. H.: Accelerated snow melt in the Russian Caucasus mountains after the Saharan dust outbreak in March 2018. Journal of Geophysical Research: Earth Surface, 125, e2020JF005641. https://doi.org/10.1029/2020JF005641, 2020.