

# Authors reply to Dr. Dirk Scherler's comments

## “Brief communication: Supraglacial debris-cover changes in the Caucasus Mountains” by L. G. Tielidze, et al.

The Cryosphere Discuss.,  
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Dear Dr. Dirk Scherler,

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 what we did in the text are in **yellow**.

### General comments

This contribution presents satellite imagery derived changes in supraglacial debris cover in the Caucasus Mountains between 1986, 2000, and 2014, based on Landsat and Spot imagery. The paper presents interesting data although I find some of the methodology unclear. The analysis of the data could be extended to support, or refute, some of the inferences in the discussion, which is sometimes rather speculative. When addressing these issues, the paper should be a relevant contribution, but may be better published as a standard format paper, instead of a brief communication?

We agree that the methodology section was confusing in the previous version of the manuscript, and because of this, we are presenting much comprehensive methodology here. The analysis of the data has been expanded as well. Please find the new methodology section P3 L20-34; P4 L1-24.

Due to many corrections and new text/figures, the manuscript was extended but we decided to keep it as a brief communication.

### Main comments

The description of the methods takes up a considerable fraction of the entire paper, but there still is some information missing. I had the biggest difficulties to understand how the GPR data was used. Hardly any information is given about it, but it appears to be relevant for “correcting” the debris covered area on the Elbrus Massif. If the GPR data was used in this study, I think the authors should provide much more information about the data and the results. At present, I’ve only seen one figure in the supplementary material (Figure S6). How reliable are the GPR measurements? Is there room for interpretation or was it all straight forward? I don’t question the observations; I would just like to see more of the data the authors collected.

Due to the GPR data caused some awkwardness, we excluded it in the current version of the manuscript. We agree that it required much more explanation and methodology definitions.

Overall, I found the discussion quite confusing. It starts with a chapter on possible reasons for the observed SDC increase, but this chapter also addresses the question of spatial differences in SDC, without any temporal aspect. The authors mention many potential reasons for either spatial differences or temporal changes (and I think many of them are truly meaningful), but they remain speculative. I see potential to address some of these reasons with the current data, but that would require additional analysis. For example, the authors suggest that rock avalanches after 2000 may be one of the reasons why SDC increased more during the period 2000-2014 and they provide examples in the supplementary material.

<p>Wouldn't it be possible to quantify these in order to assess their relevance? From the supplementary figure, it wasn't clear to me if all of the rock avalanches were deposited in the ablation zone. If not, some of them may be gone again when buried under snow and ice in a few years. The authors also suggest that topographic differences between northern and southern slopes are responsible for spatial differences in debris cover. Instead of opposing just the two regions, wouldn't it make sense to analyze the glaciers and their topographic setting for testing this idea? If true, there should be a correlation between the topographic reason and the observed difference. There exist other inferences or statements ("Little Ice Age moraine can affect the SDC increase on the glacier tongue, as debris often falls from lateral moraines onto the glacier surface"; "in the eastern Greater Caucasus, a large percentage of the debris cover is a result of the lithology") that should be better backed up by observations, for example, from the spatial distribution of debris cover and its increase on the glacier surfaces.</p>
<p>We provided a different version of the Discussion with many corrections and new texts and tried to avoid any speculations. Relevant figures have been provided in the main manuscript and supplement, that shows e.g. up-glacier migrations Fig. 3, S3, and SDC increase after rock-fall (related to permafrost) Fig. S4. etc.</p>
<p>The comparison with previous estimates of debris cover in the Caucasus Mountains is useful and worth reporting. However, when comparing results with the values reported in our recent paper (Scherler et al., 2018), it should be explicitly stated that the scope of our study was a different one. We attempted an automatized global assessment, knowing and discussing the issues of erroneous glacier outlines in the RGI and we explicitly stated that we did not correct any outlines in the RGI. In other words, we did not pretend to get the debris cover correct, if the RGI outlines are not correct. This is an important point that should be acknowledged to avoid making a straw man argument! It is also not clear to me how the data of Figure 2 was put together. Were only those glaciers compared that were analyzed in both studies? And what about the circular glaciers? Overall, I find Figure 2 not relevant. More relevant would be the comparison of the clean ice-debris cover boundary between our and this study, as in our automatized mapping, we were relying on a single threshold value for the entire Earth.</p>
<p>We certainly do not question work by Scherler et al. (2018) and we mentioned (end of the Discussion) that the goal of your study was an automatized global assessment of SDC from optical satellite data, without correcting any outlines in the RGI. The big difference between these two results is just caused by RGI inconsistent outlines (that we mentioned before as well, e.g. Tielidze and Wheate, 2018). But, in fact, work by Scherler et al. (2018) is only one work including the SDC data-set for entire Greater Caucasus and we think that comparison of these two studies is important. Therefore, we decided to leave previous Fig. 2 but moved it in the supplement as Fig. S6. Also, we provided an explanation of how we compared these two data-set. Please see P9 L23-24.</p>
<p><b>Specific comments</b>  P1L24: "Thereby": I don't see the causal connection to the foregone sentence  P1L26- 28: It would be good if you could provide an explanation, or your favorite explanation, why this is the case.</p>
<p>We agree and provided new Abstract. Please see P1 L24-34</p>
<p>P2L2: "supraglacial debris thickness"</p>
<p>We agree, please see P2 L8</p>
<p>P2L8: "Europe": Nothing important, but I'm wondering if all of the Caucasus Mountains and thus all of the glaciers and their area are part of Europe?</p>
<p>We changed this sentence, please see P2 L13</p>
<p>P2L10: Delete "similarly"</p>
<p>We agree, please see P2 L16-17</p>
<p>P2L15: How does it contradict earlier studies? Please specify.</p>

We have changes this sentence, please see P2 L20-22
<i>P2L25: What determined your selection of glaciers? Does this mean there exist glaciers that you did not consider? Please clarify</i>
We have changed this sentence and added appropriate citations, please see L2 L31-32
<i>P2L29: "a largest" -&gt; "the largest"</i>
We agree, please see L2 L35
<i>P2L39: "Additionally, . . ." -&gt; Please specify how you included what kind of GPR results in which way. Also give references if it is published. If it is not published, I think you need to provide much more information on the GPR data.</i>
We excluded the GPR data in this study
<i>P3L1: ASTER GDEM asks for a certain way of acknowledgement that is missing.</i>
We agree and an appropriate link was added P3 L6
<i>P3L5: What threshold value did you use to distinguish between ice and debris?</i>
We used threshold value $\geq 2.0$ , please see P3 L21-22
<i>P3L13: "SDC is" -&gt; "SDC are"</i>
We deleted this sentence
<i>P3L14: Delete "Relatively"</i>
We deleted this sentence
<i>P3L16: Again, it is unclear how you used GPR data (see comment above).</i>
We excluded the GPR data in this study
<i>Figure 1: I think this figure should be larger – but maybe that's just due to the formatting of the PDF</i>
We have changed Fig. 1, please see P3 L14
<i>P3L22: "sections" -&gt; "regions"</i>
We agree, please see P3 L15
<i>P3L23: "Elbrus Massif"</i>
We agree, please see P3 L16
<i>P4L9: Delete "however" &amp; "critical to" -&gt; "critical for"</i>
We deleted this sentence
<i>P4L10: "performed" -&gt; "used" &amp; Why is method 2 giving you a more realistic uncertainty estimate?</i>
We deleted this paragraph
<i>P4L19: How is the geomorphology complicated?</i>
We deleted this sentence
<i>P4L31: "debris cover" -&gt; "SDC" &amp; comma after "increased"</i>
We agree, please see P4 L33
<i>P5L8: "Debris cover migrated up-glacier" -&gt; I haven't seen any data on the spatial distribution of the SDC. If you have, it would be worth showing it.</i>
We approved this sentence by providing new text (P6 L15-19) and images (Fig. 3 P7 L6-10 and Fig. S3 P2 L10-14)
<i>P5L10-P6L11: This chapter sounds more like results. Also see the main comments above.</i>
We have changed this chapter, please see new version from P6 L28 to P9 L6
<i>P6L14: Regarding the GPR results, see main comments above.</i>
We excluded the GPR data in this study
<i>P6L25: Not clear how the cited studies and this one are broadly consistent. In that there is an increase? It appears difficult to compare a regional study with individual glacier studies. Perhaps compare results from this studies with previous ones by limiting to those glaciers that are in common?</i>
We have changed this sentence, please see P9 L9-11
<i>P6L31: "141% increment"?</i>
We agree, please see P9 L17

<i>P6L36-P7L3: See main comments above.</i>
We have changed this paragraph, please see new version P9 L23-35
<i>P7L10: SCD -&gt; SDC</i>
We agree, please see P9 L38
<i>P7L15: "periglacial debris cover": this term comes surprising and it's unclear how this conclusion came about. Also, why is the monitoring "vital"?</i>
We have changed this sentence, please see P10 L1-2
<i>P7L16: Delete "a"</i>
We agree, please see P10 L3-4