Reply to comments by Prof. Frank Paul

Your comments are written by Century.
My reply are written by Arial and in Blue.
Revised part at main text and at supplement were written in red.

Thank you for your valuable and positive comments and suggestions. I apologize that I could not submit revised manuscript for a long time. I have revised my manuscript as your comments. My main revision was as follows.

1) I have decided that I remove Fig. S8 (Quality of Landsat imagery), because the classification of Landsat imagery were not objective. Further, instead of the Fig. S8, I can evaluate the quality of Landsat imageries by Fig. 1, which shows the number of Landsat imageries used to delineation for each path-row.
2) I have included revision of total area of GGI15, because area calculation of GGI15 by Nuimura et al.(2015) included holes in glacier polygons.
3) Revised manuscript has been substantially edited by native speaker. But, I have wrote in red for those portions which contents has changed.

(1) This study is about glaciers so a publication in The Cryosphere makes sense. However, the paper is just a description of a dataset. There is no scientific advance or analysis included warranting publication in TC. This might be an editorial decision but in my opinion this study should be published in ESSD rather than TC.
>> Thank you for your positive suggestion. I agree with your comments, but, when I received review reports, I have no time to respond to change the Journal. And paper of first version of GAMDAM Glacier inventory was published at TC, then I have selected same Journal.

(2) I agree with the comments forwarded by reviewer 1 (W. Guo) and will thus only partly or shortly repeat them here.
>> Please check my reply to comments by W. Guo.

(3) The English wording/grammar is not good. Although it is mostly still possible to understand the text, I strongly recommend having the final version of the revised ms corrected by a native speaker before resubmission. I will not further comment on grammar issues.

>> I have changed the company of English editing in this revised version. I hope the new company could edit English properly.

(4) Methods: I suggest adding here a short section explaining what a glacier is in the context of this study, how this definition has been implemented practically, and what has been done when a strict application was not possible (have outlines then be transferred from a previous inventory?). For example, in the supplement one could show the time series of available images for a particular small region and describe why a specific scene has finally been selected to map a glacier (regarding snow, cloud, shadow conditions) or which scenes have been selected to get a complete outline. This would also be helpful advice for others creating a glacier inventory under difficult mapping conditions. The practical implementation should describe how seasonal snow has been distinguished from perennial snow and completely snow covered ice. At best, also this is illustrated with one or two examples of such conditions (in the supplemental material) to understand the related decisions and improve traceability.
>> I have added one subsection '3.1 Selection of Landsat imagery' with explanation of image selection process and also added Figure S1 using five Landsat scenes. Fig. S1 includes selected scenes in GGI15 and four candidate scenes for GGI18. (Page3 line23-Page4 line8)

(5) In the methods section I would insert a further section on uncertainty assessment. Just saying it is 15% as before is not convincing in my opinion. Uncertainties will likely be much smaller for larger glaciers so that it will be closer to 5-10% overall. As uncertainty scales with glacier size, one possibility is using a size-dependent empirical function as shown in Pfeffer et al. (2014) for RGI data. Instead of an empirical function one might also use the buffer method (with ±1/2 pixel) to determine a more realistic uncertainty (all ice divides should be removed beforehand). Of course, for debris-covered glaciers uncertainties might be higher but this can be commented on. The likely best method to determine an uncertainty value for this dataset would be independent multiple digitizing (at least three times) of several (say 10-20) glaciers of different size and with different challenges (debris, shadow, snow). The related standard deviation of the resulting relative area differences would be a good uncertainty measure for this datatset. Finally, it would also be possible to select a region with clean glaciers, map them automatically (e.g. with a band ratio) and use them as a reference for uncertainty assessment of the manual digitizing (see also doi: 10.1016/j.rse.2017.08.038).2
>> Thank you for your comments with specific suggestions. In the revised manuscript, I

have carried out a delineation test for debris- and debris-free glaciers using 10 Landsat imageries (shadowed, snow-covered)(Fig. S4). And I obtained relations between mean glacier area and normalized standard deviations of glacier area (standard deviations of glacier area /mean glacier area) for debris-covered glacier and debris-free glaciers, respectively (Fig. S5). Because I did not classified debris- and non-debris-covered glaciers, ratio of debris-covered glacier's number at each area class at Eastern Himalayas (Ojha et al.(2017)) were applied to estimate uncertainty of all glaciers including both debris and debris-free glaciers (Fig. S6). Then, I have assumed that the normalized standard deviations of glacier area were uncertainty of glacier area. Then, the average uncertainty of glacier area at whole study area become about 11% as shown in Table S2. These contents are written in section '3.3 Uncertainties in glacier area'.(Page 5 line 6-22)

6. I suggest moving several of the illustrations from the supplement into the main text and arrange them differently (i.e. more compact).
>> There is a rule that "Brief communications have a maximum of 3 figures and/or tables". Then, I cannot move figures in supplement to main text.

Fig. 1 should be the current Fig. 1 plus Fig. S8 side-by-side (S8 is providing key information about dataset quality!).
>> Thank you for your pointing out the importance of Fig. S8 (Quality of Landsat imagery) . But, as I wrote my reply to Guo, I have decided to remove the Fig. S8, because the quality of Landsat imagery was classified subjectively.

Fig. 2 should be the current Fig. 2 (please add a) and b)) but side-by-side to save some space.
>> I have added a) and b) and relocate them to be side by side.

Fig. 3 should be Fig. S3 and S4 side-by-side. The a) panels of both figures can be included or remain in the supplement. Figure 4 should be the d) panels of Fig. S5 and S6, also side-by-side. The a) to c) panels of both figures and all other figures (S1, S2) and tables can remain in the supplement.
>> There is a rule that "Brief communications have a maximum of 3 figures and/or tables". Then, I could not put figures to main text.

7. When comparing the outlines from GMADAM2 with NM18, I would describe the differences more precisely. As also visible in the current Fig. 2, NM18 seems to have

included many regions with seasonal snow and is thus clearly overestimating glacier area and the number of small glaciers. As wrongly mapped seasonal snow has been mentioned in NM18 as a source of uncertainty, this can be confirmed here. I would also mention that there are sometimes larger differences in the extent of debris-covered glaciers between GAMDAM2 and NM18. In part, these might be due to the well-known difficulties in the interpretation or in-between glacier surges, but in comparison with very high-resolution GE images I have the impression that NM18 is often overestimating glacier extents, i.e. including parts that are actually rock glaciers. This might be due to the use of SAR coherence images in NM18 that might have included larger parts of them. By describing the observed differences more explicitly, the reader might also get a better impression of the main challenges and where special care has to be taken.

>> Thank you for your positive comments. I have included the statements that 'NM18 might overestimate glacier extents because ...'. But, as you wrote, terminus of glaciers in Karakoram and Pamir regions are covered with seasonal snow in GE. So, it is hard to detect terminus location of debris-covered glacier in this region. I described about these problems in the text at Page 7 line 7-14.

Specific comments

P2, L16: not sensitive to temperature change: I would write 'less sensitive'

>> I have revised.(Page 2 line15)

P2, L18/19: I think the purpose of a consistent and precise glacier inventory for the region is less on relating glacier fluctuations (changes in length and area) to climate change (which is a very difficult task), but more to facilitate calculations that rely on exact glacier extents. This includes modelling of total glacier volume, spatially constrain calculation of elevation or volume changes from altimetry and DEM differencing or flow velocity and snow cover on glaciers, hydrologic modelling from the catchment to the regional scale, determination of future glacier extents and volume evolution, and by providing stable ground for uncertainty assessment. All these would be error prone without exact outlines.

>> I have added what you pointed out with references. (Page 2 line 17-22)

P3, L20: How could you determine the size of a glacier (to decide that it is smaller than 0.01 km2) before its extent is digitised?

>> The minimum glacier area : 0.01 km^2 has correspond with 10 grid cells (0.009 km^2) of

Landsat imageries. Then, I have included nearly 10 grids of glaciers, when I digitized. I have added the explanation in the text. (Page 4 line17)

P3, L27: Please add some words on how many GE images have been consulted (can be very rough order of magnitude) and the percentage of images that supported the interpretation. We have not been very successful in finding suitable GE images for all glaciers in NM18.
>> Yes, sometimes GE did not support to detect terminus of debris-covered glaciers in the Karakoram and Pamir because of the seasonal snow cover. And we have little high resolution Google Earth images in the East Nyen Chen Tanglha Mountain. But, I can not write the number of GE images are consulted to delineate glaciers (even roughly), because I have delineated glaciers individually, not based on the unit of Landsat imagery or Google Earth image. But, anyway I have wrote about the problem of Google Earth images in the section of 'Manual delineation'. (Page4 line 33- Page 5 line 3)

P4, L18: For the total region, I would contrast directly here the main numbers for GGI18 with those for GGI15, including the percentage of change in number and area. In section 4.1 you can then describe specifics for the regional numbers (Table S2).
>> I wrote contents on Table 1 in the head of section 4.(Page 5 line23-27) And in the section 4.1, I wrote on the regional difference between GGI15 and GGI18. (Page 5 line31-)

Tables and Figures
Please see point 6 of my general comments for general feedback on Figures.

P10, Table 1: I suggest transposing this table so that is has 7 columns and three rows. This would also help in keeping the ms compact.
>>I have transposed the table. (Page 12)

P12, Fig. 2: Please use white instead of green lines, increase the brightness level somewhat and arrange both images side-by-side.
>> I have revised.

Tables S3 and S4: I suggest merging the two tables into one
>> I have merged. (Fig. S9 in the revised version)

Fig. S1: a) I suggest using yellow instead of green lines and white instead of red.

>> I have changed the colors. (Fig. S7 in the revised version)