Reply to review comments by Prof. Wanqin Guo

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.

Specific Comments

Page 2:
Line 14 - 16: The first half of this sentence is somehow repititive with previous one ("… are relatively stable"). It's better to be rewrite properly.
>> I have changed to 'a slight mass increase for former statements. (Page 2 line13)

Page 3:
Line 4: There's no other authors in this manuscript. Should you use "I" instead? Or is this refer to GGI15 data sources? It should be clearly marked if so.
>> Yes, I have to express 'I' instead of 'We'. I have checked all text, and revised them.

Line 7: "seasonal cloud - free, seasonal - snow - free" , seasonal in this part seems repititive, maybe remove the second "seasonal - " will be better. Besides, add "incidence" or other confining words between "solar angle" may be better.
>> I think 'cloud - free' doesn't need 'seasonal', then, I removed the former 'seasonal'. (Page 3 line 11)

Line 25 - 27: Although it's not consistent with common sense glacier inventory, Nuimura et al. (2015) provides a meaningful reason to exclude steep wall beyond the glaicer. Same to that paper, you should also give a reason that why you choose to include the snow - and ice - covered steep wall into the glacier, or researchers' comments or suggestions on this.

You should better also mention the criteria of the steep wall here, e.g. same as the definitions in Nuimura et al. (2015) (>40°)? Or just by visual judgements? Besides, the criteria you used to judge a patch as perennial snow or ice is also very important and should better to be presented somewhere, e.g. just as you saw in primarily used Landsat images acquired during one of the ablation season? Or carefully validated through comparing multiple images? Normally these steep back walls are always in rapid changes due to unpredictable snow/ice avalanches and/or frequent orographic snowfalls that may occur at anytime.

>>There are two main reasons for including glaciers at steep headwall. One is actual hanging glacier (glaciers at steep headwalls) has some thickness, then those thickness change should contribute glacier mass changes. Second reason is that I could found Landsat images with clear glacier boundary at steep walls by expanding searching period.

As you wrote, we have excluded steep headwalls even where snow covered in the GGI15. Because steep headwalls generally do not experience changes in surface elevation related to glacier mass fluctuations. Further, we could not find images with clear glacier boundary at steep walls, because the initial setting searching period was only 5 years from 1999-2003.

But, I have changed my mind that when I have been to field observation. In the Fig. S2a), which I took at the Trakarding Glacier in the Nepal Himalaya, some glaciers at steep headwalls has more than several meters in thickness, then I thought those ice mass should contribute to total glacier ice mass. Further, I could found many images with clear boundary of relatively thick glacier outlines at steep headwalls, which make it possible to delineate glacier outlines at steep walls by expanding the period of the acquisition year from 1990-2010. I have added summary of the above statement in the '3.2 Manual delineation' (Page 4 line22-30) .

Line 27 - 28: It's not very clear from this sentence that which part of the debris - covered glacier were omitted. Maybe add a figure to illustrator the criteria will be much better.

>> I have added two samples in Fig. S3.

Page 4:

Section 3.2: No methodology was described on how the quality of Landsat images was evaluated. It's a very important content for readers and potential glacier inventory compilers to understand the impacts of Landsat image quality on glacier inventory compilation.

Line 10 - 11: I suppose that one or a series criterion(a) was(were) used to evaluate the image quality and assign the three quality ranks (A, B, and C) to each image. It will be too subjective if only using human judgements to do that work. So It's necessory to describe the method(s) on how the ranks were evaluated on a Landsat image, at least in the supplementary material.

Line 14: What is the score represented? And how the score was assigned to each factor on each image? It's fairly obscure in this section.

> Thank you for your above comments. It's right what you pointed out about quantifying the quality of Landsat images. I have decided that I remove this section, right colums of Table S1 (Quality of Landsat images; Cloud, seasonal snow, shadow) and Figure S8, because all evaluation of quality of Landsat images are subjective. Instead of the quality of LANDSAT images, the number of Landsat images used in the GGI18 (Fig. 1) can represents the difficulty of delineation of glacier outlines, in other words, quality of images. I also revised section '4.3 Glacier outlines required to revise by other satellite images' and the example of hard mapping area in Fig S13 (Page 7 line22-27).

Line 26: On Fig.2, it is suggested to add coordinates on each sub - figures and thus will be much convenient for readers who want check the glacier outlines shown in the figure.

> I have already added the Longitude and Latitude in the explanation of the figure in the original manuscript.

Line 29: On Fig.S2, same as the suggestion for Fig.2. Besides, it's not very clear here on the meaning of glacier area shown in Fig.S2. Are the glacier area shown counted by pixels numbers in glacier facing to different aspect ranges? Or simple the area of glacier whose average aspect belong to those aspect ranges?

> I cannot add the coordinates in Fig. 2. because the each areas of GGI18 and GGI15 include whole region of HMA. Then, I added ' for whole HMA' in the legend.(Fig. S8 in the revised version)

> The aspect in Fig. S2 (Fig. S8 in the revised manuscript) was calculated based on pixel numbers in glacier polygons. I did not used average aspect of each glaciers. I added the method of calculation in the explanation of this figure. (Fig. S8)

Page 5:

Line 10: Actually there's no rule of "one glacier has one terminus" neither from the earliest WGI handbook (Müller et al., 1977), or from GLIMS tutorial (Raup and Khalsa, 2007&2010), or the guideline for glacier inventory compilation (Paul et al., 2009). Just like what is said in Raup and Khalsa (2010), it isn't always easy to delineate ice divide for these glaciers by human judgement or even by common DEM analyze. Some glaciers like the diffluent glaciers actually do have two or more termini, and some hanging glaciers that on a long slope with similar orientations are also difficult to tell where the divides are. Actually the ice divides for these glaciers are changing that may be caused by even slight differences in the accumulation rate on different parts or changes in the flow velocity. Some ice caps even don't have apparent terminus but just occuping a flat mountain top. So it's not always necessary to divide these glacier into individual glaciers with single terminus.

>I have misunderstood about the rule. As I wrote in the text, I didn't apply this rule to all glaciers. So, I have excluded these description.

Line 12: It's not very clear here that how the glacier size can determine the glacier number. It should be clearly clarified.

> I have excluded this sentence, because this sentence has been described following the previously mentioned statement.

Line 17 - 18: It's also unclear that how the glaciers in 1×1 degree grids in Fig.S6d and S7d were grouped and how the discrepancies between GGI18 and CGI2 as well as NM18 were calculated in those grids (according to their label/centre points? Or cut by grid boundaries?).

>I have added ' For each 1° × 1° grid cell, glacier polygons for all three inventories were aggregated based on the polygon barycentre, thereby enabling regional differences to be calculated (Figs S11d and S12d).' in the text (Page 7 line4-5).

What the size (three levels) of the gridded points represents is also ambiguous (largest/mean area of all glaciers in the grid?). It needs to be clarified to avoid confusions.

>I have added ' The size of each circle indicates glacier area sum of GGI18 at each grid cell.' in the Figure explanation. And I thought 'Glacier area class in GGI18' in the Figure S6d might lead to misunderstand, then, revised the legend 'Glacier area of GGI2018' in the

revised version (Fig. S10d, S11d, S12d).

Line 19: Should “Figs. 7b, c and 8b, c” be “Figs. S6b, c and S7b, c”?
>>I have added several figures in supplyments. I have revised the figure number properly. (Fig. 7line1)

Line 21: See above comments on Line 10. It is not always necessary to divide the different glaciers especially the hanging glaciers into more individual glaciers.
>> This sentence doesn't relate to the rule 'one glacier has one terminus', which I miss-understood. Only compared the state of separation of glaciers in GGI18 and other inventories. So, I did not changed the content of this sentence. (Page 7 line1-2)

Page 6:
Line 2 - 3: Same as comments on Page 4, Line 10 - 11, descriptions on the methods and criteria to evaluate Landsat image qualities are needed somewhere in the manuscript for better readers’ understandings on how they are evaluated.
>> I have removed the evaluation of Landsat image quality as I described above.

Line 5 - 6: The regions you called here as “Hengduan” in Fig. S8 are actually composed by East Himalaya Mountain and East NyenChen Tanglha Mountain. These regions are also dominated thus heavily influenced by monsoon called as India Monsoon or South Asia Monsoon through the river valleys of Yarlung Zangbo, leading to very poor satellite images that are always covered by snow or clouds. Please correct it.
>> I have removed the evaluation of Landsat image quality as I described above. Then, ' Hengduan” has also removed. Instead, I described one example with figure, where it was very hard to delineate glacier outlines. I wrote the region name 'Eastern Himalaya'.