Author Reply to comments by M. S. Pelto

The detailed comments by the Prof. M. S. Pelto are appreciated and will help correct mistakes and strengthen the results of this paper. I greatly appreciate Prof. M. S. Pelto and carefully reply each point in turn.

Reviewer comments in bold
Author reply in normal text

3483-19: There is an east to west gradient in precipitation and temperature. This is certainly evident in the degree of cloudcover. Also Su and Shi (2002) observed a change in precipitation from 3000 m to 4900 m of 1.89 to 3.0 m. This altitudinal gradient deserves some mention. It would also be useful to add to Figure 1 to place in a climate context better the Gongga Range, much like Figure 1 in He et al (2008). Is the main moisture source the southeast monsoon flow?

Thanks for your suggestions! According to your comments, I have added the climate context to Figure 1. I also add the text about altitudinal gradient in Gongga Mountains.
3483-19：“The altitudinal gradient of temperature described by Su et al (1993) by filed observation was -0.23ºC,-0.9 ºC and -0.2 ºC on the altitudinal belt 2880-3010m, 3010-3210m and 3210-3510m, respectively. Su et al (1993) and Gao and Peng (1994) indicated that the first maximum rainfall zone exists between 2900m and 3400m a.s.l. on the eastern slope and in the 3700 a.s.l. on the western slope; and the second maximum rainfall zone lies between 4900m and 6000m a.s.l., which is equal to the height of the present snow line with annual precipitation about 3000 mm.”

Based on the studies of Li et al (1986) and Su and Pu (1993), monsoonal temperate glaciers in China are mainly affected by two major climatic systems. The first is the mid-latitude westerly circulation, which brings limited moisture to the region. The second is the South Asian monsoon circulation, which is the dominant source. The monsoonal climate can be divided into winter and summer circulations. He et al (2008) thought that the regional climate is dominated by the southwest (India and Bengal monsoons) and southeast monsoons in the wet season，and by the westerly and the Qinghai—Tibet monsoon in the dry season. According to the meteorology station records, the precipitation on the eastern slope is lager than that on the western slope. We extrapolate that the main moisture source may be the southeast monsoon flow, and the southwest monsoon flow is also important flow.

3484-26: How can you resample from the original 20 m contour interval DEM down to 15 m in DEM and maintain accuracy?

Here, the 20m contour interval stands for an elevation interval. General work flow is to digitize the 20m contour lines, convert the results in a Triangle Irregular Network (TIN) for relief representation and transfer into a high resolution grid with a 15m cell size (Etzelmüller, B., 1993). The vertical accuracy of DEM is about 10m (1/2 map contour interval) (SBSMC, 2007, Zhang et al 2010). This is a generally flow and we could not improve the original vertical resolution. The result of resample is a grid image with a 15m cell size.

3486-1: Mention the visual characteristics utilized in manual identification of the glacier perimeter. Figure 3a and 3b indicate sector distribution not aspect. Make sure to be clear about aspect or orientation versus sector of the mountain range throughout.

The visual characteristics utilized in manual identification of the glacier perimeter were totally based on the *Technical Documentation of Glacier Inventory in China (2007)* and glaciologists' experience. These are summarized in brief as below:

1) If a large amount of ice is buried beneath the terminal moraine, the glacier terminus is drawn outside the glacial terminal moraine (Figure 1a);

2) If there is no ice buried on the terminal moraine, the terminal moraine is not a part of the glacier (Figure 1b);

3) If there is a distance between the terminal moraine and the glacier terminus; it will be difficult to identify the terminus. In this case, the head of glacier melt water can be considered as the terminus of the glacier (Figure 1c);

4) If the glacier is connected with a glacial lake and there is no ice below the glacial lake, the boundary between the glacier and the lake should be the glacier terminus (Figure 1d) .

5) The lateral moraine is often reorganized as the glacier outlines.

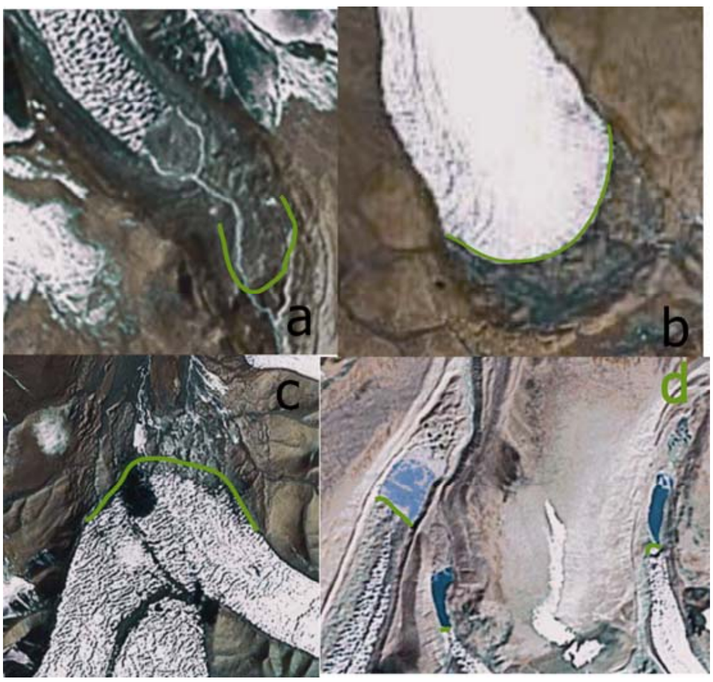

Fig 1 the glacier terminus

3684-1: "Terminal moraine, the head of glacier melt water, a glacial lake and lateral moraine are visual characteristics utilized in manual identification of the glacier perimeter."

In my manuscript, Figure 3a and 3b show the aspect of glacial, like Figure 4b in Andreassen

L.M.et al (2008). The mean aspect of each glacier is calculated from the arc tangent of the respective sine and cosine grids following Paul (2007).. Andreassen L.M. et al (2008) also discussed the aspect orientation and glacier size by this method. I will make sure to be clear the aspect and orientation in my manuscript.

3486-21: Where are these points, at least indicate those on the key glacier in Figure 4. Much like Figure 1 in Zhang et al (2011). What is the accuracy. In the 2008 GPS work on Hailuoguo Glacier it was noted by Zhang et al (2010) that GPS survey data define the 2008 outline of the Hailuogou glacier tongue, and were used to generate a DEM of the glacier surface with a pixel resolution of 15m.

I have added the survey data in the Figure 4, like Figure 1 in Zhang et al (2011). The accuracy of single-level positioning by GPS (SF-2040) is less than 10cm. Comparing the survey data in 2009 and glacier outlines, we estimate that there are about 30m errors (about a pixel of Landsat ETM+). From 2008, we have begun to work in this region, including the survey of the surface elevation and glacier outline of glacier ablation area in HLG, YZG and DGB glaciers.

3487-11: The climate gradient needs to be emphasized more in the lack of glaciers in the northern sector.

The lack of glaciers in the northern sector may be caused by topography and climate gradient. From Figure 1, we can find that the ridge line is approximately south-north direction, with 80 km long and 15 to 40 km wide (Su et al., 1992). Hence, there is a narrow space for glacial settled in the northern sector. Additionally, the rainfall in northern sector is less than others sectors. These two reasons may cause the lack of glaciers in the northern sector.

3488-5: That the number of glaciers has increased due to glacier separation is not a proper summary of the change. If a glacier disappears that is a reduction in number, if a glacier separates into multiple parts via disintegration that is not the same as glacier formation. Though it may be a separate glacier, it should not be considered an added glacier in the count total. As glaciers diminish they do separate into many parts that should not be counted separately, this is inconsistent practice to identify former tributaries as additional glaciers. For example as the Aral Sea shrinks and separates into different parts we do not say there are now more seas. Table 3 needs to be adjusted accordingly.

According to the *Technical Documentation of Glacier Inventory in China (2007),* when a glacier separates into multiple parts via disintegration, if these parts have individual accumulation zones and ablation zones, they should be separate glaciers. For example, the Glacier No.1 of Urumqi River has separated into two branches, West Branch (WB) and East Branch (EB) in 1993(Li et al., 2003).Now they are two separate glaciers. Although the numbers of glacier increase, the areas of glaciers do decrease. If we want to estimate the change of these glaciers in the future, it is better to observe them individually..

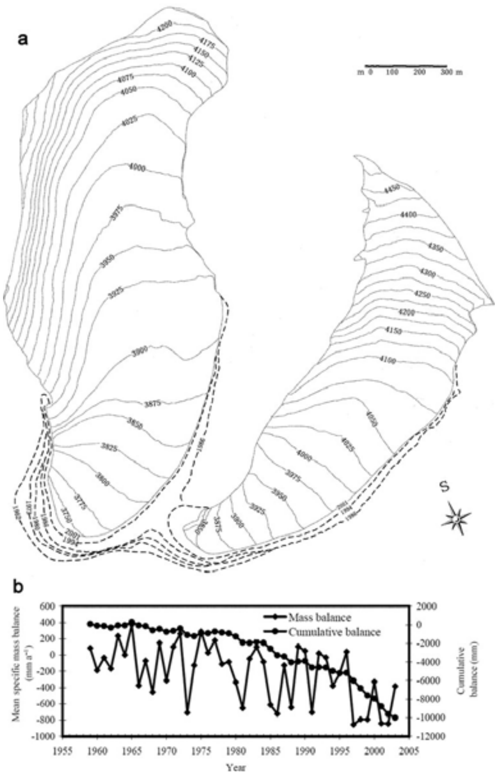

Fig 2. (a) Repeated photogrammetric mapping of UG1 at different times during the past 40 years (Wang and others, in press). Dashed line with number shows the terminus position in the numbered year, and solid line with number is the altitude isoline. (b) Mass-balance processes (Ding et al., 2006)

The comments of Prof. M. S. Pelto let us to rethink about the separated glacier. If a glacier separates into multiple parts via disintegration that there has no ablation zone, they may be not a separated glacier. In the future work, we will note this question, especially the compound basins glacier.

3489-7: At the start of each of these sections it is key to give a background paragraph as is done for Dagongba Glacier. It is crucial to note the terminus elevation, ELA if known, extent of debris cover and for each glacier. Hailuoguo Glacier has a much lower terminus elevation than the other glaciers. The debris cover importance is summarized by Zhang et al (2011) who note that 67% of the ablation zone has experienced enhanced ablation and 19% reduced ablation due to the debris cover. The main change in the lower ablation zone was noted as thinning and not ice retreat (Zhang et al 2011). There needs to be a measure of the debris covered extent as a percent or area on HLG, XGB DGB, MZG, and YZG much as Liu et al (2010) for the HLG basin. Given the crucial role in suppressing ablation as Figure 7 in Zhang et al (2011) indicates, this needs more emphasis though in this paper quantifying the impact is not the goal.

I will reply this comment and next comment together.

According to advice, we add a background paragraph of HLG, YZG and MZG glacier.
3489-2: “In 1966, HLG glacier was 12.2 km long and 250–1200m wide, with an area of 26.1

km^2. The glacier flows eastwards as it descends from 7556 m to 3000 m. Four distinct zones can be recognized: the accumulation zone (from 7556 m to 4980 m), a large icefall zone (from 4980 m to 3850 m), a zone of glacier arches (from 3850 m to 3480 m) and a debris covered zone (from 3480 m to 3980 m). According to Li and Su (1996), the ELA of HLG is about 4900m a.s.l.; and about 0.28 km^2 of glacial area is covered by thick debris. …”

Additionally, I could not see the paper by Zhang et al (2011) before I submitted my manuscript. Now this paper is available to be cited to explain the change about HLG glacier.

3492-20: “Additionally, the ablation of HLG glacier by Zhang et al (2011) note that about 67% of the ablation area on HLG glacier has undergone accelerated melting, whereas about 19% of the ablation area has experienced inhibited melting, and the sub-debris melt rate equals the bare-ice melt rate in only 14% of the ablation area, because of the inhomogeneous distribution of debris thickness. Although, the thick debris may give a crucial role in suppressing ablation in the terminus Zhang et al (2011), the ice crevasse and subglacial river also may cause the glacier accelerating ablation. The change of HLG glacier is a quite complex process.”(Fig 3).

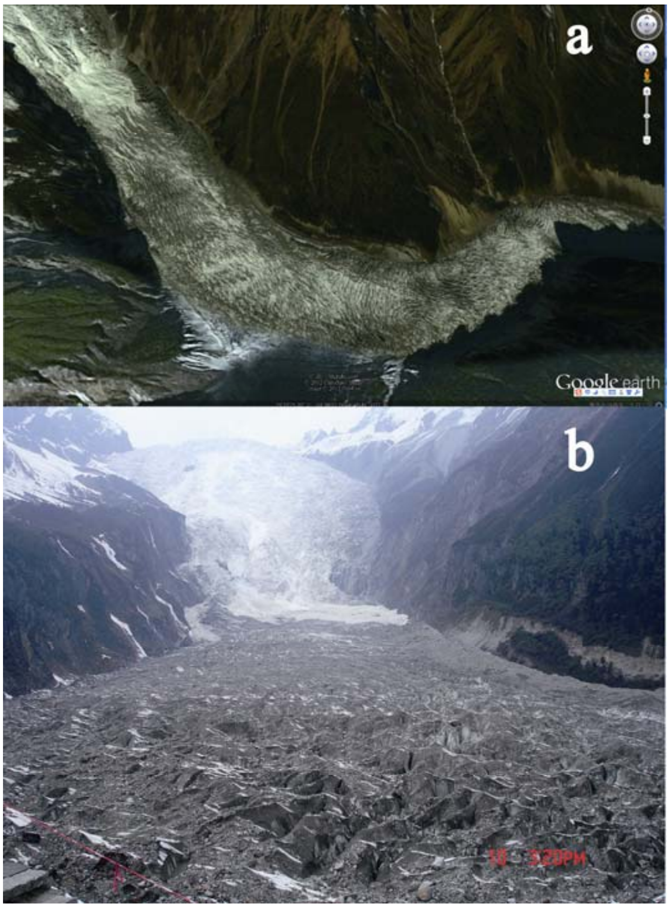

Fig 3 (a) this is a HLG glacier screenshots from Google earth. (b) this is a photo in 2009. Those picture show that there were numerous ice crevasses on the ablation area of HLG glacier.

3489-15: “The area of MZG glacier was 27.6km^2, with a length of 11.6 km in 1996. The terminus elevation of MZG glacier is 3600 m a.s.l., about 600 m higher than that of HLG glacier. The ELA is about 5240m a.s.l. and no debris covered on the glacier. The terminus of the MZG glacier retreated about 501.8 m in length from 1966 to 2009 (Fig. 4c and d; Table 5). This relatively slow retraction may be attributed to its higher mean elevation and larger accumulation area ratio (0.75). The terminus of glacier is quite steep and narrow (Fig. 5b and c), There was no debris covered on the ablation zone of glacier. The glacier change in MZG is different from other glaciers. This is an important question and we will explore it in the future works. From 1966 to 2009,the shrinkage area of MZG glacier is 7.7 % (Table 6) which is larger than that of the HLG and YZG Glaciers. By comparing remote sensing images from 1974, 1989, 1994, 2005 to 2009 with CGI, we found that some parts of the MZG glacier lay beneath a blanket of snow in the images except 2009; hence the snow fields should be included in the determination of the glacier outline. When the snowfields melted away in 2009 (Fig. 5a), the exact glacier outline exhibited a sudden shrinkage. In Figure 5a (Uncertain area), although some glacier change was found, we could not identify whether the MZG glacier has been already separated into two parts by a steep cliff (Fig. 5b and c).

3489-23: “When the snowfields melted away in 2009 (Fig. 5a), the exact glacier outline exhibited a sudden shrinkage.” When compare the images of the 2009 with that of the 2010 and 2011, we can find a obvious shrinkage. Additionally, the emergent bedrock of new rock outcrops has been found, as Pelto M. S. (2010) described. Figure 4 shows the topography and a sketch map of longitudinal section in MZG glacier. The terminus of MZG glacier is different from other glaciers.

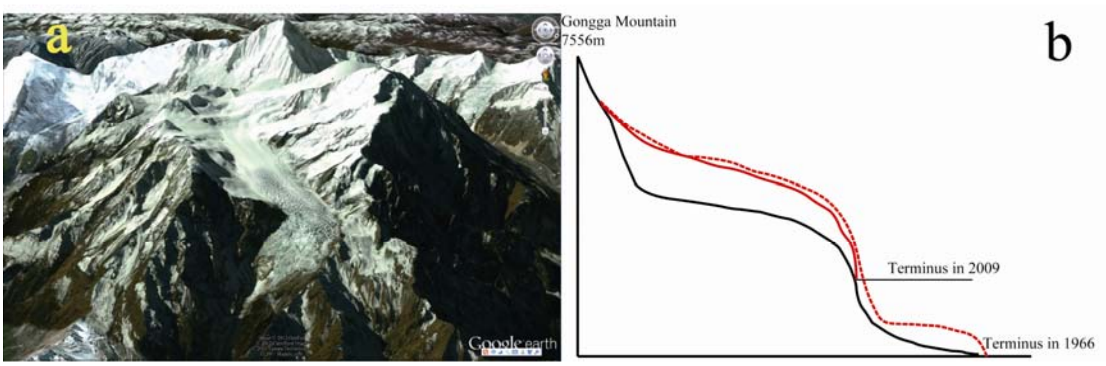

Fig 4. (a) this is a MZG glacier screenshots from Google earth.(b). this is a sketch map of longitudinal section in MZG glacier.

3490-1: “The YZG glacier was 30.1 km^2 in area and 10.5km in length, with the terminus elevation of 3680m a.s.l. The ELA is about 4840 m a.s.l. for YZG glacier and. about 0.81km^2 in the ablation area was covered by debris (Pu,1996)…….”

3489-16: For Moziguo Glacier the terminus is much higher than Hailuguo Glacier. There is a significant difference in the distinct lack of debris cover compared to the other glaciers discussed in detail, this must be addressed. The terminus is also quite steep at present as indicated by Figure 5. Both the lack of debris cover and steepness of the terminus reach will lead to a different terminus response. This is important. The change in area for the MZG notes, “When the snowfields melted away in 2009 (Fig. 5a), the exact glacier outline exhibited a sudden shrinkage” . Is this change real or just suddenly well observed. Be careful in this determination.

This comment has been replied in the response to the previous advice (3489-7).

3492-9: Should be percent of the loss for the east side and west side, not the fraction of the loss for the entire range.

I have recalculated the percent of the loss for the east side and west side based on your advice. 3492-8: “The rate of area loss on the western slope (14.6%) is a little faster than that on the eastern slope (9.8%) on the Gongga Mountains”

3493-10: Johannesson et al (1989) were examining the response time of a glacier to a step change in climate, where the response is the 2/3 adjustment of that glacier. The more immediate response time to a climate change or ongoing warming is faster. Porter (1986) is a good reference for that or Pelto and Hedlund (2001).

3493-11: “According to Porter (1986), the small temperature glaciers in low-latitude and middle-latitude are especially sensitive to climate change; therefore the dynamic response of the terminus is generally rapid with a lag time of a decade or less. ”
3493-15: “Based on the study of Pelto and Hedlund (2001), HLG,YZG, MZG and DGB glaciers are all type 1 glacier, which is distinguished by steeper slope, extensive crevassing and higher terminus region velocities. The lag time of this type glacier should be 4 to 16 yr. ”
We have cited these two papers and discussed the lag time in this revised manuscript.

3493-21: How many small glaciers vanished this is important to note, what were there characteristics? Are there any others that now lack an accumulation zone that would indicate impending loss Pelto (2010).

Pelto (2010) studied the changes of accumulation zone of glaciers. We also found the same phenomenon in Gongga Mountains like Pelto (2010) studied the changes of accumulation zone of glaciers that are characteristics of substantial accumulation zone thinning, marginal recession or emergent bedrock areas in the accumulation zone. In the Gongga Mountains, two small glaciers have vanished, which did not have consistent accumulation zones. Under the increasing of the air temperature, the accumulation zone has been thinning and in a condition of marginal recession. In this region, it is hard to survey the accumulation zone, because of the abrupt steepness of the terrain and the high frequency of the avalanche. Thus, we could not provide the accurate number about glacier that now lacks an accumulation zone.

3493-21: “and two smallest glaciers have vanished, which did not have consistent accumulation zones. According to Pelto (2010) study, the characteristics of substantial accumulation zone thinning, marginal recession or emergent bedrock areas in the accumulation zone are also found in less glaciers on Gongga Mountians.”

Table 3: Revise glacier counts so a separated glacier does not count as two.
We have responded this comment in the previous question (3488-5).

Table 4: It would be more useful for the last column to show the percent loss in area for that single size classification. Also mean terminus or mean elevation for the classes would be of great value going forward.

We have added mean terminus and mean elevation for the classes.

Interval	Number in 1966		Mean	Mean	Area (km^2)						Area change (km^2)						
area (km^2)	(n)	(%)	Terminus(m)	Elevation(m)	1966	1974	1989	1994	2005	2009	09-05	05-94	94-89	89-74	74-66	Total (km^2)	Area change (%)
<0.5	22	29.7	5090.4	5416.4	6.9	6.6	6.5	5.9	5.5	5.1	-0.4	-0.4	-0.6	-0.1	-0.3	-1.8	-6.3
0.5-1.0	16	21.7	4956.9	5455.9	11.5	11.1	9.8	9.5	8.8	8.4	-0.4	-0.7	-0.3	-1.3	-0.4	-3.3	-10.8
1.0-5.0	24	32.4	4388.6	5332.9	63.5	61.9	58.3	56.9	55.1	53.4	-1.7	-1.8	-1.4	-3.6	-1.6	-10.1	-34.8
5.0-10.0	6	8.1	4320.7	5116.7	43.6	42.5	40.8	39.8	39.0	37.4	-1.6	-0.8	-1.0	-1.7	-1.1	-6.2	-21.3
>10.0	6	8.1	3616.6	5120.9	132.2	130.3	127.4	127.0	125.1	124.3	-0.8	-1.9	-0.4	-2.9	-1.9	-7.8	-26.8
Total	74	100.00			257.7	252.4	242.8	239.1	233.5	228.6	-4.9	-5.6	-3.7	-9.6	-5.3	-29.1	-100
Area change (%)											-2.0	-2.1	-1.5	-3.7	-2.0	-11.3	-

Table 5. It would be good to not repeat the numbers in the text, rates can be used in the text instead of interval distances.

Agreed!
We will calculate the rates of glaciers changes in the text and replace the number about interval distances.
3489-7: "which can be separated into 29.4%, 34.3%, 16.4%, 9.0% and 10.9%, for….."
3490-3: "including 28.3%, 25.1%, 13.5%, 23.8% and 9.3% in the periods …"
3490-24: "about 68.4% (685.7m) in the period 1966-1989 and 31.6%(316.5m) in the period 1989-2009."

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Technical Documentation of Glacier Inventory in China (2007) is an unpubished data.