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5, C2189–C2213, 2012

Interactive Comment

Interactive comment on "Glacier changes from 1966–2009 in the Gongga Mountains, on the south-eastern margin of the Qinghai-Tibetan Plateau and their climatic forcing" *by* B. Pan et al.

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Explaining and replies to the comments and suggestions of Professor K. Fujita

This response text including the changes in the revised manuscript and our replies (Answer or Reply, A&R Black) to the referee's comments (comments and suggestions, C&S, Blue color) and references (red color). [P4L95] "Italic" is improved in the manuscript.

C&S : The manuscript "Glacier changes from 1966-2009 in the Gongga Mountains, on the south-eastern margin of the Qinghai-Tibetan Plateau and their climatic forcing" by Pan et al. presents changes in glaciers in the Gongga Mountains region where the

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Hailuogou Glacier has been investigated intensively in previous studies. This study may contribute to understand the retreat and shrinkage of glaciers in regional scale. However, discussion with respect to climatic interpretation and topographical influence is too poor. Significant re-analyses / additional analyses and rewrite are required for the publication.

A&R: Thanks to the Professor K. Fujita (Referee) for giving us such valuable suggestions to help us to refine the manuscript. According to the suggestions, all the figures have been redrawn and add a new figure; three tables (Table 4, Table 5 and Table 6) have been improved, and some sentences have been rephrased. The recommend papers have been carefully read and missed references have been added. The discussion with respect to climatic interpretation and topographical influence is improved and significant re-analyses/additional analyses have been rewritten. Details about our responses and how to revise the manuscript are provided below.

Major comments C&S: In discussion (P3491-3494), the authors attempted to interpret their results derived from remotely sensed data with climatic records and topographical features. I basically agree their assertions such as (P3492L2) "the increasing amount of precipitation could not compensate for the mass loss due to the temperature increase" but these should be evaluated quantitatively within this study. Although demonstrated sensitivities of glacier mass balance, his conclusion (25% change in precipitation is equivalent to 1 degC change in temperature) could not be simply applied to real glaciers because the annual amount of precipitation (Oerlemans and Fortuin, 1992) and seasonality of precipitation affect the mass balance sensitivity (Fujita, 2008). (Figs 8 and 9) though the authors denoted its effect on glacier retreat with respect to topographical influence in the later part. In addition, dynamic response of glacier was totally NOT discussed with the climatic data. Anyhow, changes in glacier extent (area and terminus) are basically resulted from mass balance as boundary condition via glacier dynamics. Therefore the authors have to interpret their results, temporal changes in areas and terminus of the glaciers, by discussing different sensitivities of mass balance and dynamics influenced by topography.

A&R: This is a good comment! We have rewritten the discussion (P3491-3494). The mentioned reference papers were carefully read, and we learn more knowledge about the relationships between glacier sensitivity and meteorological factors (precipitation, radiation and air temperature). In addition, we will discuss the influence of precipitation and concentration on climate sensitivity of glacier mass balance based on Oerlemans and Fortuin (1992) and Fujita(2008). The recent glacial recession in the Gongga Mountains is consistent with the warming trend recorded by meteorological stations. Climate warming, however, did not always result in glacial recession owing to increased precipitation. This phenomenon also occurred in TIRB(Tarim Interior River basin), where glacier area decreased by 3.3% from the 1960s/1970s to 1999/2001, under the warming of 0.77 $\pm$ 0.16K/40a associated with increased precipitation of 22.8 $\pm$ 7.9% (Shangguan, et al., 2009). According to Oerlemans and Fortuin (1992), there was a significant relation between the sensitivities of glacier mass balance and annual precipitation, in such way that glacier in a wetter regime are more sensitive. Calculation shows that higher sensitivities for glacier located in a summer-precipitation climate than for those within a winter-precipitation climate (Fujita, 2008). The glacier mass balance in an extensive region of Asia (e.g. glaciers in the Gongga Mountains), which is located in the highly concentrated summer-precipitation and wetter climate, is sensitive to the climate change. However, we cannot evaluate quantitatively within this study because of the lack of long-period mass balance observations. We just explain the phenomenon based on climate data. This result also can be well explained by the theory of Oerlemans and Fortuin (1992) and Fujita (2008). In addition, based on the suggestions, we discuss the dynamic response of glacier with the climatic data and temporal changes in areas and terminus of the glaciers with different sensitivities of mass balance and dynamics influenced by topography. [P11-15L351-521] The “Discussion” was rewritten!

C&S: Although the authors described general influences of topographical features on fluctuations of glaciers, the descriptions are too general to understand the results analyzed by the authors. The readers cannot follow the authors' logic without topographical information.

A&R: Good comments! We will discuss the topographical features on fluctuation of glacier in detail.

C&S: Many assertions are described without evidence or references. I frequently miss the logic. For instance; [P3492L12-14] How did the authors know that small glaciers on the western slope are more sensitive to climate change than large glaciers on the eastern slope?

A&R: Agreed! We will check the assertions with evidence or references, and cite the references. Many studies indicate that small glaciers are more sensitive to climate change than large glaciers (Dyurgerov and Meier, 2000, Gordon, et al., 2008, Liu, et al., 2003). In my study, the fact is that the glacier shrinkage on the western slope is faster than that on the eastern slope. The warming climate and stable precipitation could not explain the difference. Hence, we extrapolated the different size of glaciers may be the main influence factor. The "small glaciers on the western slope are more sensitive to climate change than large glaciers on the eastern slope" was not accurate assertion in the study. Based on the suggestion, we reevaluate the reason about the difference of glacier shrinkage with climate and topography factors. [P13L408-425]

C&S: [P3492L14] Though the authors do NOT explain why small glaciers are more sensitive to climate change than large glaciers, the authors describe "can be interpreted". A&R: Based on the research of Racoviteanu et al. (2008), the wide range in the magnitude of glacier area changes for small glaciers (<1 km2) may be partly explained by factors such as (a) differences in the maximum elevation of glaciers relative to their ELAs, (b) the elevation of the mountain on which they are located and (c) the altitudinal range of the glaciers(Racoviteanu, et al., 2008). At the same time, Racoviteanu et al. (2008) indicated that that glaciers with a smaller altitudinal range are losing more of their area and this result supports the idea that small glaciers with narrow altitudinal range are losing more of their area(Kaser, 1999, Mark and Seltzer, 2005). This may be explained by the fact that a change in local climate may raise the ELA of those glaciers above their maximum elevation, putting the whole area of the glacier in the year-round ablation zone (Kaser and Osmaston, 2002). In contrast, larger glaciers have a very wide altitudinal range, with ELAs well below the maximum elevation at the glacier head. Therefore, the reason of different retreat rates on both slopes is not climate change but the discrepancy of topographic factors. We have rewritten this part to avoid the misunderstanding. [P13L408-425]

C&S: [P3492L20] The authors just mentioned orientations of the HLG and YZG Glaciers but did NOT explain why the HLG Glacier showed faster shrinkage.

A&R: This is a good comment. In my manuscript, we did not explain why the HLG Glacier showed fast shrinkage. Now we have added contents to explain HLG Glacier shrinkage. Although the YZG and HLG Glaciers are on the eastern slope of Gongga Mountains, the HLG Glacier showed faster shrinkage than YZG Glacier. Consider topographic factor, the terminus of HLG glacier (3015 m a.s.l.) is lower than YZG glacier (3726 m a.s.l.) and they have same top altitude. According to calculation, the mean slope of HLG glacier is smaller than that of YZG glacier. Additionally, there is a large icefall zone from 4980 m to 3850 m in HLG glacier. So the mean slope of ablation area is far smaller than that of YZG glacier. We extrapolate that the smaller slope is an important effect factor on glacier shrinkage. The influence of aspect is reflected in a displacement of the period with shortwave radiation for the surface oriented against east, south and west respectively, with a higher midday solar radiation value(Bøcker, 1996). The aspect of HLG and YZG glaciers are southeast and northeast which influence the incident solar radiation. The solar radiation income of HLG glacier is more than that of YZG glacier because of different aspect. Su et al. (1996) showed the temperature gradient in HLG Valley is 0.43K/100m between 2880 and 3510m. According to temperature gradient, we may extrapolate that the temperature on the terminus of HLG glacier is 2.8K warmer than YZG glacier. The warmer temperature can also accelerate the shrinkage of HLG glacier. Li and Su (1996) calculated the ablation gradient is about 40-42cm/100m in Gongga Mountain based on the fieldwork. The ablation gradient also explains why the HLG Glacier showed faster shrinkage. According to Debeer and Sharp (2009) study, sites with a northern and eastern orientation are well suited for sheltering small glaciers(Debeer and Sharp, 2009). Although HLG and YZG glaciers are not small glaciers, the different aspect is also an element of local topographic setting that might affect the local shrinkage of glaciers.[P13L425-432]

C&S: [P3493L16] How did the authors guarantee "shorter time lag" of the targeted glaciers? Though the authors mentioned that the lower parts of large glaciers were covered by debris-mantle, little discussion was made for the effect of debris-cover on the different retreats of glaciers. For instant, difference of debris thickness distribution may also affect the different shrinkage rates between the HLG and YZG Glaciers.

A&R: This question is similar to Prof M. S. Pelto's one short comment (3493-10). 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(Pelto, M.S. and Hedlund, 2001). We just extrapolate "shorter time lag" of the targeted glaciers based on others studies (Jóhannesson, et al., 1989, Pelto, M.S. and Hedlund, 2001, Porter, 1986), and could not calculate the specific lag time. Debris-covered glaciers are ubiquitous in alpine environments such as the Himalaya, the Peruvian Andes and the Southern Alps of New Zealand(Benn, D.I., et al., 2004). Empirical relationships between debris thickness and ice-melt rates were first established by Øtrem(strem, 1959), who showed that under thin debris (<2 cm), ablation rates are higher than for clean ice, and that under thicker debris ablation rates progressively decline(Nicholson and Benn, 2006). However, the amount by which debris alters ablation rate compared to that of clean ice, and the threshold debris thickness determining whether melt rate is accelerated or inhibited, varies under the influence of local climate and debris lithology (Nakawo and Rana, 1999, Nicholson and Benn, 2006). The glacier surface of Gongga

Mountains was covered by a large amount of debris, which may inhibit or accelerate glacier ablation. According to Li and Su (1996) study, the ablation of Gongga Mountains become weaker with the increased thickness of the debris, and no ablation occurs when the thickness of the debris is over 2m (Li, 1996). Difference of debris thickness distribution may also affect the different shrinkage rates. 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. However the HLG and YZG Glaciers are all covered by different thickness of debris-mantle, we could not guarantee which glacier is faster shrinkage affected by different thickness debris-mantle between the HLG and YZG Glaciers because of the lack of thickness debris-mantle study data. [P12L387-395]

C&S: [P3492L19-20].Different retreats associated with slope and size have to be re-analyzed by categorizing debris-covered or debris-free glaciers. Zhang et al. (2011) provide some suggestions to this issue.

A&R: Good suggestion! We have re-analyzed the different retreats associated with slope and size and redraw a new figure. When we submitted the manuscript, we have not found the literature of Zhang et al. (2011). Now we read this paper and get some suggestions about debris-covered glaciers retreat. In Gongga Mountains, most of large glaciers were covered by debris. Zhang et al. (2011) just calculated the distribution of debris on HLG glacier (Zhang, et al., 2011), but the debris distribution of most glaciers is unknown, especially to the small glaciers. Although the “different retreats associated with slope and size have to be re-analyzed by categorizing debris-covered or debris-free glaciers” is a good suggestion, we cannot well discuss the different retreats by categorizing debris-covered or debris-free glaciers with the lack of enough observation data. The different retreats associated with slope and size will be re-analyzed in my manuscript. [P13L433-441]

C&S: [P3482L27] The authors emphasize that previous studies in this region have dealt a single "Hailuogou" glacier and few systematic/comprehensive study has been made so far. I don't think this study show any systematic/comprehensive advances of knowledge for the glacier behavior in this region as I pointed out above.

A&R: Agreed! Most of previous studies in this region focus on a single "Hailuogou" glacier not all the glaciers in the Gongga Mountains. We want to express that this study will present a new result about area of all glaciers and length change of large glaciers in Gongga Mountains using remote sensing in regional scale. More knowledge for the glacier behavior needs to be done in the further works. We will rewrite this sentence. [P4L91] "However, most of these researches focused on a single glacier in the Gongga Mountains, and there was little study about the changes of length and area of all glaciers in Gongga Mountains, especially using the remote sensing images." C&S: English editing by native speakers or commercial services is appreciated to understanding the manuscript. I found lots of incomplete sentences though I don't point out one by one.

A&R: Agreed! The language of manuscript will be improved by English editing by native speakers or commercial services. The language of manuscript has been improved by Ms. Emily Derbyshire.

Minor comments [P3480L11-15] Are specific values necessary?

A&R: We think the specific values are necessary. Those specific values can make reader clearly to understand the changes about Gongga Mountains. Based on referee suggest, we have rephrased this content. [P2L36-40]

[P3480L19] How do these warming trends affect the glacier retreats?

A&R: According to Oerlemans and Fortuin (1992), the changes in the mean specific mass balance for a 1K warming, uniform through the year, varied from-0.12 to-1.15m/yr. the mass loss due to a uniform 1K warming need a 10-25% increase in annual precipitation to compensate (Braithwaite and Zhang, 2000, Oerlemans, Johannes, 2001, Oerlemans, J. and Fortuin, 1992).

[P2L45] "The increasing amount of precipitation could not compensate for the glacier mass loss due to the temperature increase in the Gongga Mountains."

[P3481L9] It should be clarified what is "The response".

A&R: This is the original of Oerlemans (Oerlemans, J., 2005). "The response" can be understood "a reaction of glacier (e.g. area, length, mass balance) to climate that has happened ". [P3L55] "The area and length retreat"

[P3481L13] Ohmura (2001) is a good reference here. A&R: Agreed! We have read the paper of Ohmura (2001) and cited this reference. [P3L58] "(Ohmura, 2001)"

[P3481L16-17] Many of these references are remote sensing studies in the Euro-American continents though the authors mentioned "by fieldwork investigation(s)". References dealing fieldworks in Asian glaciers are more appropriate here. A&R: Agreed! References dealing fieldworks in Asian glaciers are cited (e.g. (Aizen, et al., 2006, Bishop, et al., 1998, Kääb, 2005, Liu, et al., 2006). [P3L61] "(Aizen et al., 2006; Kääb, 2005; Liu et al., 2006)"

[P3481L22] References written in Chinese are not appropriate if alternatives are available. With respect to high sensitivity of "humid" glaciers was firstly shown by Oerlemans and Fortuin (1994). In terms of summer monsoon glaciers, Fujita and Ageta (2000) and Fujita (2008) have shown their high sensitivity. On the other hand, references such as Cui (1958) [P3482L8] are reasonable to be cited because of its own originality even if they are written in Chinese.

A&R: Agreed! We have read the paper about high sensitivity of "humid" glaciers (Fujita, 2008, Fujita and Ageta, 2000, Oerlemans, J. and Fortuin, 1992). We also learn more knowledge about high sensitivity of "humid" glaciers. We will cite these references in my manuscript. [P3L65] "(Oerlemans and Fortuin, 1992; Fujita and Ageta, 2000 and

Fujita, 2008)"

[P3482L4] Haeberli et al. (2000) has to be replaced by Kargel et al. (2005) as a reference for the GLIMS project. A&R: Agreed! Kargel et al. (2005) is a good paper to introduce the GLIMS project. [P3L72] "(Kargel et al., 2005)"

[P3482L14] Aizen et al. (199x) is missed from the references of investigations in the 1990s. A&R: Agreed! We cite this reference of investigations in the 1990s [P3L80] "(Aizen, et al., 1994)."

[P3482L17] I don't understand "steady-state ELA". What is this? How is this derived or estimated? The authors also mention "the mean climatic ELA" later [P3487L5-7]. The definitions and methods to derive the ELAs have to be explained.

A&R: The equilibrium line is the boundary between the two zones, where accumulation equals ablation for the year; its altitude defines the equilibrium line altitude, or ELA(Cuffey and Paterson, 2010). The ELA value associated with zero annual mass balance for the whole glacier is known as the steady-state ELA (Benn, D. I. and Lehmkuhl, 2000). When the annual ELA coincides with the steady-state ELA, ice mass and geometry are in equilibrium with climate, and the glacier neither grows nor shrinks. The steady-state ELA is thus a theoretical construct which may never actually occur in nature (Benn, D. I. and Lehmkuhl, 2000). "The climatic ELA" can be understood the "Climatic" snowline. The "Climatic" snowline was defined that a multi-year average of ELA in a plane and bare surface (Shi, 1988). [P3L82] "Using the equilibrium line altitude (ELA0) (ELA0 is defined that the ELA when the mean specific balance is zero) method and the observed melting data. . .. . ."

[P3482L26] "mainly influenced by climatic fluctuation": This is too unclear. More specific descriptions are necessary.

A&R: Agreed! According to Li et al. (2010) study, HLG glacier retreated considerably in the middle Holocene because of the warm climate, and weathering and erosion in the

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monsoon climate conditions contributed to the lack of a preserved terminal moraine; during the Neoglacial, the HLG glacier advanced three times, and there were also three advances in response to three cold periods during the Little Ice Age. There is an evident relationship between glacier change, forest line change and climate change in the Hailuogou basin during the period 3000 a BP–100 a BP.(Li, et al., 2010).

[P4L89] "...the HLG glacier retreated considerably in the middle Holocene because of the warm climate, and during the Neoglacial, the HLG glacier advanced three times, and there also were three advances during the Little Ice Age, in response to three cold periods."

[P3484L11] Potential errors of the first Chinese glacier inventory have to be evaluated. D'Agata and Zanutta (2007) will be helpful.

A&R: Agreed! We have read D'Agata and Zanutta (2007). This paper is a quantitative analysis in the volume and thickness of the Brenva Glacier based on the comparison of digital elevation models derived from historical records (D'Agata and Zanutta , 2007). We can learn some knowledge about methods of discussion from D'Agata and Zanutta (2007). The accuracy analysis of first Chinese glacier inventory is an important work. Based on the data sources and technology, many potential errors were existed in the first Chinese glacier inventory. For instance, some glacier was missed on glacier mapping; the glacier outlines was a visible mistake. So the potential modification by aerial photographs and field investigation were necessary. According to the caption of Pu (1994), the error of the first Chinese glacier inventory retains in the range of $\pm 0.5\% \sim 1\%$ (Pu, 1994; Shi et al. 2008). We also check the result of first Chinese glacier inventory by the topographic map in 1966 and remote sensing image in 1970s. However, we cannot evaluate the precision because we cannot get the aerial photographs in 1966. We will add the accuracy evaluated by Pu (1966) and Shi et al. (2008). [P5L130] "The error of the first CGI retains in the range of $\pm 0.5\% \sim 1\%$ (Pu, 1994; Shi et al. 2008)."

[P3484L25] The CGI and DEM should have another coordinate system. The authors have to describe how they convert the coordinate system to the UTM WGS84 and the potential errors associated with the conversion. Zhang et al. (2010) and references therein (Guo et al., 2002).

A&R: Agreed! We will add the contents about converting the coordinate system and potential errors based on Zhang et al. (2010) and Guo et al., (2002). [P5L143] "The DEM and results of CGI were different spatially reference to the remote sensing images and they were re-projected onto the Universal Transverse Mercator coordinate system (UTM zone 47N, WGS84) by using a seven-parameter datum transformation model (Guo et al., 2002; Wang et al., 2003). The detail process was described by Zhang et al. (2010). The error using a seven-parameter datum transformation model is <0.002m (Wang et al., 2003)." [P3484L26] Errors from resampling have to be evaluated. A&R: Agreed! We evaluate the errors from reseampling less than 1.2 pixels (18m). [P3484] No description is found for co-registration of different images. Tie-points for the co-registration have to be depicted in figure. A&R: This is a good suggestion! We have drawn a new figure about co-registration of different images (Fig. 1).

Although the co-registration of different images is important, we think that it is unsuitable for my work. Firstly, their were too more figures in my manuscript; secondly, it is a larger figure which will occupy too much space of the manuscript but show a little information about image process; lastly, this is not an important content which we want to express. Thus, we will show this figure here but do not add it in the manuscript. Many thanks for your understand!

[P3484L27] How many "verification points" the authors have? The points have to be depicted in figure. A&R: Agreed! Twenty independent verification points were selected from each image in order to check the accuracy of co-registration. Some GCPs were most selected as verification points and others were visible markers.

[P3485L10] How did the authors confirm "more accurate"? A&R: We verified the results from TM4/TM5 by visual interpretation. We found the results from TM4/TM5 were more accurate and effective than that from TM3/TM5, at the same time, the mistakes from TM4/TM5 were also less than that from TM3/TM5. Hence, we choose the TM4/TM5 method to extract glacier outlines. [P6L159] “For the Landsat TM, the band ratio of TM3/TM5 or TM4/TM5 was selected for glacier mapping mainly based on glacier ice with very low reflectance in the middle infrared (Paul, 2000; Zhang et al., 2001; Pau and Andreassen, 2009). In contrast, however, for the 74 glaciers studied in Gongga Mountains, the TM4/TM5>2.4(Table 2) was more effective than TM3/TM5 in this region,”

[P3486L1] Methods and thresholds to determine "debris-covered area" have to be described in detail.

A&R: The image ratio and supervised classification is the most common method to extract glacier borders (Paul and others, 2002; Paul and others, 2004). However, due to the limitations of the method employed (Paul and others, 2002), misidentification is frequent, for instance, on seasonal snow patches adjacent to glaciers or on debris-covered surfaces which are difficult to distinguish from bedrock owing to their similar spectral properties. In these cases, visual interpretation was applied, combined with multispectral satellite images and the 1989 DEM (Paul and others, 2004). In this study, the outlines of debris-covered glacier were not mapped by ratio methods and thresholds. The outlines of debris-covered glacier were digitized by visual interpretation. [P6L175] “The image ratio and supervised classification is the most common method to extract glacier borders (Paul and others, 2002; Paul and others, 2004). However, due to the limitations of the method employed (Paul and others, 2002), many debris-covered glaciers in the Gongga Mountains are difficult to extract the glacier outlines. In these cases, visual interpretation was applied to correct the mapping results to correct the mapping result, combined with multispectral satellite images and the 1989 DEM (Paul and others, 2004).”

[P3486L17] Ground survey is helpful to verify the ASTER images. But how do the

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authors verify the accuracies of the other images? Need more explanation in detail. A&R: We have added accuracy analysis in the revised manuscript. The accuracies of images can be evaluated by theoretical analysis or by experimental investigation (D'agata and Zanutta, 2007, Florinsky, 1998, Hall, et al., 2003, Ye, et al., 2006). Verified the ASTER image by ground survey is experimental investigation. Verified the other images are evaluated by theoretical analysis. [P6-7L181-205] "……"

[P3486L19] What does it mean "dual"? Dual frequency? A&R: Agreed! Dual frequency differential NavCom's SF-2040G integrated StarFire™ receiver provides worldwide decimeter level accuracy anywhere, anytime (Navcom Technology, 2003). [P7L188] "dual frequency differential NavCom's GPS"

[P3486L19] What does it mean "single-level"? If it means "single receiver measurement", it is unbelievable. A&R: According to NavCom's SF-2040G products user guide, coupled with the StarFire subscription service, the SF-2040G delivers 10 cm position fixes without the use of a second receiver serving as a base station(Navcom Technology, 2003). Although the GPS data were surveyed by single receiver measurement (NavCom's SF-2040G), based on this GPS product feature, we have pays a StarFire subscription service for two months. We think the results of GPS data are reliable.

[P3486L20] Depict the 100 survey points. Figure 1 contains only 11 points. A&R: We have redrawn this figure and added survey points on figure 2. Figure 1 just shows a sketch about GPS data, Figure 2 depicts the 100 survey points. [P3486L27/Fig. 2b] I don't understand what "distribution of number of glacier" means though I understand histogram for glacier number in Fig. 2a. Did the author count one glacier as "one" at a certain altitude band if the median altitude (how to get this?) of the glacier is within the altitude band? If my understanding is correct, what does this index mean?

A&R: We have redrawn this figure as new figure 3. The median altitude of glacier is the elevation of contour line which divides the glacier area into two equal portions (Liu and Xie, 1995). The median altitude of glacier is determined by glacier type and supply nourishment ways. It can be index the water-heat condition of glacier developing (Liu and Xie, 1995). The median altitude can be calculated by DEM data.

[P3487L3] Is this one glacier reaching higher than 6000 m the same glacier reaching lower than 4000 m? Glacier name(s) and location(s) in figure are appreciated. A&R: According to calculation of the median altitude, there is one glacier reaching higher than 6000 m, and only one glacier reach lower than 4000 m. They were not the same glacier and no names. We will not mark them on the figure1.

[P3487L5-7] How did the authors obtain "the mean climatic ELA"? The definition and method to derive the ELA have to be explained in detail. A&R: We have explained in detail on previous questions. In my manuscript, the ELA is not calculated but cited from Su et al. (1992) or Pu (1994). Hence, we have deleted this sentence from "[P7L227]" and rewritten on the "[P4L109]"

[P3487L5-7] What is "sector"? How did the authors define it? A&R: This is a mistake. We have rewritten this sentence. This should be "aspect of glacier". [P7L219] [P3488L2] Definition of slope orientation and showing in figure is appreciated. Is this shown in Figure 1 by black line along the main ridge? A&R: In my manuscript, the eastern slope and western slope is shown in figure 1 distinguished by a black line along the main ridge. From figure 1b, we can find that the ridge line is approximately south-north direction, and the glaciers are located on two sides. So we define the sides as eastern and western slopes.

[P3488L7] Figure 2 did not show any trends. And I don't understand what is remarkable with Table 3 and Figure 4. A&R: Agreed! We have improved this result and deleted this sentence.

[P3488L17] Figure 2a did not show shrinkage of glaciers in size class. A&R: Agreed! We have improved this result.

[P3488L17-18] What does "all glaciers" mean? A&R: We want to express the glaciers in northwestern are all located on the western slope. [P8L267]

[P3488L20-21] Discussion in terms of slope seems important. More detailed descriptions are appreciated. How the mean slopes are calculated? Figure is helpful to understand the relation between slope and shrinkage. A&R: Agreed! We have added a new figure about relation between slope and shrinkage (Fig. 5). The mean slope is a mean angle of glacier surface and horizontal plane calculated by DEM based on the Technical Documentation of Glacier Inventory in China (2007).We will add more detailed descriptions about relation between slope and shrinkage. [P8L223] "The mean slope is a mean angle of glacier surface and horizontal plane calculated by DEM." [P8L251-255] ". . .. . ."

[P3489L17] How did the authors get the accumulation area ratio? This part is related to how the authors derived the climatic ELAs. A&R: The calculation of AAR and ELA was not included in this work. We miss the reference here. We can get AAR and ELA from Pu (1994) or Li (1996).

[P3489L21] Why did the authors use "might" here while the glacier boundaries had been delineated by the authors themselves? These kinds of "quality check" had to be done in advance. How did the authors guarantee that the other glaciers were delineated precisely? A&R:ãĂĂWe have checked all the glacier outlines again and improved this discussion. All the glaciers boundaries had been delineated by us with the same standard. We could not guarantee the glaciers outlines had no error because of the perpetual snow. Like MZG glacier, some snowfields lay in the middle of glacier and we cannot figure out the snowfields is not a part of glacier. When the snowfields melted away, we can find this is not a part of glacier but a rock. According to Pelto M. S. (2010), the survival assessment based on accumulation zone thinning as evident by the emergence of new rock outcrops or the recession of the margin of the glacier in the accumulation zone along a substantial portion of its perimeter is applied to thirteen North Cascade glaciers(Pelto, M. S., 2010). We can recognize that the emergent bedrock of new rock outcrops is a new evidence of glacier thinning. This is not a question about quality of glacier mapping. This should be a phenomenon of glacier shrinkage. In summary, we can guarantee that the delineated precisely of glaciers is credible. [P9L275-289] “MZG glacier” was rewritten.

[P3490L24] It is difficult to follow changes in retreat rate from the retreat distances in different periods. Retreat rate is better expression here (other glaciers too). A&R: Agreed! We will recalculate the retreat rate and rewrite this sentence. [P3491L2-3] Need references for thick debris layer of the DGB Glacier. A&R: We have added a background paragraph of HLG, YZG and MZG glacier based on Pelto’s suggestions. The background includes the terminus elevation, ELA, extent of debris -covered. We will add the information about thick debris layer of glacier based on field investigation. [P10L312] “. . .. . .because the ablation zone was covered by a thick of 6-160cm debris layer (Li, 1996).”

[P3493L1] I don’t understand "a significant negative correlation". Is this really "statistically significant" with five samples? A&R: We want to say that if the mean precipitation is high, the retreat rate of glacier will be slow; in contrast, if the precipitation is low, the rate of glacier retreat is fast. This is not really "statistically significant" with five samples. We will rewrite this sentence.

[P13L380-383] “Compared the mean temperature to mean retreat rate of glaciers, the mean temperature is not related in a clear way to the retreat rate of glaciers, however, the mean precipitation show a well corresponding relation with the retreat rate of glaciers (Fig. 8). When the mean precipitation is high, the retreat rate of glacier is slow, and vice versa (Fig. 8)”

[P3495L8-9] The authors did not evaluate the warming as the main cause of glacier retreat throughout the manuscript. They just showed retreat and temperature in parallel. A&R: We will reevaluate the warming as the main cause of glacier retreat in discussion. In my manuscript, we deduce a main conclusion that the warming climate is a trigger of glacier retreat, and the rates of glacier retreat depend on the local precipitation.

[P12L361] “Therefore, the glacier area shrinkage of 11.3% in the Gongga Mountains is attributed to the warming temperature.”

[Tables 4 and 6] Left part (area change) for "each period" is unnecessary because of no discussion in the main text. A&R: This is a part result of our study. Based on suggestion, the area changes for each period were deleted.

[Table 5] Retreat "rates" is more , isn’t it? A&R: Agreed! We have improved this table. [Figure 1] Black and white map of (a) is appreciated. Figure 1b should be enlarged. Black and white back image of (b) is appreciated. It is difficult to see the boundary of east/west slopes, large glaciers and met-stations. Define east/west slopes in the main text. Only 11 GPS points are depicted in (c) while the authors mentioned they performed 100 measurements. Show all points. I see debris-covered surface outside of red boundary in (c). Is this real boundary?

A&R: We have redrawn this figure, and deleted the figure 1(c). We also try to make a black and white map, but the result is not perfect as expected. Figure 1b has been enlarged. All the measurements of GPS points are depicted in figure 3. The debris-covered surface outside of red boundary in (c) is not the real boundary. We have corrected the final boundary based on the measurements of GPS points.

[Figure 2] Vertical axis caption should be "Fraction of total number "and" area (%)" instead of "of". I cannot understand meaning of number distribution with altitude in (b). Altitudinal bin should be finer than 200 m. In addition, more analysis of this area altitude profile will be fruitful, for instance, features of profile in terms of glacier size or orientation. A&R: We have redrawn the Figure 2. In the figure 2 (b), we want to discuss the characteristic of number distribution with altitude. This is also good suggestion. When the altitudinal bin is finer as 100 m, we found that only one glacier or no glacier is in some altitude. The altitudinal bin will be not finer than 200m. Moreover, we will add more analysis of this area altitude profile based on reference suggestion.[P12L396]

[Figure 3] I cannot understand this figure. For instance no northeastward glacier is

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Interactive Discussion

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in this figure, whereas the MZG (No. 2 in Figure 1b) Glacier seems northeastward oriented glacier. How did the authors define the orientation of glaciers? In addition, it is probably meaningful to discuss climatic causes of the orientation biases. A&R: We have redrawn this figure based on suggestion. We have corrected this mistake. The aspect of glacier was calculated from the arc tangent of the respective sine and cosine grids following Paul (2007). According to aspect calculation, the MZG (No. 2 in Figure 1b) Glacier is not northeastward but southeastward glacier. We agree that it is meaningful to discuss climatic causes of the aspect biases. [P12-13L408]

[Figure 4] Figure alphabets do not match those of the caption and text. Shading maps are difficult to see. I think the oldest (1966) and the latest (2009) are good enough. For terminus lines, colored lines are appreciated. Anyhow, year notations are required. A&R: Agreed! We have redrawn this figure based on suggestion

[Figure 5] Three rock walls in the left-bank upstream from the uncertain area discussed here are shaded in Figure 4b. I don't think that these parts have been covered by glacier even in the 1990s or earlier. Quality control/check should be carefully made. In addition, I could not follow the logic in the text which part the authors discussed, uncertain area or box b? A&R: This is good comment. According to Pelto' short comment (3489-23), we have improved this figure and relevant paragraph. Rechecked all the remote sensing images, the rock in uncertain area were covered by permanent snowfield, not glacier. It is hard to check the glacier mapping because the rock covered by permanent snowfield is close to the accumulation area. In my manuscript, we want to discuss the "uncertain area" whether the MZG glacier has been separated into two parts. Box b and c illustrate the terminus of MZG glacier is quite steep and narrow.

[Figure 6] I could not follow the descriptions in the text on the figure, where and when the tributary glaciers have detached from the main glacier. Glacier in red circle seems to contact the main glacier in the satellite images in 2005 and 2009. Glacier in yellow circle seems to contact the main glacier in the 2005 image.[Figures 7-9] Few discussion is made for these climatic data. Anyhow, "Year" should be depicted in the horizontal axis. A&R: The figure 6 was deleted based to another anonymity reference suggestion. We added more discussion about climate data on manuscript. "Year" is depicted in the horizontal axis of Figure7-9.

Misc [P3482L4] Two Paul et al. (2004) are found in the reference list. A&R: We miss a reference in my manuscript, and add Paul et al. (2004b) on P3485. [P3482L22] Probably Zhang et al. (2010)? A&R: Yes. [P3484L16/Table 1] Show years for "two ASTER". A&R: Two ASTERs were in 2009. [P3488L24] Locations of large glaciers are difficult to see in Fig. 1. A&R: We have redrawn Fig. 1. [P3480L1] All abbreviated names should be spelled out in the subtitles. A&R: This is a good suggestion. We spell out the abbreviated names in the abstract. [P3489L10/15L/P3490L5/L21] Figure notations are incorrect. A&R: Agreed! We have corrected these figure notations. [P3494L1] "pre" is replaced by "per". A&R: Yes.

References Aizen, V. B., Kuzmichenok, V. A., Surazakov, A. B. and Aizen, E. M.: Glacier changes in the central and northern Tien Shan during the last 140 years based on surface and remote-sensing data, Annals of Glaciology, 43, 202-213, 2006. Bøcker, C. A.: Using GIS for Glacier Volume Calculations and Topographic Influence of the Radiation Balance. An Example from Disko, West Greenland, Danish Journal of Geography, 96, 8-20, 1996. Benn, D. I. and Lehmkuhl, F.: Mass balance and equilibrium-line altitudes of glaciers in high-mountain environments, Quaternary International, 65–66(0), 15-29, 2000. Bishop, M. P., Shroder, J. F., Hickman, B. L. and Copland, L.: Scale-dependent analysis of satellite imagery for characterization of glacier surfaces in the Karakoram Himalaya, Geomorphology, 21(3-4), 217-232, 1998. Braithwaite, R. J. and Zhang, Y.: Sensitivity of mass balance of five Swisss glaciers to temperature changes assessed by tuning a degree-day model, Journal of Glaciology, 46(152), 7-14, 2000. D'Agata, C. and Zanutta, A.: Reconstruction of the recent changes of a debris-covered glacier (Brenva Glacier, Mont Blanc Massif, Italy) using indirect sources: Methods, results and validation, Global and Planetary Change, 56(1-2), 57-68, 2007. DeBeer, C. M. and Sharp, M. J.: Topographic influences on recent changes of very small glaciers in the Monashee Mountains, British Columbia, Canada, Journal of Glaciology, 55(192), 691-700, 2009. Dyurgerov, M. B. and Meier, M. F.: Twentieth century climate change: Evidence from small glaciers, Proceedings of the National Academy of Sciences, 97(4), 1406-1411, 2000. Florinsky, I. V.: Accuracy of local topographic variables derived from digital elevation models, International Journal of Geographical Information Science, 12(1), 47-62, 1998. Fujita, K.: Effect of precipitation seasonality on climatic sensitivity of glacier mass balance, Earth and Planetary Science Letters, 276(1-2), 14-19, 2008. Fujita, K. and Ageta, Y.: Effect of summer accumulation on glacier mass balance on the Tibetan Plateau revealed by mass-balance model, Journal of Glaciology, 46(153), 244-252, 2000. Gordon, J. E., Haynes, V. M. and Hubbard, A.: Recent glacier changes and climate trends on South Georgia, Global and Planetary Change, 60(1-2), 72-84, 2008. Hall, D. K., Bayr, K. J., Schöner, W., Bindschadler, R. A. and Chien, J. Y. L.: Consideration of the errors inherent in mapping historical glacier positions in Austria from the ground and space (1893–2001), Remote Sensing of Environment, 86(4), 566-577, 2003. Jóhannesson, T., Raymond, C. and Waddington, E.: Time-scale for adjustment of glaciers to changes in mass banalce Journal of Glaciology, 35(121), 355-369, 1989. Kääb, A.: Combination of SRTM3 and repeat ASTER data for deriving alpine glacier flow velocities in the Bhutan Himalaya, Remote Sensing of Environment, 94(4), 463-474, 2005. Kaser, G.: A review of the modern fluctuations of tropical glaciers, Global and Planetary Change, 22, 93-104, 1999. Li, Z., et al.: Changes of the Hailuogou glacier, Mt. Gongga, China, against the background of climate change during the Holocene, Quaternary International, 218(1-2), 166-175, 2010. Liu, S., et al.: Glacier changes during the past century in the Gangrigabu mountains, southeast Qinghai–Xizang (Tibetan) Plateau, China, Annals of Glaciology, 43, 187-193, 2006. Liu, S., Wenxin, S., Yongping, S. and Gang, L.: Glacier changes since the Little Ice Age maximum in the western Qilian Shan, northwest China, and consequences of glacier runoff for water supply, Journal of Glaciology, 49(164), 117-124, 2003. Mark, B. G. and Seltzer, G. O.: Evaluation of recent glacier recession in the Cordillera Blanca, Peru (AD 1962–1999): spatial distribution of mass loss and climatic forcing, Quaternary Science Reviews, 24(20-21), 2265-2280, 2005. Nakawo, M. and Rana, B.: Estimate of Ablation Rate of Glacier Ice under a Supraglacial Debris Layer, Geografiska Annaler: Series A, Physical Geography, 81(4), 695-701, 1999. Nicholson, L. and Benn, D. I.: Calculating ice melt beneath a debris layer using meteorological data, Journal of Glaciology, 52(178), 463-470, 2006. Oerlemans, J.: Extracting a climate signal from 169 glacier records, Science, 308(5722), 675-677, 2005. Oerlemans, J. and Fortuin, J. P. F.: Sensitivity of Glaciers and Small Ice Caps to Greenhouse Warming, Science, 258(5079), 115-117, 1992. Ohmura, A.: Physical basis for the temperature-based melt-index method, 40, American Meteorological Society, Boston, MA, ETATS-UNIS2001. Østrem, G.: Ice melting under a thin layer of moraine, and the existence of ice cores in moraine ridges, Geogr. Ann.„ 41(4), 228-230, 1959. Pelto, M. S.: Forecasting temperate alpine glacier survival from accumulation zone observations, The Cryosphere, 4, 67-75, 2010. Pelto, M. S. and Hedlund, C.: Terminus behavior and response time of North Cascade glaciers, Washington, U.S.A, Journal of Glaciology, 47(158), 497-506, 2001. Porter, S. C.: Pattern and forcing of Northern Hemisphere glacier variations during the last millennium, Quaternary Research, 26(1), 27-48, 1986. Racoviteanu, A. E., Arnaud, Y., Williams, M. W. and Ordoeñz, J.: Decadal changes in glacier parameters in the Cordillera Blanca, Peru, derived from remote sensing, Journal of Glaciology, 54, 499-511, 2008. Shangguan, D., Liu, S., Ding, Y., Ding, L., Xu, J. and Jing, L.: Glacier changes during the last forty years in the Tarim Interior River basin, northwest China, Progress in Natural Science, 19(6), 727-732, 2009. Ye, Q., Kang, S., Chen, F. and Wang, J.: Monitoring glacier variations on Geladandong mountain, central Tibetan Plateau, from 1969 to 2002 using remote-sensing and GIS technologies, Journal of Glaciology, 52(179), 537-545, 2006. Zhang, Y., Fujita, K., Liu, S., Liu, Q. and Nuimura, T.: Distribution of debris thickness and its effect on ice melt at Hailuogou glacier, southeastern Tibetan Plateau, using in situ surveys and ASTER imagery, Journal of Glaciology, 57(206), 1147-1156, 2011. Xie, Z., Su, Z., Shen, Y. and Feng, Q.: Mass banlance and water exchange of Hailhuogou Glacier in Mount Gongga and their influence on glacier melt runoff, J. Glaciol.

Geocryol., 23(1), 7-16, 2001. Kaser, G. and Osmaston, H. (Eds.): Tropical Glaciers, Cambridge University Press, Cambridge, 207 pp 2002. Su, Z., Song, G., and Cao, Z. : Maritime characteristics of Hailuogou Glacier in the Gongga Mountains, J. Glaciol. Geocryol., 18, 51–59,1996 (In Chinese, with English abstr.). Technical Documentation of Glacier Inventory in China (2007) is an unpubished data. Li, J.: Glacier in Hengduan Mountains, Science Press, Beijing, 282 pp., 1996 (In Chinese). Aizen, V.B., Nikitin, S.A. and Song, G.: Model of the dynamics of the Hailuogou glacier (southeastern Xizang). In Xie, Z. and Kotlyakov, V.M. eds. Glaciers and environment in the Qinghai-Xizang (Tibet) Plateau (I) - the Gongga Mountain: reports on the Sino-Russian Joint Glaciological Expedition. Beijing and New York, Science Press, 121-132, 1994. Shi, Y. (Eds.): An introduction to the glaciers in China contents, Science Press, Beijing, 16-17, 1988. Wang, J., Wang, J. and Lu, C.: Problem of coordinate transformation between WGS-84 and BEIJING 54, J. Geod. Geodyn., 23(3), 70–73, 2003 (In Chinese, with English abstr.). Xie, Z., Su, Z., Shen Y., and Feng, Q.: Mass balance and water exchange of Hailuoguo glacier in Mountains Gongga and their influence on glacial melt runoff, J. Glaciol. Geocryol., 23(1), 7–15, 2001 (In Chinese, with English abstr.). Kargel, J. S., et al.: Multispectral imaging contributions to global land ice measurements from space, Remote Sensing of Environment, 99(1-2), 187-219, 2005. Pu, J. (Ed.): Glacier inventory of China VIII. The Changjiang (Yangtze) River drainage basin, Gansu Culture Publishing house, Academia Sinica. Lanzhou Institute of Glaciology and Geocryology, Lanzhou, 142pp., 1994 (In Chinese.). Shi, Y. (Eds.): Concise Glacier Inventory of Chinese, Shanghai Popolar Science Press, Shanghai, 205pp, 2008. Zhang, Y., Koji Fujita, Shiyin Liu, Qiao Liu and Wang, X.: Multi-decadal ice-velocity and elevation changes of a monsoonal maritime glacier: Hailuogou glacier, China, journal of Glaciology, 56(195), 65-74, 2010. Guo, C., Bo, M., Ji, Z. and Mao, L.: The transfer model between the Xi'an 80 and WGS-84 coordinate systems, Northeast Surv. Map., 25(4), 34–36, 2002 (In Chinese with English abstr.). Liu, Z. and Xie, Z.: Plotting of trend of firn line and median altitudes of glacier in the interior water systems of the Tibetan Plateau and their main features,

Interactive comment on The Cryosphere Discuss., 5, 3479, 2011.

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5, C2189–C2213, 2012

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Interactive Comment

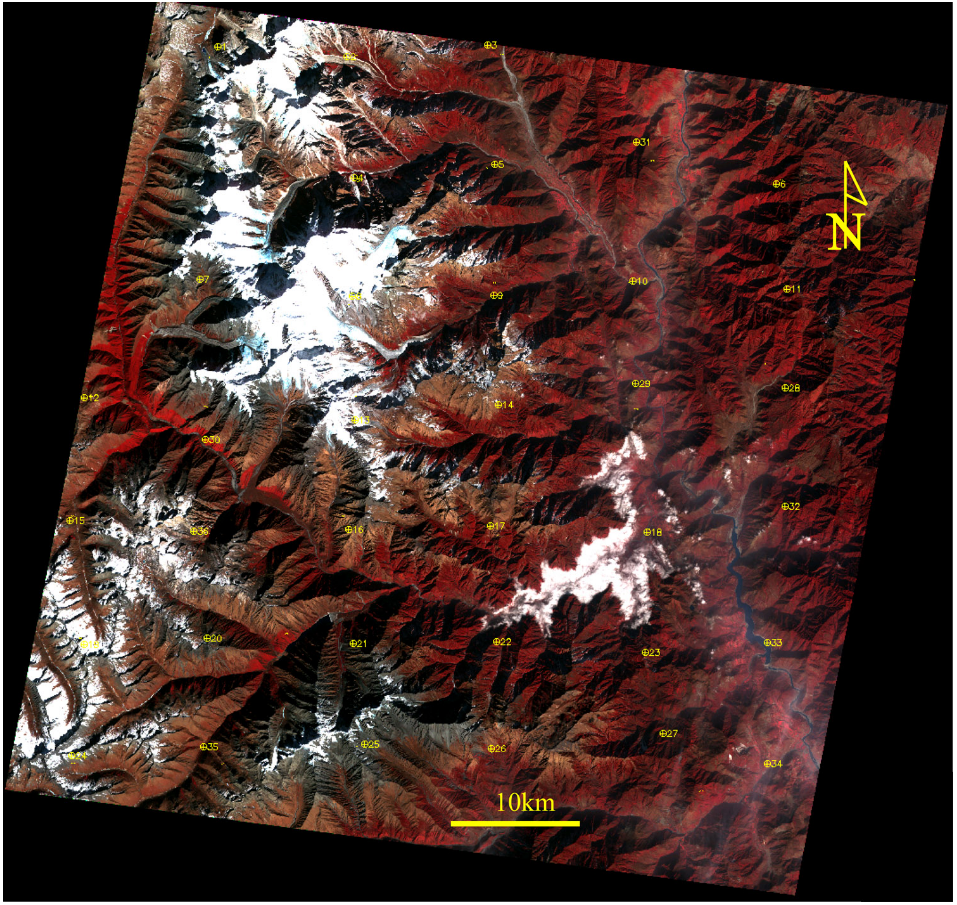

Fig. 1. Fig. 1 ASTER image was orthorectified using Landsat ETM+.