

Interactive comment on “A glacier inventory for the western Nyainqentanglha Range and Nam Co Basin, Tibet, and glacier changes 1976–2009” by T. Bolch et al.

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Final author comments

We appreciate the thorough reviews and the useful comments of both reviewers as well as the short comments of M. Peltó that help improving the paper. We address all comments of the reviewers (RC) in the following.

Reply to comments of the anonymous referee#1

General reply

The main comment of referee #1 is the lack of climatological data and the climatological
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interpretation and that the content of the paper is too thin for The Cryosphere without it. We have already included a general description of the climate and briefly discussed the probable climatic controls of the glacier shrinkage in the discussion paper. However, we agree with the referee that the paper is lacking a thorough description of the regional climate and that we do not provide detailed climate data.

Hence, we improved the description of the regional climate and the climatic interpretation. The data from the surrounding lower elevation stations indicate the SE-NW gradient of precipitation and significant temperature increase and a slight precipitation increase (Chen et al. 2009). However, as indicated in the discussion paper, there is a lack of climate data at the elevation where the glaciers are situated. Hence, a discussion on the climatic causes of glacier changes remains speculative, so far, and detailed measurements and modelling efforts are needed in order to improve the knowledge on the climatic controls on glacier recession. Ongoing meteorological and mass balance measurements on Zhadang Glacier within our Chinese-German project will significantly improve the data basis in the future. However, a data record covering at least a couple of years is needed for this purpose.

Detailed knowledge of recent glacier coverage and glacier changes is the basis for climatologic analysis and needed to improve our understanding of the contribution of glaciers to run-off and sea-level rise. For this reason we will also make the data publicly available for the community through the GLIMS database. In addition, this is one of the first papers reviewing previous studies using declassified imagery, and we found significant deviations. Correct glacier outlines are also important for correct calculation of glacier volume changes, and for evaluating numerical glacier models.

Further detailed replies to the comments of referee #1 are given below.

Reply to general comments:

RC: Although a little too long, the paper is clearly written and organised, the methodology is well described and discussed, the state of the art is exhaustive.

AC: We shortened the original text and removed redundancies as also suggested by reviewer #2. However, the overall length of the manuscript is now similar as we included more details on the climate as requested.

RC: The paper is missing a thorough description of the regional climate (including figures—air temperature, precipitation, humidity...) to reach significant conclusions.

AC: We improved our description of the regional climate and included a figure showing climate diagrams of stations in the surrounding. We refer also our general comments at the beginning.

RC: Indeed, the objectives of the paper (to generate a glacier inventory, and to analyse glacier changes from 1976 to 2001 or 2009) are by themselves too light and would largely benefit from a climatic interpretation.

AC: We improved our climatic interpretation. We refer also our general comments at the beginning.

RC: This paper gives a qualitative climatic explanation (temperature rise) of the general glacier retreat observed in the range, but no climatic study can support this statement. In general this paper is lacking climatological data to better describe the regional climate affecting the region, in order to relate that to glaciers.

AC: We put more emphasis on existing studies on climatic variability in the greater region. We agree with the reviewer that the paper is lacking climatological data. However, as mentioned above, the general lack of reliable data does inhibit any in depth analysis of climate variability. We refer also our general comments at the beginning.

RC: Moreover, I guess that there is a large precipitation gradient between the leeward side (NW) of the mountain range compared to the SE side (Indian monsoon effect). I believe that this gradient is probably responsible for a different behaviour of northern and southern glaciers as well as for the distribution of polythermal and temperate glaciers. A short qualitative discussion (p 434, lines 10-14) on this last point is provided

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but not supported by data. A comparison (regarding glaciers and climate) between both sides of the range should be included.

AC: We agree with the reviewer that there is a gradient. However, convective precipitation at both sides of the mountain range might also play an important role which weakens the precipitation gradient. We included an NW–SE comparison. The ice covered area NW of the main ridge is significantly less, the average glacier area and the absolute ice loss also, but the relative ice loss is higher. This finding in principle backs the hypothesis as stated by the reviewer.

RC: Glacier volume change. The authors say that volume changes could be assessed (p442, lines 2 to 4), which could be a great contribution in this paper. I would therefore suggest to improve this paper by including climatic analysis of the region, and also, for selected glaciers, a volume change estimate.

AC: We included a climatic interpretation based on the existing data. We refer also our general comments at the beginning. We agree with the reviewer that the calculation of volume changes is highly interesting. However, this requires a completely different methodology. Generating DEMs from declassified data is not straightforward (see Bolch et al. 2008, J. Glac.) and exceeds, for our understanding, the scope of this study.

Specific comments

RC: P 430 line 4: I agree that the region is probably of “special interest for glacioclimatological research” but at the stage of your study, there is no evidence of that. That is why reading your paper gives the impression of a study lacking a second step analysis concerning climate, and not only glaciers, as suggested above.

AC: We agree with the reviewer and excluded this statement from the abstract. However, we clarified the special interest of this region in the section about the study area.

RC: P 430 line 13: provide the referring year corresponding to the total ice coverage of 795.6 km²

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AC: Information included

RC: P 430, line 14: remove “a” after _5800 m or add a.s.l.

AC: “a” removed

RC:- P 43, line 21: in general and along the paper, you should not talk about relative values for length or area variations of glaciers since it depends mainly on glacier size.

AC: We removed the statement regarding the relative change in the abstract. However, we do not agree with the reviewer's statement in general. Relative values of glacier changes are important to consider, because the changes generally are relative to the glacier's size. This is especially important for smaller glaciers which are highly sensitive to climate but can also preserve their mass when situated in favourable topographic settings (Kuhn 1995; De Beer and Sharp, 2009).

RC:- P 431 line 17: How far is Amdo met station from Nyainqentanglha Range?

AC: The station is ~ 220 km in the NE which was already stated in the Discussion section. But we agree with the author that this important information should be given earlier.

RC: Introduction: the introduction could be shortened. It gives a general overview of the interest of glaciers as climatic proxies, water reservoirs, or potential natural hazards although the study mainly focuses on glacier area variations.

AC: We shortened the introduction.

RC: P432 line 24 : where ! were

AC: corrected

RC: P433 line 12 : SW-NE instead of SW-NW

AC: corrected

RC: P434 regional climate data : the paper would need a figure with meteorological
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data (T, precipitation, other available variables) recorded at Nam Co station, and around the range (Amdo? Lhasa?), if available. Also, when giving meteorological data, provide the kind of instruments used to collect temperature data as well as precipitation data (which is kind of tricky when measuring snow falls.)

AC: We included climate diagrams for surrounding stations with available data. There are only five years of measurements at Nam Co station. The measurements are according to WMO standard (AWS for temperature and manual observation for precipitation).

RC: P437 lines 5 to 10: As said in this part, I believe that debris-covered glaciers are sometimes hard to identify. I understand that different kinds of imagery may help to identify covered glaciers (like in Fig 3), but is it possible all the time? Which error regarding covered glaciers can you expect? And what is the total debris-covered area compared to the total glacier area of the whole range? This should be discussed in more details and text should be included in the error section.

AC: Mapping of debris-covered glaciers can, indeed, be tricky. The first author mapped debris-covered glaciers in several regions of the world. The termini of most of the debris covered glacier are identifiable when using different imagery. There are several supportive indicators, e.g. signs of movement when comparing multitemporal imagers, supraglacial ponds, creeks starting at the mouth of the glacier. However, we identified three debris-covered tongues where the delineation is kind of vague. We included the total debris-covered area in the text and discussed this issue more in detail.

RC: P438 lines 1-7: the error due to seasonal snow cover can be large, and how about the error on the upper part of the glaciers, where contrast can be low on images?

AC: We agree that delineation of the upper part of the glaciers can introduce high errors. Most important is the selection of a suitable satellite scene with optimal contrast. We kept the upper glacier boundary constant over the whole time of investigation in order not to introduce errors due to this problem. Also, we have clarified this issue with

more emphasis in the text.

RC: Table 2: I agree that the total number of glaciers is not a very valuable result, since it depends on how glaciers are delineated (therefore, all comments and considerations concerning the number of glaciers can be shortened). The area coverage is more interesting, but it must refer to years, which is not systematically made.

AC: We included the information about the respective years. See our reply to the comment (P440, lines 23-25) regarding the number of the glaciers.

RC: And may be I missed something, but the exact delineation of "Area around Mt N." Or "Nam Co Drainage basin" is not obvious, and perfectly located on Fig 1.

AC: We agree that the naming was not consistent throughout the paper. We changed "Area around Mt. N." to "detailed study area" as shown in Fig. 1.

RC: Fig 5B. Is the aspect given as a function of the number of glaciers? It would be more interesting to give the aspect as a function of the area.

AC: Figure included as requested.

RC: P440 lines 4-5 : Do you have any reference to support the statement that the median elevation is the best estimate for long-term ELA?

AC: We included a reference and altered the sentence to: "The median elevation of the glaciers, which is a suitable and widely used estimation for the long-term ELA based on topographic data (Braithwaite and Raper, 2010), is situated at around 5820 m."

RC: P440, lines 23-25 : any consideration regarding the change of the number of glaciers is useless (since it depends on how to count them!), and should be removed

AC: We agree that the overall number of glacier depends on definition, purpose, and approach. We calculated glacier drainage basins and kept them constant over the investigation period. Hence, we compare the same entities and the change in number does give some insight in glacier changes, e.g. disintegration is typical for shrinking

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glaciers.

RC: P440 lines 26-27 or P441 lines 12-15 or p 443 lines 14 to 16: same comment regarding the relative area change. This relative area change depends on the size of each glacier, and is consequently not significant. Remove Fig 7a and 7b. Remove % in table 5. Remove all comments regarding rates of area loss in the section.

AC: The change of glaciers in relation to its area does give some insight in glacier changes as mentioned above. Several publications address this issue. Some small glaciers can maintain their size due to a special topographic situation (see e.g. DeBeer and Sharp, 2009), while others are prone to disappear. This analysis of relative area changes is also provided in several similar publications (e.g. Andreassen et al, 2008, Paul et al. 2004).

RC: Fig 9 : not so useful, this fig could be removed.

AC: The figure shows the suitability of a resolution merge of Landsat MSS and Hexagon data and compares the glacier extent in 1976 with the situation in 2001. In addition, it shows the separation of one tributary glacier to the main glacier. Therefore, we would wish to keep this figure. This is now highlighted with an arrow.

RC: P442, lines 4 to 17: some considerations here have already been discussed in the methodology (data and methods), earlier in the paper. This section 5.1 should not be included in the discussion section.

AC: We removed redundancies between the mentioned sections and discussed the use of the imagery with respect to the uncertainties of the topographic maps as suggested by reviewer #2

RC: P 443 line 3. Does the ELA estimation (5800 m) come from the median glacier altitude, or from other sources? Actually, what is the ELA of Zhadang glacier where mass balance measurements are conducted?

AC: We clarified that the ELA estimation is from the median glacier altitude. We also

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included the information that “measurements at Zhadang Glacier since 2005 indicate that the long-term ELA is situated at about 5800 m (unpublished data)”.

RC: P 443 lines 11-15 : The qualitative comparison here between glacier covered area changes (or length variations) and mass balance data is not relevant since length variations depend not only on mass balance variations but also on the own dynamics of the considered glacier. Mass balance measurements (2005-09) are moreover very interesting and could be compared to volume variations obtained from your satellite image data.

AC: We agree and are completely aware that area and length variations show only indirect signals and cannot be compared to mass balance directly. However, length and area variations are still very valuable indications of glacier changes and are explicitly requested by international organisations like WGMS and GTN-G. This kind of data is easier to obtain with less uncertainty and similar data from many glaciers around the world is available for comparison. Calculation of geodetic mass balance is not straightforward and exceeds, for our understanding, the scope of this study. However, we included some information regarding the mass balance of Zhadang Glacier.

RC: P 444, lines 21-24 : it is somehow dangerous and questionable to relate glacier area changes of five glaciers to long-term regional climate variability because length variations depend on the own dynamics of each glacier (see previous comment). That's why studies concerning volume variations (and then mass balance) are required to use glaciers as climatic indicators. This issue could rise the relevance of this paper.

AC: We clarified this issue. See also our reply above.

RC: P445 lines 1 to 21 : I fully agree that unfortunately, you “are not able to attribute observed glacier changes to specific climate elements”. However, the discussion just before qualitatively suggests that the glacier change is related to observed temperature trends. This study would gain a lot if a thorough comparison between climate data and glacier changes was conducted in this paper. Many questions arise regarding the

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importance of precipitation regimes, the intensity of sublimation, etc. but I am aware that you cannot deal with all these questions.

AC: We included a thorough comparison between climate data and glacier changes as far as possible. We refer also to our general statement at the beginning.

Reply to the comments of reviewer #2

General Comments

RC: While the paper is well written in clear English, some improvements could be made in the structure of the paper as well as the language. Some paragraphs are very dense at times, and need to be revised. Some sections have a little too much detail, making it hard to follow. Re-organization, and sub-headings are needed in other places. It is hard to extract the big picture about glacier changes in the different areas, and what governs those changes. I suggest focusing on making the trends become more obvious. Some points need to be stressed, for example that retreat rates were overestimated by previous studies, or that there are differences between the north vs south of the study area. I also recommend shortening the paper.

AC: We shortened and improved the structure of the manuscript.

Specific comments are offered below.

Abstract RC: Line 9: replace Landsat MSS (year 1976) with “1976 Landsat MSS, similarly throughout the manuscript.

AC: We think it is easier to understand if the year is indicated in brackets.

RC: Line 11: Insert what exactly the manual adjustment was done for, ie. “Manual adjustment was especially necessary for georeferencing the panchromatic Hexagon data and for delineating the debris-covered glaciers: : :..”

AC: Clarified; We write: “Manual adjustment was especially necessary for delineating the debris-covered glaciers and the glaciers on the panchromatic Hexagon data.”

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RC: Line 14, end: remove “a”

AC: removed

RC: Lines 16-17: ‘The glacier area decreased between 1976 and 2001 by about ..’
Reorder the words, split the phrase in two (long phrase), and revise the language, ie:
“The glacier area decreased by xx% between 1976 and 2001. This is less than the change reported in previous studies: : :.”

AC: Sentence improved accordingly

RC: Line 18; same as comment above on line 9 -replace “topographic maps from the 1970s” with “1970s topographic maps; similarly for Landsat, throughout the manuscript. This shortens the phrases a bit.

AC: We replaced the phrase as suggested wherever we found it suitable in the manuscript.

1. Introduction

RC: p.430, Lines 25-26- The importance of glacier runoff in the Himalayas is generally overstated in the literature (and the media), with little evidence offered. Glaciers are certainly important in the hydrologic cycle in the Himalaya, but some clarifications are needed. Do you mean people living close to the glacier terminus and depending on glacier runoff directly? Or people living downstream? Please clarify and provide some references- otherwise, I suggest revising the statement.

AC: We agree with the reviewer and stated the glaciers are contributing but omitted “significantly”.

RC: p.431, line 1: “Like in many other parts of the world: : :” I suggest being more specific do you refer to global temperatures? Give references for other mountainous parts of the world where increases in temperatures have been reported. Give the rates of increase in temperature reported in these studies. The trends are different at high

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altitudes vs low altitudes (more increase at high altitudes in the TiP). However, in other parts of the world such as the Andes, this trend is reversed, ie less increase in temperature at higher elevations (see Vuille et al 2000 and 2003 papers). Please revise/clarify.

AC: We agree with the reviewer and omitted “Like in many other parts of the world: : :” Detailed information is given in the discussion section. We think they fit better here in order to discuss the link between glaciers and climate.

RC: Lines 1-6: The phrase is too dense, I suggest splitting in two parts: one for temperature/precipitation trends, and one for glacier changes reported in the TiP.

AC: We improved the phrase as suggested.

RC: Line 6: replace “This trend is also confirmed “ With: “Similar trends have been reported..”

AC: We wrote: “Glacier shrinkage is also reported. . .”

RC: Lines 7 – 15- The paragraph doesn’t tie together well, the ideas need to be re-ordered. The discussion about the importance of glaciers is not so much needed here, this is well known. Also, mentioning GLOFs could be omitted. I suggest revising this paragraph, remove lines 7 -15 and re-phrase to something shorter like: “There is a concern about increased GLOF potential [refs] and decreased water resources in the long run. This poses a need for glacier monitoring in this area, etc etc.” This provides a good lead into second paragraph on p. 432, the need for remote sensing studies (see my comments below).

AC: Paragraph rewritten as suggested.

RC: Lines 16 – 22- again, change the focus of the paragraph here- you might want to emphasize that climate data are scarce, which makes glacier change studies difficult.

AC: We changed the focus accordingly.

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RC: Lines 19-22 belong to study area. Lines 22- 20 on p. 431 and 1 -3 on p. 432 also belong to the study area, rather than introduction. This is redundant with lines 10 – 20 on page 434.

AC: We moved the mentioned sentences to the section “study area” and removed the redundancy.

RC: p.432, line 1- as far as I know, Ageta and Higuchi refer specifically to Nepalese glaciers as ‘summer-accumulation type’. Can you provide some other reference that supports the statement that glaciers in your study area also belong to summer-accumulation type? Is it based on your analysis of climate data, or previous studies?

AC: Most of the glaciers on the Tibetan Plateau are strongly affected by monsoons and have ablation and accumulation simultaneously (see: Ageta, Y., and K. Fujita (1996), which is cited here). Nevertheless we omitted the term “summer-accumulation-type, also to shorten the paper.

RC: Line 4: Before talking about remote sensing, I suggest introducing previous glacier inventories (the Chinese inventory) and the problems associated with it (lines 20 – 29 on p. 243 and 1- 10 on p. 244) here. Also introduce uncertainties associated with this inventory to transition to the need for RS.

AC: We improved the structure as suggested.

RC: Line 19: a) “continental climate” - Which winds do you refer to here?

AC: We included the information that the prevailing wind direction in winter is west.

RC: b) replace “comprehends” with “comprises of” c) replace “one glacier where mass balance measurements were started” with “ one glacier with mass balance measurements”. Remove “and” after Kang et al and start a new phrase. Replace “that is” with “which is”.

AC: Text improved accordingly

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RC: p. 433, line 1. Place “there is” after “currently”, and replace “paper” with “study”

AC: Text improved accordingly

2. Study area RC: Line 12: Break phrase after Nyaingqetanghla, and replace “which is’ with “The area is” Line 20” replace “few is” with “little is” Replace “on the” with “about the”

AC: Text improved accordingly

RC: Page 434, lines 10 – 20: consolidate with paragraph from p. 431.

AC: Redundancies removed

3. Data and methods RC: This section is quite dense and there is a lot of detail. I suggest thinning it quite a bit.

AC: We shortened this section.

RC: p. 434, line 22; replace “the glacier inventory are’ with “this glacier inventory IS”

AC: corrected

RC: p.435: “level (1T)- explain or omit

AC: The processing level is important to know -> We explained Level 1T.

RC: The use of the “deviation” (eg line2 1, 8 on p.435, so on) is not appropriate throughout the manuscript. Replace with “difference”, “horizontal shifts”, or RMSE, as needed.

AC: We replaced “deviation” throughout the manuscript.

RC: Line 6; remove “time around”

AC: Removed

RC: The use of the verb tense is not consistent. Sometimes past tense is used, other times present tense. I suggest checking this throughout the manuscript and using the

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past tense.

AC: We carefully checked the tense and corrected it when needed.

RC: line 13: "SLC-off"- needs to be explained if included. This is too much detail.

AC: It is important to mention this, as many studies face the same problem due to the data gaps of the SLC-off scenes. Therefore we explain "SLC-off" in the revised version of the paper.

RC: When the word 'resolution' is used, please specify if you refer to "spatial", "spectral" or "temporal, ie. line 25.

AC: We refer to the spatial resolution and included this information.

RC: Lines 1 – 25- this is too dense, try to shorten and include only essential information.

AC: We shortened this section.

RC: p. 436, line 16 -17: "However, the quality of the ASTER GDEM.."- I suggest removing, for sake of being more concise. I think the quality of the GDEM is the same for now.

AC: removed

RC: Line 23- can you comment on the quality/accuracy of the various versions of SRTM in this area?

AC: Different versions of SRTM data show horizontal shifts to each other while the representation of the topography is the same. We omitted the information about the different SRTM sources in order to shorten the article as it is not important for the content of the paper.

RC: Line 15; holes: : "are common for DEMs derived from ASTER: : ..due to availability of few scenes"- CONFUSING. Specify that holes are due to difficulty in stereo-correlation procedures in steep mtn terrain.

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AC: Text improved accordingly.

3.2 Glacier identification RC: Line 25; remove "Due to the size: : ..coverage". Start with "We applied: : .."and move the idea at the end, ie, semi-automated approaches are appropriate for large study areas, etc.. Add the reference Racoviteanu et al, 2009, Annals of Glaciol after Paul et al, 2009.

AC: Text improved accordingly, reference included.

RC: p. 437, line 18: replace "could" with "were".

AC: Replaced with "was"

RC: Lines 24- 29- it seems to me that this belongs to section 3.3 (at the end of that section on p.438), since these glaciers were selected for a detailed change analysis.

AC: We moved these lines at the end of section 3.3 as suggested.

3.3 Glacier inventory and change analysis RC: p. 438, Line 13: replace 'had to be' with "were". Same comment as the use of 'could' .

AC: Text improved accordingly

RC: Also, avoid the use of "correct" (lines 16, 23), since this cannot be proven. Replace with "accurate" or "accurately".

AC: Text improved accordingly

RC: Lines 15 – 23- reduce the detail here. Such difficulties are discussed in the Annals paper, you can refer to it.

AC: The described difficulties are important to mention here as it is also specific for this region. I referred to Bolch et al. 2010 who, for the first time, presented the buffer method.

3.4 Error analysis RC: Move this section as part of the discussion section, and merging with lines 1 – 8 on p. 444, which also refer to error analysis.

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AC: The section on the error must be presented here because the subsequent error terms are based on this error analysis.

4. Results RC: p. 439, lines 20 – 23- too much detail here, this phrase could be removed.

AC: We think the information on the number of glacier is an important issue as also addressed by referee #1..

RC: Line 25: avoid the use of “little less” , or “little higher” , “little lower” (line 19 – 20 on p. 440) and quantify where possible, or replace ‘little’ with ‘slightly’

AC: We replaced little with slightly or included the detailed number.

RC: p. 440. Line 3- does glacier orientation reflect the wind circulation patterns?

AC: The ice covered area is probably influenced by monsoon winds as there is a higher ice cover on the windward side. See also our reply to the comment of referee #1.

RC: Line 16- too many numbers, I suggest referring to the table and just giving the rates of retreat.

AC: We agree and altered the text accordingly.

RC: Line 25: insert “The” before “Analysis”

AC: Text improved accordingly

RC: Line 27, end of phrase- refer to Table, and give numbers, ie xx % loss for smaller glaciers vs xx% loss for larger glaciers.

AC: Information included as requested.

RC: p.441, line 1: there is a small tendency that glaciers ..lost relatively more area: :
:’ revise the language to: “Glaciers with lower median elevation tend to lose relatively more area: : :’

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AC: Sentence improved accordingly.

Line 4. Break the phrase after (Fig. 7B).

AC: Sentence improved accordingly.

RC: A few suggestions for further analysis: -it would be useful to have the change in glacier termini (Z min) for the entire range as well as the selected glaciers -also, a correlation analysis between % change and median elevation, min. elevation, orientation, glacier area, debris cover respectively to better understand the changes. -an estimate of % debris cover would be useful, as well as the change in area for the debris-covered glaciers only.

AC: A correlation analysis between % change and glacier area, as well as the median glacier elevation is already presented in the discussion paper. We expanded the analysis and present information about the percentage of debris cover, the area changes for the debris-covered glaciers and the minimum elevation.

RC: Do you conclude that the selected glaciers are representative of the entire range? If so, state this at the end of section 4.2. How do selected glaciers compare to the entire range in terms of glacier area and debris-cover?

AC: These glaciers are comparative large glaciers and therefore, are not representative for the entire range. These glaciers were selected because there is data from previous studies existing for comparison and evaluation as stated in the discussion paper.

5. Discussion 5.1 Images and methodology

RC: This would fit better at the end of discussion in an errors/accuracy assessment along with the discussion of the Chinese inventory. I suggest starting section 5 with the discussion of glacier changes (section 5.2) Also, there is some redundancy here with material from the introduction (eg lines 10 -18 on p. 442) , please revise.

AC: We started the section with a discussion on the glacier changes and avoided re-

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dundancy.

5.2 Glacier changes RC: p.442, line 26: "The study reveals a long-term trend of glacier changes.." revise to something like: "This study found a long-term trend.." Also, what do you mean by longterm? Define here- decades?

AC: We improved the sentence and omitted "long-term" as it is stated that the analysis started in 1976.

RC: First give the rates of retreat, again, and then interpret here.

AC: Rates given as requested.

RC: p.443, line 3: it is not correct to refer to ELA here- but instead, refer to the median/mean elevation. Phrase is too long, separate after "ELA".

AC: We explicitly mean the ELA here. We changed the sentence to: "Analysing the glacier hypsometry indicates that a rise of the ELA above 5850 m will cause an increased area loss as the largest portion of glacier coverage is in the range of 5750 – 5850 m."

RC: Line 6: replace "in line' with "in agreement"

AC: Replaced accordingly.

RC: Line 7. Insert "the' before "southern"

AC: Done as requested

RC: Line 10: remove "and above"; remove decimal from 10.0 m a-1; replace "significant' with "significantly"

AC: Changed accordingly.

RC: Line 11: insert "the" before 'debris-covered' The result is interesting, this is not a typical pattern- usually debris-covered glaciers (with thick debris) show slow rates of retreat. Comment on this, and offer some potential explanations for the behavior of

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Xibu.

AC: "the" inserted. We found that this unusual high retreat rate, which is based on a comparison with a topographic map, is erroneous as stated in line 18. We clarified this issue.

RC: Lines 12- 12: "...show that negative balance values occur since 2005" Remove "that", "occur" and insert "mass" before "balance"

AC: Text improved accordingly.

RC: Can you say what % of the glacierized area is covered with debris?

AC: The debris-covered glacierized area is about 3.4%. We included this information in the text.

RC: Line 17: 'This study results in lower values" Replace" results in ' with "found" Line 18: "...reveal similar values".. Insert "to previous studies"

AC: We wrote "results in" as we used "found" already in the previous sentence and wanted to avoid the repetition of the word. "to previous studies" inserted.

RC: Lines 20 – 29 on p.443 seems like it belongs to the introduction

AC: We do not agree. We compare results of previous studies with ours. This cannot belong to the introduction. However, we additionally included the information about the use of the topographic map for the Chinese inventory in the introduction.

RC: Lines 1-9 on p.444 belongs to error analysis (as suggested, this would be better at the end of discussion)

AC: The error analysis is for our own data while lines 1-9 discuss possible uncertainties of the Chinese topographic maps. We combined the use of the declassified imagery and the issue of the topographic maps in one section.

RC: p.443, line 29- replace "deviation: with 'difference'

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AC: Text improved accordingly.

RC: p.444- lines 1-2 "Our results ..seem to be reliable"- remove this, it is subjective

AC: Removed as suggested.

RC: Line 9- 10- redundant with paragraphs above, compress into one paragraph. Break line after Li et al, 2008.

AC: This is not redundant as we compare here the results with studies in other regions of Tibet, while before, we compared our results with previously published results in the same area.

RC: Lines 14- 19 would fit better in conclusions; however, this is rather vague, I suggest removing these to keep the paper more concise.

AC: Removed as suggested.

RC: Lines 20 onwards: the Climate discussion needs a subheading in the discussion, it is buried in the discussion of glacier changes.

AC: Subheading included

RC: Line 20: "None of the five glaciers.." – this is already stated.

AC: Sentence removed

RC: Line 22: "mean annual rates'- which rates? area? Length?

AC: We modified this sentence for clarification.

RC: Line 27- remove "cells"- it is too technical

AC: removed

RC: p.445- lines 1-4 – long phrase. What do you mean Liu and Chen assumed a higher increase at higher elevation? Was this based on data? Please explain.

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AC: We improved the sentence.

RC: p.445: lines 22 – 27- this looks like material in the introduction, remove or revise

AC: We moved it to and included it in the introduction

RC: line 6; 'increase of annual precipitation"- replace "of" with 'in"

AC: Improved accordingly

RC: line 8- "stable fluctuations in precipitation'- what do you mean here? If it's fluctuating, then it cannot be stable. Please rephrase.

AC: We rephrased the sentence.

6. Conclusions RC: p.446- Line 4: remove 'precise'- again, this is subjective

AC: This is not subjective. Several level 1T scenes don't have horizontal shifts and do not need any processing prior to use for change analysis. Therefore, we wish to keep the phrasing as is.

RC: line 7: 'the correction of the outlines: : ...concentrate on debris-cover correction"- redundancy. Replace with "Future steps will involve..correction of debris cover.."

AC: Replaced.

RC: line 13 "In addition, this enables to show the consistency of the data'- this is vague- which data are you talking about?

AC: Statement omitted.

RC: Line 25 is wordy. I suggest removing "In this respect the advent of", and start with "Gridded data".

AC: Text improved accordingly

RC: Line 28 "This kind of investigations is currently followed by the authors"- awkward phrasing, revise to something like "further studies are conducted.."

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AC: Sentence removed.

Tables: RC: these could be consolidated/simplified. Table 1: move to Data/methods What kind of data is USGS, are you referring to topo maps? The site where data are archived/ also, need to explain DLR and GCLF in the table heading. These are not discussed in the data section

AC: We are referring to Table 1 in the Data and Methods section. We downloaded the majority of the Landsat scene from the USGS Global Visualisation Viewer (gloves.usgs.gov). We explained the abbreviations as requested.

RC: Table 2- Need to specify these regions in the Study area or methods. You have 5 regions here, however, in the text you only focus on 3 of those add “Number of glaciers” to table column “Number”

AC: We renamed the regions and referred to Figure 1 where these regions are shown. “Number of glaciers” included.

RC: Table 3 caption – ‘extends’ should be ‘extents” You could add the area from Table 4 to this table, since this table is about basic stats. Table 4 would be more manageable.

AC: “extent” corrected. We cannot add the area from Table 4 to Table 3 as one table presents the general characteristics of the five selected glaciers the other table area changes for larger regions.

RC: Fig 4: doesn’t seem so essential.

AC: Figure 4 illustrates the difference that would be introduced especially to smaller glaciers if the seasonal snow was still visible in the imagery. We think this is of high interest for the readers.

RC: Fig 5 caption: reverse “covered area to ‘area covered”

AC: Caption improved accordingly

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RC: Fig 7: reverse axis, is easier to see.

AC: The order of the axis is commonly used. The x-axis shows increasing values from left to right. The y-axis shows decreasing values from top to bottom. Negative values are presented below the zero line. Hence we would prefer to leave the order.

Reply to the comments of Mauri Pelto

RC: 434-13: This mentions polythermal and subpolar glaciers. If this study has developed any further information on the distribution of these glaciers it would be useful to include: What percentage of the glaciers in the western Nyainqentanglha Range are polythermal or subpolar? Is there any attempt to distinguish these glaciers in this study? Are their characteristic settings or elevation ranges of these glaciers from previous studies? Is the response of these glaciers any different?

AC: This is an important issue. Unfortunately we do not have any further information about the distribution of these glaciers except for Zhadang Glacier, which is polythermal (or even cold) as our own measurements of ice temperatures reveals. This will be subject for further studies within our ongoing project.

RC: 440-7: Debris covered glaciers are noted for their lower termini elevation. Is there a pattern to the maximum elevation, elevation range, or glacier length? The one example given, Xibu Glacier, indicates a much higher maximum elevation and a significantly increased length versus the other glaciers, is this typical?

AC: Xibu Glacier with a large debris-covered glacier tongue is situated below the Mt. Nyainqentanglha which is the by far highest peak and has steep slopes which are probably the major source for the debris. The location of some other debris-covered glaciers are similar. We included this information in the text.

RC: 440-24: A couple of specific examples of glaciers that disappeared or disintegrated would be useful. How many were noted? Elevation range? Initial sizes? Top elevation?

AC: We agree that this issue is of interest and provide now some information on the

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disappeared glaciers.

RC: 441-8: Additional comments on the likely change in ELA based on the results of Fig. 8 should be made. It appears that the overall areal extent percentage change is considerably reduced between the 5800 m to 5850 m interval, with all intervals 5800 m and below having considerable change. Is this a useful indicator of the recent ELA or is the change too subtle?

AC: We used the median elevation as estimation for the ELA. Fig. 8 indicates that the ELA has risen since 1976. We included now the information about the rise of the median elevation (~9m) in the paper.

RC: 441-20: Separation of Panu Glacier is noted. The Fig. 9 caption should indicate which tributary has separated and the figure itself could be annotated.

AC: We now indicate the separation with an arrow in the figure.

RC: 445-23: Specify how substantial has the rise in Lake Nam been according to Wu and Zhu (2008).

AC: We included the number of lake expansion given in the reference.

RC: Table 3: For the five glaciers if their polythermal, temperate or subpolar nature is known note it.

AC: So far we have we have only some information about Zhadang Glacier (see above). We included this information in the text.

RC: Table 5: This detailed important data should be used to construct a figure, either focusing on the three period changes or the annual quantities from the 5 specific shared years.

AC: We included a figure which visualizes the length changes.

RC: A minor issue with the paper is the frequent use of the wrong word, for example.

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432-27: comprised or consists, not comprehend

AC: corrected

RC: 432-24: were not where

AC: corrected

RC: 433-20: little not few

AC: corrected

RC: 438-9: extent not extend

AC: corrected

RC: 438-20: remove own

AC: "own" removed

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