The Cryosphere

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Discussions

Interactive comment on "Brief Communication: Glaciers in the Hunza Catchment (Karakoram) are in balance since the 1970s" *by* Tobias Bolch et al.

Tobias Bolch et al.

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We'd like to thank the reviewer for the constructive review. Please find below our reply to the comments. We will provide a more detailed reply along with the revised manuscript.

RC: This is a useful study that provides the first long-term information (since the 1970s) about geodetic glacier mass balance for a region of the Karakoram. This is a region where many recent papers have suggested that glaciers are changing little in mass, but prior to this study little previous information has been available about glacier elevation changes before _2000. The techniques are well described, the errors are well quantified, and useful final conclusions are produced. Most of my comments are relatively minor and focused on technical issues, but there are two useful analyses that could be

undertaken that would help to strengthen the paper:

1. A computation of the total elevation changes over the period 1973-2009 should be completed. This would help to validate the patterns shown in the individual periods, potentially reduce the effect from individual surges, and provide evidence that mass balance has been stable over the long term.

Reply: We have done so for few glaciers to clarify that the results agree well to the results of the individual periods. We agree, however, that it would be beneficial to also include the DEM difference for the entire period. This will therefore be done for the revised manuscript.

RC: 2. Provide a plot and discussion of the change in geodetic mass balance with altitude for non surge-type glaciers. This could provide insight into whether changes are occurring at particular altitudes, even though the overall mass balance may be close to zero.

Reply: We agree that this information would be valuable. However, there are several other interesting analysis which could be done, e.g. comparison of the elevation change with altitude of debris-covered and non debris-covered glaciers. However, we chose the format of the Short Communication as we wanted to focus on the main new findings. In addition, we cannot add another figure due to the limitations in the chosen format.

Individual comments:

P2, L22: there is actually this mass balance study available for a glacier in the Karakoram prior to 2000, although it only covers a 5 year period: Bhutiyani, M. R. 1999. Mass-balance studies on Siachen Glacier in the Nubra valley, Karakoram Himalaya, India. Journal of Glaciology, 45(149), 112-118.

Reply: Fully agreed, Thank you for this correction. We will include: "The only exception is Siachen Glacier in eastern Karakoram for which Zaman and Liu (2015) corrected the

clearly negative value of 0.51 m w.e. a-1 by. Bhutiyani (1999) and estimated the mass budget to be between + 0.22 m and - 0.23 m w.e. a-1."

P2, Fig. 1: it would be useful to label the location and names of some of the main peaks or towns in this region to make the map easier to follow. The lat/long labels around the margins are also currently too small to see.

Reply: We agree. We will include the names of few larger villages and known mountain peaks and enlarge the font size of the coordinates

P3, L11: the sentence 'The major advantage: : :' doesn't really make sense as written. Please reword.

Reply: We agree and will write: "The major advantage of this dataset is besides the high spatial resolution the 12 bit radiometric resolution.

P3, L13: please provide the resolution and spatial extent of the KH-9 imagery. I also think that you mean to refer to Table S1 here, not Table 1

Reply: We agree and will include the information ". . .which has a ground resolution of about 8 m and a coverage of about 250 x 125 km. . ." and refer to table 1.

P3, L16: should be 'database' (one word)

Reply: corrected

P31, L21: a few words to explain what the 'reseau grid' is would be useful as it's not a commonly used term. I also think that it should be spelled 'Réseau grid'

Reply: We agree and will integrate few words.

P31, L23: change 'GCPs have been collected: : :' to 'GCPs were collected: : :'. Also describe how and where the GCPs were chosen – e.g., Were they located on bedrock areas? How many were used? Were they chosen across a range of elevations?

Reply: The numbers of the utilized GCPs were listed in Table S2. We will include the

following information in the manuscript: "GCP collection in rough terrain is challenging. Finally we were able to find 26/28 GCPs located at mountain peaks, large terrain features, and bridges which we distributed throughout the scenes and in different elevations as best as possible."

P5, L5-6: I'm unclear as to why a 5% uncertainty was chosen for the glacier area mapping. If there are good optical satellite images available for this area, then presumably it should be relatively straightforward to map the glacier areas with <5% uncertainty?

Reply: The glaciers are not that straightforward to map as there are several debris-covered ones. The major issue is, however, the correct delineation of the upper glacier boundary as several glaciers are avalanche fed and located below steep slopes where the boundary is not fully clear. Taken this into consideration and the fact that the study by Paul et al. (2013) revealed similar uncertainties in a mapping experiment where different experts provided glacier outlines, we think this estimate of the uncertainty is reasonable.

P6, Fig. 2: I find the labels and dots on these figures quite difficult to see as they're so small. Also please indicate the source of information for identifying which glaciers are surge-type. As mentioned above, it would also be very useful to produce a DEM difference map for the entire study period (1973-2009).

Reply: We will increase the size of the labels and dots and include the information about how we identified the surge-type glaciers in the text of the manuscript. We will analyse the elevation difference of the entire study period and include the figure in the text.

P7, Table 1: similar to the comment for Fig. 2, please include a column to show the glacier mass balance values for the entire study period 1973-2009.

Reply: We will include also the mass balance values for entire study period in table 1.

P7, L11: 'where lower' should be 'were lower'

Reply: corrected

P8, L1-3: the first sentence in this para is difficult to follow. The rest of this para is also quite awkwardly worded, with quite a few typos. Please be sure to check carefully. E.g., L8: change 'allowed to detect the surge activity' to 'allowed for detection of surge activity'. Also – what does 'south exposed glacier' mean? Do you mean southerly facing?

Reply: We agree that the paragraph is a bit difficult to understand. We will improve it in the revised manuscript.

P8, Fig. 3: also show the total change from 1973-2009

Reply: We will do.

P9, L7-9: it would be useful to add a few words here (or elsewhere) about the relatively rapid surge periodicity in the Karakoram: i.e., that within a 40 year period it's likely that you've captured a large part of a surge cycle (or even more than one). This is different to locations such as Svalbard, where the active and quiescent phases are typically much longer.

Reply: We agree and will include the information in the revised manuscript.

Figure S1: it's unclear as to which dates refer to which areas, particularly for the 1999-2009 image. Colour coding the date label and associated box would help

Reply: In general, it would be possible to identify as the dates are placed in the middle of the polygons representing the scenes. We agree, however, that it is a bit difficult to understand and the suggestion to colour code the date level is very good and we will improve the figure accordingly.

Table S1: indicate what (P/R, K/J) indicate in the header for column 3

Reply: (P/R, K/J) are indeed confusing and not needed. We forgot to delete and will delete for the revised version.

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Discussion paper