The Cryosphere Discuss., 5, C1777–C1784, 2012
www.the-cryosphere-discuss.net/5/C1777/2012/

The Cryosphere Discussions

Interactive comment on "Worldwide widespread decadal-scale decrease of glacier speed revealed using repeat optical satellite images" *by* T. Heid and A. Kääb

T. Heid and A. Kääb

torborgh@geo.uio.no

Received and published: 23 January 2012

Anonymous Referee #1

Thank you for the very thorough review of our paper. Your comments and helpful suggestions on how to solve the problems are highly appreciated. We plan to edit the manuscript as indicated below.

1/ For the final version we will rework both the Introduction and the Methods to make these sections shorter and more concise. The paragraph on DInSAR will be completely deleted from the Introduction. We also plan to put the mass balance measurements referred to on page 3028 and the technical details about Landsat and ASTER on page

3029 in two tables (according to the other referee D. Quincey's suggestion). Equations for the subpixel routine will be skipped in the final version and a reference provided instead. However, we prefer to keep the equations on orientation correlation, because this method is not commonly used within glaciology. We therefore think that providing these equations will make the paper easier to read because the reader does not have to look for another paper. We will however rework the text here to make it more concise. The details on how the speeds are compared will be moved from the Results to the Methods.

2/ The regions with negative mass balance to investigate were mainly chosen so that they represent areas of the world with different climatic influences. However, we could only select areas were it was possible to derive yearly speeds for two periods separated by more than a decade, and hence the availability of Landsat images also influenced the selection. Karakoram was chosen because Baltoro glacier has increased its speed during the last years according to Quincey et al. (2009) possibly due to positive mass balance, and we therefore wanted to investigate whether this was the case also for other glaciers in this region. In addition we wanted to look into the temporal and spatial variability in glacier speeds in this region. This will be added to the Introduction.

3/ We will discuss the problem of having snapshots and include a sentence explaining that it is possible that there have been several velocity variations during that time. We will also include an additional time period for two of the regions. Pamir (2004-2005), Caucasus (1999-2000) and Penny Ice Cap (1997-1998) are regions where this should be possible. However, it is not possible to add images for Pamir before the first period presented here (2000-20001) because of lack of images until the late 1990s.

4/ In the final version we will include information about where the speed variations are measured. The referee is right when suspecting that most of the measurements are in the ablation area where the contrast is good, but this will be inspected closer in the final version. Because we do not have outlines of each individual glacier, we plan to do this by comparing the mean altitude of the measurements with the mean altitude of the

glaciers or the centerlines.

5/ It is certainly true that there are no mass balance measurements available in Karakoram. The statements about the mass balance in Karakoram will therefore be downplayed according to the referee' technical comments. Excluding well-known surging glaciers to provide a velocity analysis restricted to non-surging glaciers, will, as the referee mentions, be difficult. This is due to the enormous variations in speed also for glaciers that are not known to surge. These speed changes are most likely not linked to changes in mass balance because neighboring glaciers behave very differently. Excluding only well-known surging glaciers will therefore not be sufficient, as the knowledge base of surging glaciers in the Karakorum seems, according to our results, not complete.

6/ Karakoram was actually the first region we focused on because of work conducted in Heid and Kääb (in press). As noted by the referee, the speed changes in Karakoram are very complex, and this is why this region was not included in Table 3 or Figure 1 and 2. However, we do agree that it can be included in Table 3 and Figure 2. We will also switch Fig. 2 and 3 so that all speed changes are presented together. To include Karakoram in Table 3 we have to include the standard deviation so that it becomes clear to the reader that the spread in the results from Karakoram is large and that this percentage can not be interpreted as representative of the region.

7/ Worldwide will be deleted from the title.

P3026 L16. “Therefore the average speed change calculated is not representative for this area.” will be added. See also point 5 and 6 above.

P3028 L1. We will change the sentence to ”For a steady-state glacier, the mass flux through a cross-section equals the mass balance upstream of the cross-section. In negative mass balance regimes, the ice fluxes will decrease to adjust.”

P3028 L 18. Ok.

P3028 L25. Acceleration during a period of negative mass balance. This will be clarified.

P3028 L3029. Quincey et al., (2009) will be cited in the final version.

P3029 L15-20. The information on Landsat and ASTER will be collected in a table to shorten the text and make it easier for the reader to compare these two sensors. We prefer to keep the information about ASTER since this sensor is most commonly used for deriving regional velocities. Clarifying the differences between these two sensors helps explaining why Landsat is preferred in the present study. However, by referring to a table and shortening the text, this paragraph will be more concise.

P3031 L13. Ok.

P3032 L1. We will delete “stress transfer”.

P3032 L8. The low-pass filtered displacement field is only used to filter the displacement field, and not for the final speed comparison. This will be clarified.

P3033 L12-18 and L20-22. These parts will be moved to the Methods.

P3033 L26. We will cite the USGS Satellite Image Atlas of Glaciers.

P3035 L6-10. We will include kinematic wave theory in the final version. We will also discuss response times for different glacier sizes.

P3035 L27. Frappé and Clake (2007) will be cited.

P3036 L17. We agree that flow instability is vague. We will clarify this paragraph by writing more explicitly that we think these speed variations are not connected to changes in mass balance but to changes that are more related to surge type activity.

P3037 L5. Ok.

P3037 L6. The label of the right Landsat image in Fig. 3 is unfortunately inverted. This will of course be corrected in the final version.

P3037 L8. Ok.

P3027 L20-23. We will go through the Discussion and move the description of the velocity change to the Results.

P3037 L25-onward. We will indicate this in Figure 3.

P3038 L11. We will change this sentence to “which is an area where climatic trends are consistent with a possible positive mass balance” like suggested by the reviewer for a sentence in the Introduction.

P3038 L 21. We fully agree that we do not have the data to test whether there is a relationship between speed changes and mass balance. This is due to all factors listed in the paragraph P3038 L18-28. We will therefore change this paragraph to make this clearer.

P3039. We will include this in the Conclusion.

Table 1. We will include in the title of this table that Path/Row refers to the Landsat satellite orbit coordinate system.

Table 2. We guess the referee meant Table 3 since Karakoram is included in Table 2 but not in Table 3. We will include Karakoram here together with the standard deviations so that it becomes clear that this average is not representative for the region.

Figure 0. A global location map will be included in the final version.

Figure 1. We plan to use one full page in the final version to display Fig. 1.

D. Quincey

Thank you for your comments. They are highly appreciated and will improve the final paper. We plan to follow your comments as indicated below.

1. Worldwide will be deleted from the title.

2. We certainly agree that Karakoram can be better integrated. In the final version

we plan to include it in Fig. 2, switch Figure 2 and 3 so that all speed changes are presented together, and also include Karakoram in Table 3. To include this region in Table 3 we have to include the standard deviation so that is becomes clear to the reader that the spread in the results from Karakoram are large and that this percentage can not be interpreted as representative of the region. We will also rework the text to make sure that Karakoram does not look like an after-thought. Cf. answer 6 to referee #1.

3. See answer 1 to Anonymous Referee #1.

4. See answer 3 to Anonymous Referee #1.

Introduction: The paragraph about DInSAR will be deleted from the Introduction in the final version, according to a suggestion from Anonymous Referee #1. The numbers in the first paragraph page 3028 will be put in a table and deleted from the text, like suggested by the referee.

Page 3026

Lines 13-15: Ok.

Page 3027

Lines 16-22: This paragraph will be deleted from the final version.

Line 23: Ok.

Line 26 Ok.

Page 3028

Lines 1-5: “under equilibrium conditions” will be deleted.

Lines 8-16: This text will be replaced by a table.

Page 3029

Lines 5-12: We plan to replace this text with a table and shorten the text. This will

make it easier for the reader to compare the two sensors, and thereby it will also be less necessary to emphasize the strengths of Landsat versus ASTER in the text.

Line 22: The Landsat-7 image-to-image systematic product accuracy requirement is 7.3 m. We will emphasize that this is Landsat-7 requirements and not our requirements.

Pages 3030-3032: Equations for the subpixel routine will be skipped in the final version and a reference provided instead. However, we prefer to keep the equations on orientation correlation, because this method is not commonly used within glaciology. We therefore think that providing these equations will make the paper easier to read because the reader does not have to look for another paper. We will however rework the text here to make it more concise.

Page 3033

Line 14: Ok.

Page 3034

Line 20-21: Reference will be changed to Hewitt (2005).

Lines 25-27: The label of the right Landsat image in Fig. 3 is unfortunately inverted. This will of course be corrected in the final version.

Page 3035

Line 10: Will be changed to receding.

Line 12: In this paragraph we will include kinematic wave theory and a discussion on response times for different glacier sizes.

Lines 15-16: A table will be provided in the final version.

Lines 26-28: We will rewrite the part on sliding and surges to make it clearer. We will emphasize that sliding may be increased and decreased due to the amount and pressure of water at the bed. We will also refer to Frappe and Clark (2007) to make it

clear what is meant by “surge-type activities, at lower magnitudes”.

Page 3037

Line 25: Ok.

Page 3038

Lines 3-5. These glaciers have high speeds in both periods, but the speeds are varying considerably between the periods. This will be clarified in the final version.

Page 3039

Lines 1-14: We agree that this paragraph is unnecessarily long and detailed. We plan to replace it with a short summary of the speed changes.

Table 3: This should be correct because the lower one is the denomination.

Figure 2: The speed changes in Karakoram are very complex, and this is why this region was not included in Figure 2. However we do agree that this region can be included in the figure, and this will be done in the final version.

Mauri Pelto

Thank you for your valuable comments on our paper. We plan to follow your comments as indicated below.

3032-15 and 3035-21: See answer 4 to Anonymous Referee #1.

3035-12. We will include kinematic wave theory in this paragraph together with a discussion on response times for different glacier sizes.

3026-11: This sentence will be rewritten according to the suggestion.

3039-13: Image matching is not a suitable method in most of the accumulation zones because of the lack of contrast in these areas.

Interactive comment on The Cryosphere Discuss., 5, 3025, 2011.