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The Cryosphere
Discussions

Interactive comment on "Surface motion of active rock glaciers in the Sierra Nevada, California, USA: inventory and a case study using InSAR" *by* Lin Liu et al.

Lin Liu et al.

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We thank Dr. Humlum for his insightful and constructive comments. We have addressed all of them and made the suggested changes in the new version of our manuscript. Our point-by-point replies (in black) to his critical comments (in blue) are listed below.

This linked pdf file is our revised manuscript with all changes highlighted in yellow (http://www.the-cryosphere-discuss.net/7/C437/2013/tcd-7-C437-2013-supplement.pdf). Please note that the page/line numbers are different in the original discussion paper and our revised paper. And in our following replies, we refer to the line numbers in our

revised paper.

As one example of this might be mentioned the geographical position provided in figure 4 of the main study locality, the Mount Gibbs rock glacier. The position given in the text for this particular rock glacier (page 348) takes you nicely to the correct place, but this position differs from that provided in figure 4, which takes you to an entirely different place.

AUTHORS: Dr. Humlum's first comment on 'geographical position' is unclear to us. We believe this is about the different viewing angles of the Mount Gibbs rock glacier in Figs. 2 and 4 (now Fig. 5), which may be confusing to readers. We rotate both Fig. 5a and 5b clockwise by 180 degrees to match Fig. 2.

It might actually be useful for the reader if you clearly stated in the text that many of the rock glaciers in Sierra Nevada really come out nicely using Google Earth.

AUTHORS: We state explicitly in section 2.1 (lines 95-97) that most of the Sierra Nevada rock glaciers are clearly visible on optical imagery such as air photos and Google Earth images. And our supplementary materials include a Google Earth KML file that gives the location of all active rock glaciers in our inventory.

For another example the reader might be referred to page 345. In line three is stated that rock glaciers may sustain surface runoff in a warming climate. Presumably what you mean is that they are important for runoff in climates which are dry during the growing season, and this not being dependent upon climate warming or cooling?

AUTHORS: Thanks for pointing this out. Yes, we mean that rock glaciers sustain runoff in dry years, which is now clarified (line 25).

A third example can be found on page 348. Here you write that 'The till flowing into (the?) lake origins from the ice glacier at the peak of Mount Gibbs'. What do you here mean by 'till'? In a geomorphological/sedimentological context 'till' is defined as sediment deposited by a normal (ice) glacier. Are you instead referring to melt water coming from the ice glacier at the head of the rock glacier, or what? Please clarify what is meant by this statement. Looking at the Mount Gibbs rock glacier on Goggle Earth I see no indications of till flowing into the lake (Kidney Lake) in front of the rock glacier.

AUTHORS: We do mean unconsolidated sediment deposited by an ice glacier. We clarify this in our revised manuscript as "To the east of the rock glacier terminus is glacial till that extends into the lake and forms the lake's concave shoreline. The glacial till, which is labeled in Fig. 2, is not part of the rock glacier but originates from the ice glacier at the peak of Mount Gibbs." (lines 118-120)

At some places the meaning of the wording used seems unclear to me. As an example, on page 353 (line four) I was left wondering what exactly was meant by the expression 'deeper in cirques' and also how this might affect flow rates?

AUTHORS: We now clarify that the southern rock glaciers are located on cirques that have steeper slopes and lower basins, resulting in more rock sliding and less solar radiation, both contributing to faster speed (lines 247-250).

Then moving on to more important matters, on page 352 it is mentioned that your study (database) considers 59 rock glaciers in total, but I was not able to find any information to how many of these are classified as inactive or active by previous studies (especially Millar and Westfall 2008)? This would be very useful for the reader to know, to compare with your findings.

AUTHORS: We are not sure why Dr. Humlum missed the entire paragraph on page 353 (original discussion paper) that compares our database with the Millar and Westfall

2008 database. We choose not to make any changes to the previous version. Here we provide a short summary of the comparisons and more details are given in the text (now lines 257-271): 14 out of 59 rock glaciers in our database are classified as active by Millar and Westfall 2008; 16 of the active ones in the Millar and Westfall database are not included in ours; ours includes 44 ones that are missed by Millar and Westfall 2008. We also discuss the causes for the differences and conclude that these two databases are complementary.

Another important question which came up was this: how can you feel sure that you are recording the true rock glacier movement by your analysis, and not only (or partly) normal periglacial surface creep? In my opinion, this important question deserves to be discussed in the paper. The movement pattern shown by figure 4 apparently makes much sense when interpreted as representing the true rock glacier movement, but it would have been even more convincing, had you also shown the periglacial surface creep rate (if any) recorded for the slopes around the rock glacier. On figure 4, the rock glacier is masked out, and movement only shown inside the rock glacier limits, so it is impossible for the reader to carry out this visual test.

AUTHORS: We add a paragraph in the method section on InSAR inventory (lines 205-216, section 3.2) to describe our strategy to separate rock glaciers from other moving features in high mountains. Locations of soil solifluction and boulder streams are listed in the database of Millar and Westfall (2008), which is used to exclude these two types of periglacial features from our inventory. All other features (debris flows, landslide slumping, avalanches, rock fall/slides, or regular ice glaciers) typically move at speed sone order of magnitude higher than rock glaciers, and therefore lose coherence in our 46-day-long ALOS interferograms. These features also have distinct geomorphic characteristics and can be easily separated from rock glaciers by visual inspection using Google Earth images.

A third critical remark relate to the rather short observation period your analysis is based on. Most observations are done between April 2007 and January 2008 (latest in May 2008), within one year only. Can we feel sure that the seasonal differences described in your manuscript represent persistent phenomenon, and are not only (by chance) due to the short observation period? Again, I tend to agree that your interpretation makes a lot of sense, but I would very much prefer to see it substantiated by an analysis based on observations made over a period of several years.

AUTHORS: Only ALOS SAR data acquired in 2007 and 2008 are available to us (line 141). We point out at several places including abstract and conclusions that the seasonal variation occurred in 2007-2008 season (e.g. lines 11, 12, 275, 351-352, 421). At the end of section 5.3 (lines 407-410), we mention that a few recently launched and future InSAR will continue the observation period.

Finally, I would also like to see a more detailed comparison between field measurements observations and your results based on a remote sensing technique. Let me give you one short example of how this might be achieved: One of your conclusions is that rock glaciers in the southern Sierra Nevada move faster than rock glaciers in the central Sierra Nevada, but you also mention that there was no significant correlation between the movement rate and elevation or size of the rock glaciers studied. Here it struck me that you might easily be able to carry the analysis one important step further. At least, looking at snow drift forms clearly visible in the Google Earth images I obtained the impression that your study region must be dominated by snow blow from the southwest? This visual impression (if correct) might represent a nice and easy way of testing the importance of snow drifting and snow avalanching for the activity (movement rate) of rock glaciers in the Sierra Nevada? At the Mount Gibbs rock glacier you even see (in Google Earth) nice traces of snow avalanches transporting snow and rock debris down onto the ice glacier at the head of the rock glacier. The diagram shown along with these comments is based on your own supplementary data and shows the distribution pattern of your rock glacier sample and their associated flow rates as found by your analysis. To me it appears that there is a pronounced dominance of rock glaciers facing NE, that is, downwind in relation to the SW winds suggested by snow drift forms visible in Google Earth. In this way (presumably there are several others) I believe that your analysis in the 'Regional inventory' might be taken further by comparing with available field observations.

AUTHORS: To our knowledge, there are no field observations on rock glacier flows in the Sierra Nevada of California. We hope our remote sensing study could provoke the interests of the US community and highlight the need of field observations. We add a histogram similar to the one made by Dr. Humlum as a new figure (now Fig. 4) to show the NNE dominance. We discuss that such this is common for rock glaciers and normal ice glaciers to form in the northern hemisphere because of the solar radiation aspect. Snow accumulation due to drifts from SW winds and snow avalanching in this region may also contribute to such N-NE dominance (lines 236-239).

Interactive comment on The Cryosphere Discuss., 7, 343, 2013.