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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.

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We thank Dr. Kääb 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.

page 344/line 11: the surface flow is influenced by surface geomorphological features? How do you know that it is not the other way round? I don't find such evidence from your data. Perhaps just say the both are correlated, or so.

AUTHORS: Agree. We now state that surface flow is correlated with surface geomorphological features (line 9).

349/16: date of DEM? Potential influence of elevation changes between DEM date and PALSAR acquisitions?

AUTHORS: We now specify the date of DEM (1999-2001) and point out that the errors in surface flow measurements due to the elevation changes between DEM date and PALSAR acquisitions are regarded as topographic errors, which have been estimated and removed in time series analysis (lines 145-149).

352/16, 352/4: no correlation between speed and elevation or size. This contradicts 353/4, where you state that elevation is responsible for the regional speed differences.

AUTHORS: We delete the sentence regarding the correlation between speed and elevation or size because such simple correlation analysis gives little insights about the controlling factors on rock glacier speeds and could be misleading.

As to the regional speed differences, we speculate that they are due to the difference in topographic relief. Compared with the ones in the central Sierra Nevada, rock glaciers in the Southern Sierra Nevada occur on slopes with greater relief (steeper slopes and lower basins), resulting in more rock sliding and less solar radiation that both contribute to faster speeds (lines 246-250).

Further, to what extend could your simplified incidence angle and slope be responsible

for diluting a potential correlation? In any case, you NEED to provide an estimate on the potential impact of this simplification in incidence and slope angles. And you should explain why you used the simplification. If I am not wrong, the computation of pixel-wise correct incidence angles and slopes should not be very complicated.

AUTHORS: Thanks for your suggestion. We now use site-wise incidence angles and mean local surface slopes to convert the InSAR line-of-sight motion into downslope motion using eq (1) for all rock glaciers, as we did for the Mount Gibbs Rock Glacier (lines 222-224). The updated flow speed values are similar to the ones obtained using simplified constant angles. For instance, the regional mean values are 56 cm/yr (as opposed to our previous mean of 57) and 39 cm/yr for southern and central Sierra Nevada, respectively. Out inventory (including Fig. 1, supplementary spreadsheet and KMZ files) and Table 2 have also been updated.

352/20: such comparison to other speeds is not very conclusive. See Fig 3 in Kääb et al. 2007 (in your ref. list). If, you might want to relate it to some MAAT for your region and average rock glacier height, or so.

AUTHORS: We remove the comparison with other rock glaciers. We choose not to compare the InSAR-based rock glacier speeds with temperature records such as MAAT because as pointed in Kääb et al. 2007, MAAT serves better as an index of maximum rock glacier speed in a regional scale than to correlate with individual targets.

353/3, 359/1: is the regional difference between 57 and 39 cm/yr statistically significant??? Could it also be due to your simplification of incidence and slope angles? What if rockglaciers in the different parts have actually different average slopes, or have different average ground ranges?

AUTHORS: As described above, we recalculate flow speeds for all rock glaciers using correct incidence and slope angles. The updated regional means are 56 $\pm$15 cm/yr

and 39 $\pm$ 8 cm/yr for the southern and central regions, respectively (lines 244-246). Therefore, the regional difference is significant, which is also visually demonstrated on our regional map (Fig 1). The uncertainties of the mean values are represented by the standard deviations of the speed values within these two groups.

354/26, and later: your 3 months delay is reasonable, but if I am looking at Fig 5 it could also be only 1 months taking into account the error bars. Give some, at least rough, error estimate/consideration for the delay. On the other hand, your 3-months estimate is similar to the one found by Kääb et al. (2007) (their Fig. 6).

AUTHORS: Considering the uncertainties and data gaps, we now state that the estimated delay ranges from 1 to 4 months with a median value of 3 months (lines 296-298). We also add a reference to Kääb et al. (2007) when we compare this observation with the few other existing observations (line 356).

355/9 and further: I agree with the strengths of InSAR, but you should mention somewhere that airphotos have also been used for regional rock glacier speed inventories, with some advantages (besides the mentioned disadvantages) to InSAR, e.g. are they in principle spatially more complete (no layover etc.) and provide 2-D velocities. E.g. Roer I., Kääb A. and Dikau R. (2005): Rockglacier acceleration in the Turtmann valley (Swiss Alps): Probable controls Norwegian Journal of Geography. 59, 157–163. Roer I., Kääb A. and Dikau R. (2005): Rockglacier kinematics derived from small-scale aerial photography and digital airborne pushbroom imagery Zeitschrift für Geomorphology N.F. 49(1), 73-87.

AUTHORS: We point out that InSAR and optical remote sensing techniques are complementary as the latter can provide 2-D velocities at even higher (e.g. sub-meter) spatial resolution and it is not limited by the layover problem (lines 312-314).

356/26: Kääb et al. (2007) themselves found a similar discrepancy between purely thermal diffusion-based speed variations, and observed ones, and suggest melt water penetration as reason. See also 357/1-16.

AUTHORS: We add that Kääb et al. (2007) found a similar discrepancy between the in-situ observations and the modeled speed variations that are solely driven by thermal diffusion. (lines 363-365).

357/1-16: a bit weak and unclear. Perhaps tone down. E.g. ice melt at depth? How should that work? Do you mean basal melt from lateral water influx? Or warming of ice due to penetrating melt water?

AUTHORS: We clarify the discussion related to internal melting (line 367), which is related to both thermal diffusion and warming effects of penetrated water. We also include penetrating of melt water from surface as a possible mechanism (lines 370-371).

It would be good to see more examples like Fig 3(a), i.e. interferometric displacements, to give the reader a better feeling about the kind and quality of results you build upon. Perhaps in the Suppl. But also the main article could easily contain 1-2 such figures more. (sorry, if such figures are present in the Suppl. and I didn't find them). You could also include them in the .kmz.

AUTHORS: The overall file size of a supplement is limited to 50 MB. But each KMZ file containing our high-resolution (10 m) interferogram is about 40 MB (after compression) and the total supplement material size would be over 150 MB. We believe that Fig. 3a already provides a good visual example of interferograms and therefore choose not to provide these large images.

page 344/line 6: ... at speeds THAT range ... (?)

AUTHORS: We add 'that' (line 5).

344/18: ... changes of rock glacier KINEMATICS in a warming ...

AUTHORS: We add the word 'kinematics' (line 16).

353/9: also solid material (i.e. debris) supply could be important, itself depending on among others geology and topography.

AUTHORS: We add 'debris supply' to the list of local factors (line 254).

356/4: annuAl

AUTHORS: We correct this typo (line 325).

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