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Interactive Comment

Interactive comment on "Landslide dynamics and coupling revealed by L-band InSAR in central Georgia" *by* E. Nikolaeva et al.

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We greatly appreciate the comments and suggestions made on our manuscript. According to the comments, we improved this manuscript considerably. Please, find our answers, following the original reviewer comments.

COMMENT: Further, the title "Landslide classification and hazards" does not really reflect the content – I suggest "Landslide mechanisms" or similar.

REPLY: We fully agree with that that the title 'Landslide mechanisms' better reflect the content that 'Landslide classification and hazards'. Accepted and changes made.

COMMENT: Introduction It seems long and could be condensed. In particular, section

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1.2 could be shortened (e.g. the first sentence is not needed).

REPLY: Section 1.2. We considered this section and deleted several sentences (the first sentence and whole paragraph 'The appearance of a landslide may depend on the type . . .').

COMMENT: Regarding section 1.3 (Landslide detection: : :), your work is focused on a single slope failure and, therefore, some comments (and references) on broad-area landslide investigations and generating landslide inventories could be omitted. What does InSAR work by Perski et al (2009) on mining subsidence have to do with landslides?

REPLY: Section 1.3. We shortened the broader introduction and removed the Persky reference. We would like shortly present a wide range of remote sensing methods and data to detect and study landslides in this section and where the output from remote sensing can be useful (hazard analysis, early warning, inventories among so on). We remove the reference Persky et al (2009). This paper describes a landslide area but not focuses on the landslide.

COMMENT: Section 3.2 InSAR – some parts and terminology used could be hard to understand to landslide scientists unfamiliar with radar interferometry and "sending" the readers to very technical literature alone may not be the best solution - you can consider making a reference to works on InSAR written for landslide people (eg Colesanti, 2003, 2006).

REPLY: Section 3.2. We are very grateful for this remark. We followed it and added references as suggested. However, we kept the references to technical literature in case if reader would like learn more about method.

COMMENT: Data interpretation Section 4.1 InSAR – interferograms like those in Fig. 4 are most often used for qualitative-type interpretations. Since you interpret them in a quantitative way (velocity profiles in Fig. 4 and, especially, velocity changes in

Fig. 9), it seems necessary to explain the quality/reliability of these results in terms of precision (displacement velocity results) and errors involved (I can see some noise in the results).

REPLY: Section 4.1. We selected only interferograms with high quality. However, the interferograms (F, G, H) have still nose level due to slave image from 4 Mar 2009. We decided to include for lack of better data.

COMMENT: Also, the sites G, B, R and M should be explain in Fig. 4 caption. Further, are you considering polygons including several pixels?

REPLY: Fig. 4 We added a caption in Fig. 4. 'Polygons are marked with the letters G, B, R and M present areas where average velocities were calculated for Fig. 9'

COMMENT: Section 4.4 Slide volume –exponent 1.3 applicable for both shallow soil and deep bedrock landslides? From the descriptions of the slope geology and morphology it seems you have a deep slide involving bedrock. Some explanation is desirable here.

REPLY: Section 4.4. The exponent 1.3 is applicable for both shallow soil-based and for deep bedrock landslides (Larsen et al. 2010).

COMMENT: Section 5.1 Impacts – the landslide directly affected 4 villages? This is an important statement, but while understandable for Itskisi, it remains unclear in the case of the other 3 villages. Please clarify. Fig. 10 alone, though nice, is not enough.

REPLY: Section 5.1. We added a description of the villages locations relatively to landslide to show possible impacts: 'The villages Savane and Makhatauri are separated river at the foot of landslide. In the scenario of landslide occurrence the landslide may block a river and reach the village Savane which is 300 m away from the landslide area. The village Itavaza is located on the opposite slope of the landslide'

COMMENT: Further, Fig. 10 deserves some more explanation. To what period refer the presented InSAR LOS displacements?

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REPLY: Fig. 10 We added period on InSAR in Fig 10 caption (2009 09 04- 2009 10 30).

COMMENT: In addition, the displacement vectors on the profile would indicate that the predominant mechanism is rotational with significant away from the sensor movements occurring more than 200 m further upslope from the inferred "headwall fault" position (red dashed line in Fig. 10). This need to be explained.

REPLY: We have revised 'headwall fault' based on geomorphological and InSAR data. Please see changes in Fig. 10. The small displacement observable on the right (relatively to 'headwall fault') is due to activity on the left (relatively to 'headwall fault').

COMMENT: Section 5.2 Triggering factors – should explain the spatial resolution/quality of the precipitation information from ECHAM5. Further, the interpretation of rainfall data in terms influence on changes in landslide movement velocity is a bit simplistic. Average monthly precipitation alone may not necessarily be significant in case of deep landslides that are often characterized by very complex hydrogeologic regime (some such slides "respond" to multi-month or annual variations in precipitation). And you deal with a large, deep landslide complex and have no information about groundwater levels in the slope and their variations. Thus your conclusion about rainfall and landslide acceleration is weak and speculative. Considering the July 2007 earthquake parameters (and the general magnitude-distance relations – cf. Keefer, 1984 GSA Bull., 2002 Surveys in Geophysics), it is very unlikely that this event could have resulted in the increase of the landslide displacement rate. The above interpretations are illustrated with the aid of Fig. 9, which, however, needs to be improved: need to select other colors, because your choice of red, magenta on top of magenta bar graphs simply does not work well.

REPLY: Section 5.2. We added description of ECHAM5: 'The spatial resolution roughly equivalent to 2.8 degrees in both directions, latitude and longitude (Roeckner et al., 2003)'. We agree that conclusion about rainfall and acceleration is weak and specu-

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lative. In the absence of other data (about complex hydrogeological regime, ground water levels) and the inability to obtain them from private mining companies, we used only remotely data to guess possible processes. It is a reason why we included this part in Discussion and not in Results paragraph. Similar situation is with earthquake triggering factor. Because of we do not know and cannot investigate impacts of private mining area on the landslide activity, we could only discuss about possible earthquake influence. Also we agree that the July 2007 earthquake unlikely could have resulted in the acceleration of the landslide displacement rate. However, we would like to save this information together with information about earthquake 2009 to show maximum seismic events which were occurred during Jun 2007 - Oct 2009 in the area away 30 km from the landslide. Fig. 9. We changed a color, as you suggested us.

COMMENT: Section 6 Conclusions You invoke a possible catastrophic scenario in reference to future earthquakes. However, deep pre-existing landslides are rather rarely reactivated by earthquakes (cf Keefer, 1984 GSA Bull., 2002 Surveys in Geophysics), though some cases of delayed post-seismic reactivations are known (eg Wasowski et al, 2002, Surveys in Geophysics). It would appear, however, that landslide toe mining represents a more immediate and concrete threat in your case. Last paragraph – a bit vague (complex remote sensing techniques for early warning) – differential InSAR could help, especially considering the shorter re-visit time (and resolution) of new generation radar sensors (cf. Bovenga et al, 2012, Remote Sensing of Environment).

REPLY: We would like to change a sentence 'The danger of a landslide is that earthquake can cause it to suddenly become catastrofic' to the next sentence: 'The landslide or its part may be activated given the proximity (~30 km) of a possible focus of a strong earthquake (Keefer 1994, Wasowski 2002).' Follow your note about last paragraph we would like to delete it: 'The results of this study demonstrate . . . investigated with remote sensing data'.

Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., 1, 4925, 2013.

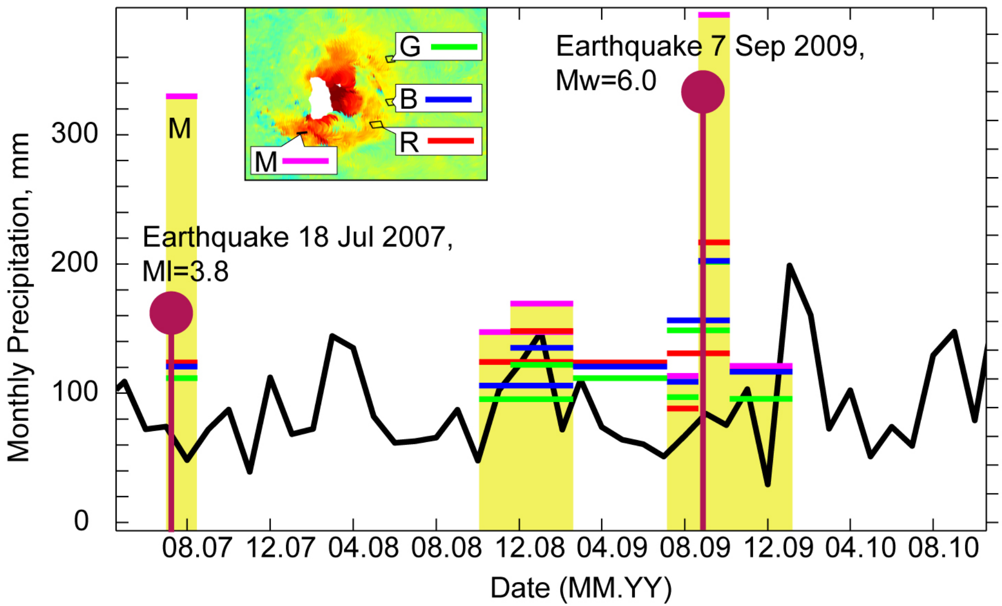

Fig. 1. Figure 9

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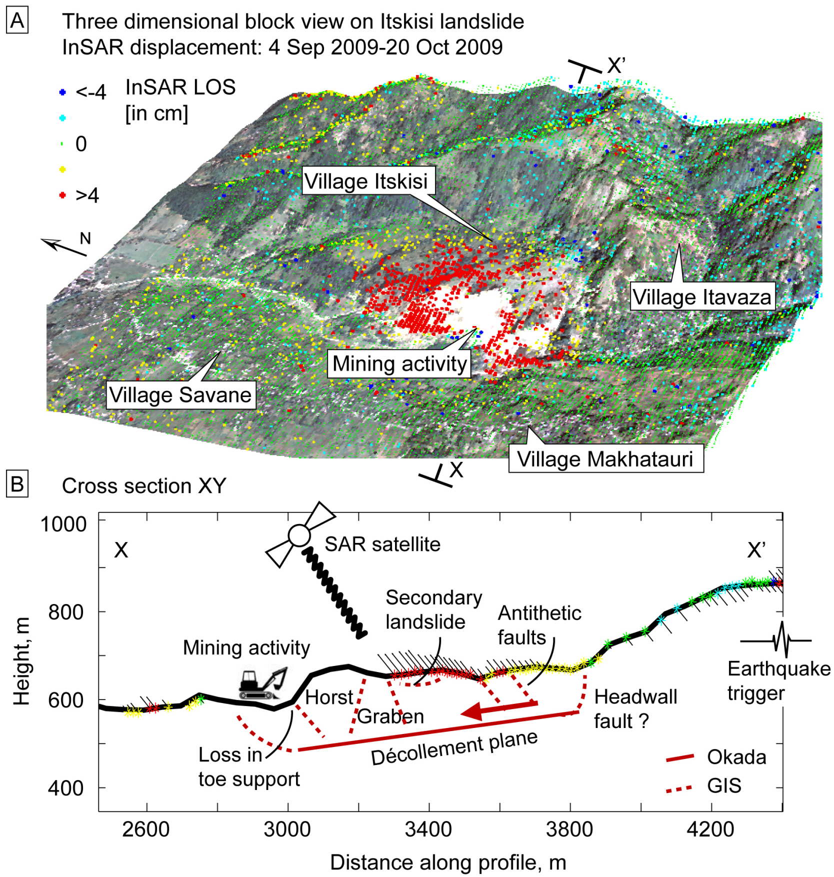

Fig. 2. Figure 10