

Interactive comment on “Effects of finite source rupture on landslide triggering: The 2016 M_W 7.1 Kumamoto earthquake” by Sebastian von Specht et al.

Sebastian von Specht et al.

specht@gfz-potsdam.de

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Dear Odin,

thank you for commenting on our manuscript. We considered your suggestions in detail to improve the presentation of our study. Please find below our point-by-point response to the *original comments*:

1. *P8 L5-20 : In this paragraph I think you want to cite Marc et al 2016 (JGR about landslide total area and volume) and not Marc et al 2017 (about affected area).*

Reference is corrected.

C1

2. *P11 : L20 – 25 : the comparison of the 2 equations is a bit misleading because you add 2 terms (anelastic attenuation ,and M_w dependent geometric spreading c_5), and shuffle the order : c_3 becomes c_4 in the second equation... Why not writing the second Eq : $\ln(l) = c_1 + c_2M + (c_3+c_4M)\ln(r) + c_6 r$ Also note that including anelastic attenuation has also been done in various studies (Meunier 2007, 2013, Yuan 2013) so it is not completely new. Nevertheless, I agree that it is often difficult to constrain the attenuation coefficient and thus, using geometric spreading only is often preferred.*

The entire equation paragraph has been rephrased in more detail and the first equation uses now coefficients p_i that are compared and discussed with coefficients c_j of the second equation. The remarks on anelastic attenuation are now incorporated (page 13 lines 8-15). This refers also to the last comment.

3. *P14 L 11: indicating a landslide failure process starting from the crown and according to simulations by Dang et al. (2016). Sentence with a missing word ?*

Indeed: indicating a landslide failure process starting from the crown and which is according to simulations by Dang et al. (2016).

4. *Fig 5 : Maybe indicate the Attenuation parameter obtained from the MLE exponential fit ?*

This comment is in connection to the comment for Fig. 9. The y-axis label reads now landslide concentration and is consistent now with Fig. 9, 12, 14, and 15. The figure has been reworked to account also for different distance metrics (rupture distance and asperity distance). The parameter estimates have been added to the figure.

5. *P15: L 1-9: Unclear what is the main message or aim of this paragraph. L1 Locations rather than localities ? L1 “Propagated progressively” : What do you mean? Are you talking about rupture propagation (as suggested by the following*

C2

lines) or about run out (i.e landslide downslope, rapid, motion after failure). Because unless you specifically restrict analysis to scar areas the “flatter areas” are likely deposit areas, related to runout termination not rupture propagation.

This paragraph is specifically about the rupture process.

The first sentence has been changed as follows in page 15 line 3:

Most landslides originated at locations with amplified ground accelerations and steep hillslopes and propagated progressively to flatter areas with less amplified ground accelerations and deposited the material in areas of attenuated ground accelerations.

6. *L10 : Mt. Aso and its caldera and Mt. Shutendoji had a high density of landslides (Fig. 5), whereas Mt. Kinpo and Mt. Otake lack landslides, though these locations are closer to the epicenter and at comparable distances from the rupture (Fig. 5). Actually it is not so clear on Fig 5 (Aso is relatively low, similar to Otake). Referring to Fig 7 where the low spatial density is clearer (and adding Peak Names on this figure) may be better.*

Another reviewer made similar remarks and the figures showing the peaks have been updated.

7. *Figure 4 : This is a nice ans standard figure. It may be worth to show the same figure done with the non EQ landslides ? That may be a simple to do supplementary figure that would show nicely if the trend in MAF is significant and due to the EQ (as there is no reason MAF should relate to rainfall induced landslides).*

The NIED landslide inventory is unspecified with regard to the landslide trigger and we cannot extract the non-seismic landslides.

8. *Fig 6 very nice figure*

Thanks!

C3

9. *Fig 8: Density of landslide concentration is an awkward term. I guess it is the Kernel Density estimate of Landslide concentration (remind the unit of landslide concentration as in following figures)*

In Figure 9 (and Fig. 5 and 15 for that matter) the density is normalized to integrate to 1, while in figures 12 and 14 it scales to the landslide concentration, hence the different labels and units. Figure 5, 9 and 15 have been updated and the labeling and scaling is consistent with figures 12 and 14 with landslide concentration. This has implications on the parameters in Eq. 27 and 28 which have been accordingly updated.

10. *P20 L2 :“depends on the ratio of rupture and shear wave velocity and the length of the rupture (Spudich and Chiou, 2008).“ Unless rediscussed later, it would be nice to know how: If fault length and rupture velocity indicates the ptotential importance of directivity for landslide pattern, it may be included in simple models.*

The work of Spudich and Chiou (2008) explains in detail the procedure on how to use these parameters. Unfortunately, even their simplified model is relatively complex as it needs to account for the seismic radiation pattern. Describing it in more detail in this paper while not using the method would go too much off-topic and we have investigated one earthquake only here. Like the Somerville et al. (1997) model, it can be added as a term to existing GMPEs.

11. *Fig 11: On figure 11 I would have like to see the FN/FP in more details for the low frequency range. Indeed, how much of the variations in the 0.1-1Hz range remain in the 0.5-1Hz range ? Because we may expect the PGV/PGA at 0.1Hz too weak to cause landsliding, compare to the one between 0.5 and 1 Hz. If the authors can make it easily I would suggest they split the 0.1-1Hz range in 2 or 3 subplot, as it may yield useful insight for later studies on frequency effects on landslide triggering. Maybe as a supplementary figure, or as a few lines about the contribution of subranges of frequencies. This is somewhat shown in Fig 10 but*

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as far as I understood Fig 10 is model and Fig 11 is data. The text is somewhat unclear about that and does not call Figure 10, I think.

This comment may arise due to the missing link between Fig. 10 and 11. and the requested frequency dependence is actually addressed by Fig. 10. Similarly to Fig. 11, we added now the KDE in Fig. 10 to show the data distribution. In the text, we link Fig. 10 and Fig. 11 better.

12. *P25:L32: Maybe not so intractable : Using an estimate of landslide width, and expectations on landslide scar aspect ratio (Domej et al., 2017) the scar area can be estimated and the corresponding high elevation pixels can be extracted within each polygons. This requires high quality mapping where individual landslides are not bundled together. But this approach has been validated and shown to improve correlation with rainfall in Marc et al., 2018a, and shown to improve volume and erosion estimates in Marc et al., 2018b. This is a side topic for your study, but it could be mentioned, and at least this statement may be more nuanced.*

This comment highlights the landslide complexity and we changed the sentence.

Changes in text:

The reconstruction of the landslide failure planes is limited to statistical assessments of landslide inventories (Domej et al., 2017; Marc et al., 2019).

13. *Fig 12 : I would say the caption can be simple and clearer as : a) Aspect and hill-slope inclination distribution within areas of the earthquake triggered landslides. This distribution is normalized by the distribution of the aspect of all hillslopes in the landslide affected area.*

The formulation is less redundant and we changed it as stated.

14. *P21 L9 : This is an interesting and important point, but I would maybe rephrase it in terms of slopes. Because it is the slope that control the aspect of a landslide (that is what you measure on your DEM) and the earthquake is simply*

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preferentially causing failures in some slopes (because wave motions and accelerations are stronger in some specific directions that will increase more or less the slope parallel component leading to failure). So the pattern of ground motion favor landslides in some part of the landscape, and at finer scale the directions of ground motions (FN/FP ratio) will force failure on specific slope aspects. I would say a few lines discussing when and how different earthquakes will display strong directivity effect would be a good addition (maybe starting from your statement about Rupture speed and length ? Cf comment above).

We made changes and rephrased it in terms of slopes. As mentioned before, we investigated only one earthquake here. While the directivity effect is well studied and basically all major earthquakes display it, deriving generalizations (e.g. behaviour as function of rupture speed) with regard to interactions with landslide requires the investigation of more earthquake data. At this point, we could only speculate for the general case.

Changes in text:

This highlights that the earthquake affects the landslide locations (Fig. 6, 7); and will force failure on specific slopes facing in the direction of ground motion (Fig. 12, 14).

15. *P26 L18 : As commented above, Meunier 2007 (as well as Meunier 2013) consider landslide decay away from the source with a geometric and an exponential decay, similar to anelastic effect.*

The highlighted sentence is formulated in an ambiguous way. It should read that Meunier et al. (2007)—as one of few—incorporates the attenuation term in landslide related GMMs.

Change in text:

The latter is commonly not incorporated in landslide studies but has been incorporated by more recent studies (e.g. Meunier et al., 2007; Massey et al., 2018).

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