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Discussions

NHESSD

Interactive comment

Interactive comment on "Prediction of the area affected by earthquake-induced landsliding based on seismological parameters" *by* Odin Marc et al.

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We are pleased by the encouraging and clear review done by referee 1. In this preliminary reply we mainly aim at clarifying the meaning of a_c and why we define it like this. We believe this will resolve most of the recurring problem the referee have underlined with a_c in his comments. We hope the added sentences (Page C3 of this comment) make the definition of a_c clear and sound and encourage both referee to double check they are sufficient.

The Line numbering is following the NHESSD Latex Template, with a Page / Line schemes. We will use it to locate changes related to specific comments. Below the comments are repeated and addressed.

Page 2, paragraph 1: Examining the zone of concentrated landsliding rather than the

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extreme limits of landsliding is a sound approach to eliminate outliers and unusual conditions.

» Agreed. We will add a similar comment on Page 2 Line 6/7

Page 2, paragraph 2: Suggest adding Keefer (2002) to this list of references. His updated paper contains additional data.

» Page 2 Line 12: We will include Keefer 2002.

Page 2, paragraph 2: This relation is parallel to the relation between Arias intensity and seismic moment developed by Wilson and Keefer (1985, p. 334). This is an early and somewhat archaic reference, but it laid the groundwork for the kind of modeling done in the current paper and probably should referenced.

» Page 2 Line 31: We will also include Wilson and Keefer 1985

Page 3, paragraph 2: Unclear what the term "oversteepened slopes" means here. "Oversteepened" generally means that some geomorphic process has created a slope having marginal static stability; active cutbanks of rivers are an example this. But earthquakes trigger landslides on slopes that are perfectly stable in static conditions but that fail under seismic loading. It is not a matter of oversteepening. And the next line states that critical acceleration (ac) is independent of slope angle, so why would only oversteepened slopes be more susceptible to failure? These statements are inconsistent.

» Page 3 Line 8: By oversteepened we mean here slopes that are steeper than the coefficient of friction of the material and therefore stable only because of a relatively high cohesion. We do not want to refer to a specific mechanism, and oversteepened is probably misleading.

Our hypothesis is that these "Cohesion Stabilized slopes" will fail if the repeated cycles of strong motion cause a sufficient drop of cohesion. Therefore a_c is not the critical acceleration defined compare to a static force balance and factor of safety, but we define it as a material property, setting the acceleration at which damage (cohesion reduction) initiate. This was more developed in Marc et al 2016b, and we now have developed it here too, to avoid confusion.

We will replace: "Over-steepened" slopes by " slopes above their friction angle and thus stable due to a significant cohesion".

Then we will add: "Therefore in this paper, a_c is not related to the safety factor and slope gradient of a given hillslopes, but only defines at which level of acceleration damage and cohesion reduction will initiate (cf. Marc et al., 2016b for more details). With this definition we consider that a_c must vary modestly compared to cohesion that can vary greatly between soil and fractured or fresh rock. This is consistent with modest variations of the minimum acceleration at which landslide occurred estimated for landslide mapped by satellite (0.1-0.2g Meunier 2007, Hovius and Meunier 2012, Yuan 2013) or minor rockfall (Jibson and Harp 2016). The initiation of soil non linear behavior has also been observed around 0.15g (Wen 1994). The average value of a_c across a landscape will be important to define A_d, and we initially assume that mean (a_c)∼ 0.15g to be conservative and focus on the area where significant landsliding occur. Note, that in this approach, a_c is independent of the slope gradient, but also that a slope experiencing an acceleration larger than a_c will fail only if the resulting cohesion drop make it unstable. Thus the number and size of landslide on a hillslopes will also depends on local strength, pore pressure and slopes, but we assume that when ground acceleration reaches a_c some minor failures will initiate."

Page 7, paragraphs 2 and 3: This is a good way to define the area affected by landslides that eliminates outliers on slopes having anomalously low critical accelerations. And this should encourage more polygon inventories in the future, which are becoming the norm.

» We hope this criterium can indeed be more robust and push to develop polygon inventories.

Page 9, paragraph 1: Why not use a finite-fault model and examine distances from the point or area of maximum moment release?

» Page 9 Lines 25-30: A point source is clearly unsatisfying for most cases, and if we want to define the portion of the fault that emits wave it is difficult to define a threshold of moment release. In any case as we state on Page 10 Line 11: "Moreover, cases such as the Niigata or Iwate earthquakes, are still overpredicted when modeled with a single point-source. This suggests that for these cases, with well-constrained source depth, a better prediction of RHMAX is needed, and therefore of either the source term bsat, or the critical acceleration ac."

Page 10, paragraph 3: The statement that better characterization of strength and pore pressure is necessary to refine estimates of critical acceleration is an understatement. Dreyfus et al. (2013) discussed this and should be cited here.

» We write on page 10 Line 23: To define and obtain quantitative estimates of substrate strength or of the ground pore pressure at the landscape scale is an outstanding challenge and lacking relevant constraints, we cannot assess further their influence on the variability of a_c and A_d. Here, the reviewer thinks to the classical definition of a_c, relating to FS and therefore to pore pressure and strength. But here we question whether the sensitivity of a material to damage (the a_c we use in this study) varies with pore pressure and material type. It probably does but we can hardly explore it in this paper.

Page 13, paragraph 1: The range of 0.1-0.2 g is not accepted as a "universal acceleration threshold." The Jibson and Harp (2016) study of several of the best documented earthquakes (in terms of landslides) suggests a threshold closer to 0.05 g. The difference is between the outermost limit of the smallest landslides and the zone of concentrated landsliding. This differentiation should be made clearer here. The threshold acceleration values in the different studies are really looking at different landslide limits.

» Page 13 Line 14: We agree. We also note that if 0.15g is a good measure for the concentrated zone of landsliding and 0.05 g is only 3 times smaller for the outer limits of landsliding. Rather consistent with our assumption that a_c vary moderately compared to Cohesion itself that varies on several order of magnitude. In any case we will write: “It suggests that 0.15g is an appropriate approximation for predicting the area of concentrated landsliding, while the outer limits of landsliding may be rather controlled by a smaller critical acceleration about 0.05 (Jibson and Harp, 2016).”

Figure 1: Define Ro in caption.

» We added in the caption: Ro is the mean depth of wave emission.

Figure 5: Not clear what the red circles indicate.

» Red circles indicates the absolute difference between the modelled maximum distance to wave emission and R95 : If it is positive we overestimate the distance over which are concentrated landslides (by ∼7km for Niigata for example). If it is negative it means significant landsliding persisted further than predicted (by about 5 km for Finisterre, Limon or Wenchuan).

Figure 6: Typo in caption: “name.”

» Ok

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