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Natural Hazards and Earth System Sciences
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Discussions

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

Anonymous Referee #1

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GENERAL COMMENT:

This is a well-written paper that does a very good job of providing a seismologically consistent relation between seismic energy release and the area affected by triggered landslides. The data sets used are appropriate and well documented, and the model is explained clearly even if some aspects of it are somewhat complex. The principal limitation of the paper is that it takes an almost purely seismological view of the problem and minimizes or dismisses geomorphic and geotechnical considerations, which, in fact, play a key role in the susceptibility to landsliding and thus the ultimate landslide distribution. By better addressing these concerns and taking into account both material-based and topographic effects on critical acceleration, the paper can be strengthened considerably and be a valuable contribution to the literature aimed at characterizing seismic landslide hazards.

SPECIFIC COMMENTS: [Note: line numbering in the draft manuscript is inconsistent and non-unique; this is a best attempt to identify the locations of technical comments]

Page 2, paragraph 1: Examining the zone of concentrated landsliding rather than the extreme limits of landsliding is a sound approach to eliminate outliers and unusual conditions.

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

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 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, paragraph 2: Critical acceleration needs to be expressed in terms of units. Presumably this is in terms of g, the acceleration of gravity (this is an issue throughout the paper). The selection of ac=0.15 g seems quite arbitrary and needs justification. Failure of slopes having ac=0.05 g or less is not uncommon. Provide justification.

Page 3, paragraph 2: The statement that critical acceleration is independent of hillslope gradient is completely false. In fact, critical acceleration is exquisitely sensitive to slope steepness. The basic equation defining critical acceleration [ac=(FS-1)g sin(a), where FS is static factor of safety and a is slope angle] contains the slope gradient both explicitly in the equation and implicitly in the FS term. Jibson et al. (2000) showed that critical acceleration is strongly dependent on slope angle and less so on modest variations in material strength. That is the exact opposite of what is stated here. How is this contradiction justified?

Page 4, paragraph 2: The suggestion that critical acceleration is spatially constant is very difficult to justify. Jibson et al. (2000) show clearly that landslide distribution is a function of the interaction of the spatial variation in ground shaking and the spatial variation in critical acceleration. Treating the latter as if it were constant and simply assuming that the landslide distribution is purely a function of ground-motion variation is naïve and physically unrealistic. Critical acceleration typically varies wildly over an area shaken by an earthquake. Without relitigating Marc et al. (2016) it is necessary to provide some basis for this far-reaching and questionable assumption.

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.

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

Page 10, paragraph 3: Critical acceleration is not defined as loss of cohesion. Cohesion is only one component of shear strength. Critical acceleration is the acceleration necessary to overcome the resisting shear strength (both frictional and cohesive) and initiate permanent landslide displacement.

Page 10, paragraph 3: Critical acceleration is in no way independent of hillslope steepness. It is, in fact, extremely sensitive to slope. Not sure where this idea came from, but it is demonstrably, mathematically false. As indicated above, slope enters into the critical acceleration equation in two different places and thus is doubly important.

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.

Page 10, paragraph 3: The Saguenay earthquake is anomalous not just seismologically but also in terms of the types of landslides triggered. Ground-motion amplitude was moderate, but the duration and thus number of cycles of shear stress was fairly high. The landslides triggered by the earthquake included sensitive-clay failures and slides related to liquefaction, which are more sensitive to duration than amplitude of ground shaking. The type of landslide matters as much as the peculiar seismology. Another way of saying this is that different characteristics of ground shaking (amplitude, frequency, duration) will trigger different types of landslides, and susceptibility to those types of landslides will determine the extent of landsliding. It is more than just seismology.

Page 11, paragraph 3: Here it states that slope steepness makes an area more susceptible to landsliding, but on the previous page it is stated that critical acceleration (the measure of seismic landslide susceptibility) is independent of slope steepness. This is strongly inconsistent.

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.

Figure 1: Define Ro in caption.

Figure 5: Not clear what the red circles indicate.

Figure 6: Typo in caption: “name.”

References:

Jibson, R.W., Harp, E.L., and Michael, J.A., 2000, A method for producing digital probabilistic seismic landslide hazard maps: Engineering Geology, v. 58, p. 271-289.

Wilson, R.C., and Keefer, D.K., 1985, Predicting areal limits of earthquake-induced landsliding, in Evaluating Earthquake Hazards in the Los Angeles RegionâĂŤAn Earth-Science Perspective, J.I. Ziony (Editor): U.S. Geological Survey Professional Paper 1360, p. 317-345.

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