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Discussions

Interactive comment on "Simulation of Fragmental Rockfalls Detected Using Terrestrial Laser Scans from Rock Slopes in South-Central British Columbia, Canada" *by* Zac Sala et al.

Zac Sala et al.

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Thank you very much for taking the time to read our paper Dr. Corominas. I found your work on rockfall fragmentation to be very informative when carrying out my Master's research on the subject. Your feedback here will be very helpful in revising the content of the manuscript.

1)&2) The reference list will need to be adjusted to correct the discrepancies you highlighted. Thank you for the suggested additional references on the topic of existing models incorporating fragmentation. We will add these references and additional text in the introduction (page 2) and (page 37) for clarification.

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Suggested change – Update reference list and in-text citations so that they are consistent. Include additional reference material and text for clarification on existing rockfall models which include fragmentation on pages 2 and 37.

3) A description of the inner workings of the model was left out for concision due to the current length of the paper, and its existing description in the complete master's thesis document (Sala 2018). A brief description could be added for more clarity. The collision parameters used in the model currently are a friction coefficient, restitution coefficient, and viscoplastic dampening coefficient. The fracturing of the source rock uses a voronoi fracturing algorithm in the open source 3D modelling software Blender. There are many parameters which you can modify in this algorithm to achieve different results. The simplest method is specifying the number of fragments you would like, which generates a random fracture network in the 3D volume with that number of fragments of varying sizes and shapes. Additional parameters such as the aspect ratio of the fragments can be specified to simulate preferential orientation of fractures in the network. Without detailed information on the pre- and post-fall block size distribution, and this being a first trial using the fracturing algorithm, trial and error was used during simulation, running a suite of simulations with varying input parameters, namely the initial number of fragments. As suggested in the limitations section of the manuscript on pages 35-36, we would like to do a more detailed study of the block size distributions for these rockfall in order to calibrate our use of the fracturing algorithm in Blender.

4) Given that this modelling technique is still in its infancy, guidelines for picking initial input parameters (friction, restitution, viscoplastic dampening, source fragmentation) are still being studied. The technique should be tested on more case studies, with a variety of potential material types prior to a formal set of input guidelines being published. Testing at two additional study slopes, one in New Zealand, and one in Japan, is presented in Sala 2018, but is outside the scope of this paper. Given a particular set of inputs may not reflect the conditions at any given site when running forward models, we would advise to not treat the model as a discrete approach and instead run a

suite of simulations with a range of initial inputs. This allows you to look at the range of potential impact points, and the areas with the highest concentration of deposited material in the modelling results.

5) Additional discussion of the disaggregation vs. breakage concept can be added to the paper. As discussed in the paper, the nature of scanning the slopes infrequently means that we do not observe the rockfall event directly. While modelling the blocks as a mass of individual mobile fragments of different sizes and shapes, aligns with the material visible in the rockfall deposits, we can't be sure which scenario from Figure 22 actually takes place. If breakage of individual fragments was taking place, with new fractures being generated in each block, we would expect this to affect the amount of energy present in the rockfall system, as energy is consumed and released in the fracturing and breakup of the fragments. As is discussed in Sala 2018, there is potential with this game engine platform to specify connections between individual fragments in the source volume. These simulated connections have break forces, torques, etc. While the initial fracture pattern, and thus smallest fragments would still be pre-defined, this would allow for the incorporation of some strength-based "breakage" of the initial simulated volume. This is just proof-of-concept at the moment, as it was outside of the scope of the study, and in general requires calibration data that we do not have for these rockfall events. Nevertheless it is something we are interested in pursuing.

Suggested change – additional discussion of the disaggregation versus the breaking of intact rock fragments and how that impacts rockfall runout. Also include a comment on how our model has the potential to incorporate this in future development

6) I'm not entirely sure what you mean by the runout does not consider the size of the fragments. Each fragment that is moving, moves as a result of collisions with the slope and other fragments. This collision takes into consideration the 3D hull of each fragment, and therefore it's runout is affected by the fragments size. Similarly, the change maps produced post simulation highlight changes between the initial and post-simulation surfaces, which is affected by the size/volume of the individual simulated

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fragments. Perhaps you are referring to the deposition points on Figure 17/19. These points do not reflect the individual size of the thousands of fragments that were simulated. While this could be changed, the decision to not do this was due to the fact there are so many deposition points over the range of simulations that meaningfully distinguishing size on this figure would be lost on the viewer.

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