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Interactive comment on "Short communication: Runout of rock avalanches limited by basal friction but controlled by fragmentation" *by* Øystein T. Haug et al.

Anonymous Referee #1

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General comments:

Understanding the mechanism of long run-out of a landslide/avalanche is still a great challenge, but plays an important role in correctly describing the landslide dynamics and its deposition morphology. Models and hypotheses have been presented to explain the exceptional run-out of landslide, including fragmentation. The authors mention, that fragmentation may consume energy, potentially at a cost of the runout length. So, they are concerned to specify the integrated effect of fragmentation on the runout dynamics of rock avalanches. By analysing analogue models of dynamically fragmenting rock slides, the authors isolate the effects of friction and fragmentation on rock avalanche

dynamics. For this, they assume that there exists some mechanism that causes a low, but constant effective basal friction. So, the variation in run-out or mobility (called Heim's ratio) is assumed to depend only on fragmentation. This is summarized by presenting a scaling law which shows that the change in the degree of fragmentation can explain the large variation in runout of rock avalanches seen in nature. The authors also compare their experimental results to a set of data (that also utilizes date from some internal report) and discuss their relevance to natural systems. The topic is very important and interesting. The presented mathematical model is one of the main contributions in this paper manuscript that may play a crucial role in describing runout of a landslide. There are some appreciable, clever and novel ideas, and important observations. However, there are also several critical issues on the presented model and other conceptual aspects that must be addressed properly. This mainly concerns the presented mathematical model and explaining the observed results with underlying mechanics. Parameters should be well defined. The paper could have been better organized and discussed.

Specific comments:

Some confusions are already seen in the Abstract: Usually, exceptionally long runout is associated with the large volume that results, e.g., by some fluidization/lubrication effects. This has been discussed by presenting a mechanical analytical model in https://doi.org/10.1016/j.enggeo.2013.01.012. These relevant aspects should have been discussed.

L12: 150 km/h is not that high for rapid avalanche with exceptional run-out.

L17,22: Although friction is assumed to be low and constant in this paper, the above mentioned reference resented the first-ever explicit and unified theoretical model for exceptional mobility of landslide and avalanche: with the consideration of volumetric, physical, and topographical parameters, the authors presented a new model to quantify the scale-dependent friction coefficient of large debris avalanche events. It might be relevant to discuss.

L27: “additional controlling factors”: One such very important, dominant factor is erosion/entrainment that explains the mechanical causes of exceptional long travel distance. This is worth mentioning with reference.

L41-42: “Weassume that there exists some mechanism that causes a low, but constant effective coefficient of basal friction and keep it constant in our model.”: This is a clever idea, but is this realistic and observable in nature? Please elaborate with reference.

L58-59: The normalization is a bit strange and not justified! E.g., why the length L_spread is normalized by the vertical fall height H and not by other more relevant length scale such as l_0? Also, the definition of degree of fragmentation m_c is strange and not discussed why done this way: there can be very few fragmented big boulders and almost all small particles. Then, defining m_c in terms of m_max may not be the best representative of the fragmentation. This should be discussed.

L63-71: The readers might ask why these parameter values are chosen.

L74-78: not easy to follow. Not clear which initial conditions are used.

Fig. 2: Figures could be better organized, e.g., by first putting Fig. 3 then Fig. 2; first present model then Fig. 2, etc. The strange behaviors of increasing H/L and L_spread/H with large m_c must be clearly discussed. Is this so great to mention about the plotting script in the caption?

L79-82, 85-86: Very interesting/important, novel observation, but the writing should be improved. E.g., does it mean fragmentation results in decreased runout?

L90-92: Appreciable novel observations! However, not quite clear what you really want to say. You have not yet clearly quantified the internal friction and interactions between the fragmented particles. The energy dissipation is also due to loss of momentum because of the early depositions of (many small) fragments. Such reduction in mobility due to deposition has recently been explained with the mechanical erosion model for

mass flows.

L97-118: The following are critical issues that must be properly addressed. There are two main essences of this paper. (i) fragmentation experiments and the analysis of the data, and (ii) developing a mathematical model explaining the runout in terms of fragmentation intensity. I hope the models and the associated figures are right. However, the authors must fix the following: Readers can’t follow, please derive equation (3) e.g., in and Appendix. Equation (4) might not be right as it appears now; you need 1/Mg in W, or? L_spread and W are assumed to be implicit functions of frictions and fragmentation, that might be reasonable, but are not quantified. Equations (5), (7) and can’t be obtained in a usual way, please check and prove. Further, why do you have mu inside mu? Also, the logarithmic dependency of the work W on fragmentation m_c is not clear, must be discussed. Please check carefully and derive the model equations explicitly, may be in and Appendix. Equations (6), (7): m_c > 1, by definition, and also alpha > 0, then – alpha ln(m_c) < 0, means L_spreading <0? This is not realistic. So, please derive all the equations such that the readers can easily follow and understand the mechanisms behind them.

Technical comments:

The English should be improved (e.g., L2, L14, L41, . . .).

Notations should be clearly defined (e.g., L20, what ap stands for, . . .)

L23: Heim’s ratio can be much smaller than 0.1.

Fig. 1: Caption: would be better to replace “measurements” by “scales”?

Fig. 3: Why not the same times for panels on both columns? It is difficult to compare. Also, put scales in x and y axes, and c = ** on top of the columns.

L97, 100: Parameters are not well defined. E.g., what is L_s, which length? Please clearly define all parameters and show in the figure.

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