Interactive comment on **"Debris flow modeling at Meretschibach and Bondasca catchments, Switzerland: sensitivity testing of field data-based erosion model"** by F. Frank, B.W. McArdell, N. Oggier, P. Baer, M. Christen and A. Vieli

florian.frank@wsl.ch

Reviewer 1: Z. Han

General comments

Reviewer 1: This paper aims to simulate debris-flow process by considering bed erosion along the path. As erosion is a complex natural process and plays a very crucial role both in debris-flow dynamics, transportation, run out and deposition process, it is a very important research topic. To do so, this paper attempts to combine an empirical entrainment model which has been previously introduced by authors into the RAMMS model. The sensitivity of the developed model is tested by applying the model to two debris-flow events in Switzerland. The results show some interesting erosion and flow patterns.

Authors: We are grateful for the thorough reading of the manuscript and the helpful review, which we think will substantially improve the manuscript. We address both the general and specific comments below.

Reviewer 1: Generally, this is a straight-forward development of the RAMMS model for the simulating bed erosion in debris flows. The paper is well illustrative and authoritative. The authors build upon their previous work and extend the RAMMS model to the erosion simulation. It is a major contribution and is sound. However, in my opinion, the major limitation of this paper is that the described debris-flow entrainment model is rather sensitive to the empirical coefficients, and these coefficients are not well illustrated in the paper. Indeed, the authors show us a sensitivity analysis of erosion volume to the initial volume, erosion rate and calibrated parameters and in Fig.7. As they mention, the value of these parameters are suggested by the previous study in the same region, e.g., the erosion rate dz/dt = 2.5 cm/s. However, the rational range of these parameters may be different in other regions, there is a need to explain how to determine these parameters. The paper could be improved and made more accessible by further exploring these empirical parameters. I recommend this paper for publication after major revisions.

Authors: Yes, we agree that the results of the model are quite sensitive to the empirical coefficients and the initial conditions, which is the main focus of the manuscript. The uncertainties in the field data (e.g. initial flow volume, volume of eroded sediment, magnitude of erosion) are generally fairly large. It may be by chance that the same coefficients deliver plausible results at three different debris-flow sites in the Swiss Alps when in fact it may be possible to refine the coefficients in cases where more precise field data are available. For this reason, all of the coefficients can be adjusted when more or better results become available. We intend to edit the manuscript to make this point more clear. To further explore the influence of the parameter combinations, we also intend to highlight the inherent feedback in the model, whereby a rapid erosion rate results in an increase in flow depth leading to larger shear stresses and then to even larger potential erosion depths. This potentially explains the very rapid growth of debris flows, which is has been observed in some natural field cases and also in laboratory experiments involving realistic debris-flow sediments (e.g. Logan & Iverson, 2007, Video documentation of experiments at the USGS Debris-flow flume 1992-2006, U.S. Geological Survey Open-File Report 2007-1315).

Specific comments

Reviewer 1: Page 6, 195-196. The authors mention that the slope angle φ in the deceleration term S_f is similar to the internal friction angle of the material. Does it mean that S_f will be the same when at a steep slope and a gentle slope? Please check it.

Authors: Yes, it is true that the slope angle is similar to the angle of internal friction at this slope. However we do not imply that the value of S_f in the Voellmy friction relation is the same as the value of internal friction in general. We intend to remove this comment to avoid confusion for readers, because the Voellmy friction angle is typically selected based on other criteria.

Reviewer 1: Page 7, 221-222. The critical shear stress τ_c determines the maximum potential erosion depth e_m, the erosion will not be existed at the area where $\tau < \tau_c$. For this reason, the critical shear stress is a key parameter for controlling the shape of erosion area and erosion depth. But the authors superficially use an empirical value 1 kPa in the paper, and no sensitivity analysis is made. It seems that they could simply test and provide results on how sensitive the simulation is to the choice of the critical shear stress τ_c.

Authors: Yes, we did not include results for the sensitivity analysis regarding the value of the critical shear stress, because the influence is generally much smaller and the range of critical shear stress values is small. We disagree that our choice and use of 1 kPa is superficial, because this value based on indirect observations by Schürch et al. (2011, cited in the original manuscript) and it serves a general purpose of describing that torrent channel beds are typically not eroded by small debris flows. We do not know the precise value in the field at any field site however a value near 1 gives a good fit to the data set we used for that analysis. Using a Shields's criteria for critical shear stress from river engineering, we find a critical shear stress which is smaller than 1, depending on the grain size on the channel bed. We discussed the issue of different critical shear stresses in our first erosion model application at the Spreitgraben catchment (Frank et al., 2015). Therein, we described smaller debris flood events which produced about 4-5 kPa of shear stress but did not show any significant erosion in the channel bed, i.e. suggesting that the critical shear stress τ_c may be somewhat larger in the Spreitgraben than in the Illgraben channel.

We propose inserting a paragraph discussing this issue in more detail, especially noting that the value is close to zero, or could be set to zero if field evidence indicates that erosion is always expected. However we will gladly include such a plot as an additional figure if this is desired by the editorial staff.

Reviewer 1: Page 11, 360. The total erosion volume remains approximately constant when the initial volume exceeds a certain value. How to explain this phenomenon? Is this because the maximum erosion depth e_m is reached as controlled by the critical shear stress τ_c = 1 kPa? As such, it seems that the choice of τ_c as a model parameter should be discussed to a greater degree, especially if you want your method to be used more widely on debris flows of varying properties.

Authors: In fact, the volume continues to increase (the y-axis is a logarithmic scale). The maximum erosion depth e_m may be limiting – however e_m also increases due to increasing maximum flow heights (see also Fig. 3 in Frank et al., 2015) when systematically enlarging the initial release volumes in the sensitivity analysis. Again, the model is insensitive to the value of critical shear stress once that value is exceeded (please refer to our comment above).

Reviewer 1: Page 12, 396-397. As I see in Fig.3, there is no significant difference of runout distance in B2 (μ=0.6) and B3 (μ=0.7). Please check the sentence "μ controls the runout distance".

Authors: The sentence "μ controls the runout distance" is consistent with the Voellmy friction relation as used in runout models such as RAMMS. It is not a result from this present study. We will provide a suitable literature citation for that statement and adjust the wording to ensure that readers do not see this as a result of this project. Perhaps the problem lies in the illustration of the modeling results for three μ values. The calculation domain, where the software was used, was limited in spatial extent to the area where we have differential DTM data for comparison (e.g. the blue polygon in Fig. 3A), so we actually do not show the final runout distance. In the process of answering this comment, we noticed that the blue polygon is drawn inconsistently in figure 3B1-B3, but it is drawn correctly in Fig. 3A. We will also correct this error in the final manuscript.

Reviewer 1: Page 27, 675. The total erosion volume in both cases show an abrupt decrease, and then a significant increase with the initial release volume, i.e., 1-2 m^3 in Meretschi and 10-20 m^3 in Bondasca. Is there any rational explanation on it?

Authors: When comparing erosion depths as modeled using 10 vs. 20 m^3 as the initial volume in the Bondasca case e.g., we observed that the model run using 20 m^3 is large enough that part of the flow enters a secondary channel. The volume of the flow, then divided among two channels, causes a reduction in flow depth and a consequent decrease in shear stress, resulting in smaller erosion depths and therefore smaller erosion volumes. When using an initial volume of 10 m^3 then the flow fully stays in the main channel.

We propose adding a small discussion paragraph explaining this issue.