Solid Earth Discuss.,
doi:10.5194/se-2016-79-AC1, 2016
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Solid Earth Discussions

Interactive comment on "Combined effects of grain size, flow volume and channel width on geophysical flow mobility: 3-D discrete element modeling of dry and dense flows of angular rock fragments" *by* Bruno Cagnoli and Antonio Piersanti

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Received and published: 11 August 2016

We would like to thank Ming Zhang for his good comments that are of general interests. The answers are provided here below. The Line and Page numbers refer to the new version of the manuscript which is attached.

(1) COMMENT: Lines 20-21, Page 4: When I first read granular flow mass in this paper, many questions arose in my mind included: What does this mean? How to

determine it? Why the authors use all those masses in the simulation? Why do not the authors use particle number or other parameters to quantify of total particles used in simulation? I understood until I finished reading the paper. Could authors please simply explain those questions when it first appears?

(1) ANSWER:

> The mass is an important quantity because, since the particle density is a constant, it is proportional to flow volume (Page 9, Lines 18-19) and the rock avalanches are commonly described in the field by means of their volumes. The number of particles is not a practical quantity to measure the size of a rock avalanche because it is very hard (if not impossible) to assess it in the field.

> In scaling analysis, the actual mass values that are used are not relevant provided that the range of mass values is relatively wide so that the effect of volume on the collapse of the scaling parameters along a single straight line can be evaluated. We test here a relatively large number of mass values because the volume effect on mobility is considered important in the literature (see your comment 6). We have now recapped these concepts on Page 4, Lines 29-33 (after the introduction of the mass values).

(2) COMMENT: How to determine the properties between particles, particles and channels, particle and gates in this paper? When we do numerical simulation using discrete element method, one of the most important procedures is to determine the micro-parameters of and between elements. In this research, the authors directly gave the parameters without explanation.

(2) ANSWER:

> The values of the physical properties of materials and their interactions are illustrated in Tables 2 and 3. In Section 2.1 we explain that these values represent interactions among igneous rock fragments which travel on a subsurface made of soil (Peng, 2000). These are the same values that we have adopted in the simulations by Cagnoli and

Piersanti (2015). They were adopted because, with these values, it has been possible to obtain the same relative flow mobility of the different flows as that observed in the laboratory experiments by Cagnoli and Romano (2010 and 2012a). We now recall this on Page 5, Lines 9-11.

(3) COMMENT: This research used centre of mass of deposit to calculate the mobility of granular flow in the numerical and physical simulations. However, it is very difficult to determine the centre of deposit, especially in physical simulation and in granular deposits of a real rock avalanche. Could the authors please explain how to determine centre of the deposit in their physical simulations?

(3) ANSWER:

> Any CAD software is able to compute the position of the center of mass of virtually any 3D solid (or collection of solids) no matter its (or their) shape. In numerical simulations, the position in space of all the particles is known at any time (from behind the gate to the final deposition). When these positions are imported in a CAD software, it is straightforward to compute the position of their center of mass. On Page 8, Lines 6-7, we now state that we have used a CAD software (Rhinoceros) to compute the positions of the centers of mass.

> In the laboratory experiments (and this can be repeated in the field), we constructed three-dimensional representations (i.e., the shape in 3D) of the final deposits of the rock fragments which were then imported in a CAD software for the calculations of the position of their center of mass. The same applies to the granular masses behind the gate before release. This is explained in Cagnoli and Romano, JVGR, 2010a and Cagnoli and Romano, JGR, 2012a.

(4) COMMENT: Page 9, Lines 23_25: “The collapse along a single straight line of all the data points of the simulations with θ=27° confirms that, in Figs. 9 and 10, only the variables considered in Eq. (19) have values that vary and, consequently, determine the observed different mobility of the centre of mass of the different flows.” â′S ËŸa Not

only the variables considered in the equation (19) determine the mobility of granular flow, many other variables not considered also have influence, which were actually the constant in this research. â′SaËŻ About angle of sidewall, the authors only used 19° and 41°, which is too few to find the fitness. Furthermore, they did not try to fit the three data points with width of 6 mm and three different angles of 19°, 27° and 41°. Therefore, it is not reasonable to exclude angle of sidewall as a factor affecting the mobility.

(4) ANSWER:

> In general, there are several variables which affect granular flow mobility. Some of them are discussed in Section 5.4 to provide a useful background. In our numerical simulations only grain size, flow volume and channel width have values which vary. It is correct to vary at the same time (i.e., in the same set of simulations and experiments) the values of these three variables because these quantities can be bundled into a single scaling parameter (Eq. 19).

> However two additional ancillary simulations have been carried out also with two different θ values. Our numerical simulations show that the sidewall inclination θ does affect mobility. At the end of Section 4 (Page 11, Lines 1-2), we actually write that Figs 9 and 10 show that the larger the sidewall inclination θ, the larger the values of μA. We say also that simulations with different θ values plot along different straight lines.

> In Figs 9 and 10, eq. (18) fits only the data with θ=27° (i.e., the quantities not in eq. (19) are constant). This is so because the angle θ does no enter parameter χ (eq. (19)). Angle θ cannot enter parameter χ because θ is itself another dimensionless scaling parameter and it does not make sense to multiply or divide these two scaling parameters among themselves. We now state that θ is an independent dimensionless scaling parameter on Page 11, Line 1.

> In Fig. 9 and 10, the data point of the simulation with w=6mm, δ=1mm and θ=27° is the triangle with the smaller μA value. You can see that the three data points you

mention plot roughly along a line that is almost vertical. However, three points are not enough to be sure about the shape of the functional relation, if any. Since θ is an independent scaling parameter, chances are that the three points you mention are not fitted by a single curve. We are also not much interested in θ values here because we want to verify the laboratory results where θ does not vary because it cannot enter χ.

(5) COMMENT: Page 10, Lines 25_ 28: Authors should add the latest research "Zhang, M., Yin, Y., McSaveney, M. (2016) Dynamics of the 2008 earthquake-triggered Wenjiagou Creek rock avalanche, Qingping, Sichuan, China ", which also drew the conclusion the mobility of granular flow increases with finer grain size.

(5) ANSWER:

> We have now cited this interesting paper on Page 12, Line 10.

(6) COMMENT: About impact of the volume of granular flow on mobility, the conclusion in this research is much different from our generally accepted one that mobility increases with increased volume of the granular flow. Even if this research used centre of the deposit to calculate the u/l, the conclusion is different from the research conducted by several scientists on mobility of rock avalanches (Davies et al., 1999).

(6) ANSWER:

> Our conclusions do not really contradict what previously said about the volume effect. We, instead, highlight an important aspect of a multifaceted issue.

> We believe that the larger the flow volume, the longer the longitudinal spreading of the deposits as suggested by Davies (1982) and reported by other authors (D'Agostino et al., 2010) and this is so, in a channel for example, because the planimetric area inundated by a flow is proportional to a power of the flow volume (Griswold and Iverson, 2008). This generates an inverse correlation between flow volume and mobility when this mobility is measured by considering the front of the deposit. This relation is not particularly useful, though, because the correlation coefficient can be quite small

(please see, for example, Fig. 2c in Nicoletti and Sorriso-Valvo, 1991).

> However we have proved by two independent methods (laboratory experiments and numerical simulations) that when the mobility is measured by considering the center of mass, the larger the flow volume, the smaller the mobility of the center of mass. This is the same phenomenon observed independently by Okura et al., (2000) in their much larger experimental apparatus. This is our view reported on Page 2, Lines 19-27.

(7) COMMENT: About impact of channel width, the conclusion in this research is contrary to the statistic results on rock avalanches conducted by Nicoletti and Sorrisovalvo (1991).

(7) ANSWER:

> In our paper, all our flows are channeled and we compare their mobility in channels with different width. The narrower the channel, the less mobile the center of mass. This is so because the deposit propagates backward during its formation and, the narrower the channel, the longer the backward propagation (it is also possible that in a narrower channel the retarding effect of the sidewalls is relatively more important). Nicoletti and Sorriso-Salvo (1991), on the other hand, do not compare the mobility of flows in channels with different width. They compare channeled flows with flows that have no lateral constraints.

> A different mechanism explains the differences that are observed when comparing the mobility of channeled flows with the mobility of flows without lateral constraints. In this case, the flows without lateral constraints tend to be less mobile (Nicoletti and Sorriso-Valvo, 1991). This is due to the fact that a flow without lateral constraints spreads laterally, whereas the entire momentum of a channeled flow is spent along one single direction: that of the channel. We have added this explanation on Page 14, Lines 8-15.

(8) COMMENT: The authors did not consider grain fragmentation during movement in

their physical numerical simulations, which plays a very important role in the mobility of granular mobility. Actually, many scientists (Davies and McSaveney, 2009; De Blasio and Crosta, 2014, 2015) reached the conclusion that physical simulation cannot repeat the high mobility of granular debris flow because it is not able to simulate the pervasive grain fragmentation during movement. Could the authors please explain the reason and the impact that the grain fragmentation was not considered in this research?

(8) ANSWER:

> We thank the reviewer for this comment that gives us the opportunity to explain how we work. In our paper, we investigate the effect of grain size on flow mobility. This has been carried out by holding constant the value of grain size during flow motion to prevent other phenomena from interfering with the grain size effect under study. In laboratory experiments (our numerical simulations are also meant to verify independently our laboratory results), it is good practice to study only one phenomenon at the time. We believe that good physical simulations should not reproduce the entire complexity of natural flows because a) this would be impossible and b) different phenomena would interfere with one another preventing the researcher from reaching any solid conclusion on the effect of any single quantity.

> In any case, we believe that, in nature, particle-particle and particle-boundary interactions cause particle fragmentation during flow motion. We observed this phenomenon in stationary granular flows during laboratory experiments (please see Fig 7 in Cagnoli and Manga, 2004). In rock avalanches, there is field evidence that grain size decreases as travel distance increases and that flows with long runouts are associated with a reduced grain size (Davies and McSaveney, 2009; Zhang et al., 2016). In particular, Davies and McSaveney (2009) advance a theory in which they suggest that the fragmentation process in itself can increase flow mobility. However, our research (by means of both laboratory experiments and numerical simulations) also demonstrates that, when rock fragmentation does not occur, the mere presence of fine grain size is conducive to a reduced energy dissipation of the granular flows. We have now added

this explanation on Page 12, Lines 5-14.

(9) COMMENT: Another two corrections: (1) Caption of Fig. 9. Delete “The values in millimetres are the channel widths w and the values in degrees are the sidewall inclinations θ”. (2) Caption of Fig. 10. Delete “The values in millimetres are the channel widths w and the values in degrees are the sidewall inclinations θ”.

(9) ANSWER:

> These sentences are necessary to explain the content of Figs. 9 and 10.

Please also note the supplement to this comment:
http://www.solid-earth-discuss.net/se-2016-79/se-2016-79-AC1-supplement.pdf

Interactive comment on Solid Earth Discuss., doi:10.5194/se-2016-79, 2016.