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Mobility of Pyroclastic Flows

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We carry out experiments in the laboratory to study the mobility of geophysical granular flows such as pyroclastic flows and rock avalanches. Batches of dry and cohesionless rock fragments with different masses (5, 15 and 30 g) and different grain sizes (0.5-1, 1-2 and 2-3 mm) are released down a curved chute (1.4 m long, 5.4 cm wide) and they are imaged by a high-speed video camera at 2000 fps. Particle image velocimetry analysis enables the measurement of particles speeds. The roughness of the slope surfaces is significantly smaller than the smaller grain size we use. In our experiments we hold constant all the other variables that can affect the runout distance. For example: density, angle of internal friction, coefficient of restitution and geometric properties of all rock fragments are not significantly different. Density and viscosity of the inter-particles fluid (air) are too small to affect our flow mobility. We consider the distance between initial and final position of the centre of mass of the granular masses to assess flow mobility. These centres of mass are obtained from tree-dimensional computer representations of granular masses.

Our experiments demonstrate that the finer the grain size, the more mobile is the flow. This is accompanied by a decrease of fragments agitation when grain size decreases as shown by particle image velocimetry measurements. All the other features being equal, the smaller the grain size, the larger is the number of particles in the flow so that particles agitation at the contact with the containing boundary surfaces penetrates relatively less inside the flow. This explains the effect of finer grain size on flow mobility because the smaller the agitation, the smaller is also the energy dissipated by flows per unit of travel distance. We measure particles agitation computing parameter A which is the average squared deviation from their mean of the particles transversal speeds normalised with respect to the squared longitudinal flow speed.

A load cell is located with its sensitive plate flush with the basal surface inside the chute to measure the normal pressures exerted by the flows when travelling. Basal pressures are important because they affect the retarding forces acting on flows. The load cell shows that the interaction between flows and ground consists of collisions. We compute parameter D which is the average pressure deviation from their mean of the pressures values of each load cell profile normalised with respect to the mean pressure. A dimensional analysis reveals that D is proportional to a scaling parameter alpha whose numerator is the product of the squared grain size and the acceleration of gravity and whose denominator is the product of the cube root of flow volume and the squared initial speed of the flow. Parameter D is a normalised particles agitation expected to be proportional to the energy dissipation of the flows. This relationship (which implies that larger volume flows have larger potential mobility) is valid when comparing flows in a single spot (where the load cell is located for example) and it does not consider the entire shape of the slope which can also affect the position of the centre of mass of the deposits.

Our experiments show that the apparent coefficient of friction depends not only on the roughness of the chute surface, but also on the features of the flow that are those varied in the experiments (we do not change those of the chute). These results are an important step towards the prediction of runout distances as a function of the features that characterize the different geophysical flows.