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Granular jump properties for the design of protection dams against snow avalanches

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The current European guidelines for the design of snow avalanche protection dams highlighted the need of transforming a supercritical flow that impacts the dam into a subcritical flow which travels upstream. This transition involves the formation of a discontinuity in height and velocity, namely a jump. The jump height is crucial to predetermine the dam height needed to stop the avalanche against which one wants to be protected, and it dissipates a lot of energy if the dam is overtopped by an extreme avalanche of greater intensity than the former avalanche. For a sake of simplicity, the current European guidelines are based on the equations valid for hydraulic flows on a horizontal smooth bottom. However, the behavior of flowing snow is closer to the flow of dry granular materials.
A recent experimental study has investigated in detail the geometry of standing granular jumps formed in shallow granular flows down a small-scale laboratory smooth-base chute. A number of discrepancies between the equations strictly valid for hydraulic flows on a horizontal smooth bottom were evidenced. The discrepancies are partly explained by the fact the traditional hydraulic equations do not take into account the forces acting over the jump volume, and consider an incompressible flow. As such, it is crucial to develop a new theoretical framework capable of overcoming the limits of the current hydraulic equations used in the European guidelines.
The overarching aim of the present study is to develop this new theory for granular jumps with the help of both small-scale numerical simulations and laboratory tests. A new analytical solution based on depth-averaged mass and momentum equations is proposed but needs another length scale, that is the finite length of the jump, as well as a constitutive friction law, in order to be predictive. A number of numerical simulations based on the Discrete Element Method are conducted to access the micro-mechanical parameters in addition to the macroscopic geometry of the jump. The laboratory tests are used to test and validate the trends observed in the numerical model. The numerical simulations backed up with the laboratory tests allow to understand precisely the role of each term in the new analytical solution proposed and to develop robust closure relations, thus helping to make the analytical solution predictive over a wide range of incoming flow conditions.