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Physically-sound scaling laws for snow avalanche impact pressure

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Estimating the force on obstacles stemming from snow avalanches is a non trivial task in avalanche-flow regimes at low velocity for which inertia does not prevail. In addition to the gravity force -proportional to the weight of the undisturbed incoming flow- that takes place at low velocity, extra forces induced by friction for granular snow avalanches, or by some possible viscosity effects for more fluid-like snow avalanches, should be considered. We discuss here the case of a wall-like obstacle overflowed by a granular snow avalanche. Recent small-scale discrete numerical simulations and laboratory tests with granular flows have allowed developing and validating an analytical model to predict the force on the wall. This model shows that the force is the sum of the inertial force, the gravity force of the undisturbed flow and an additional contribution caused by the presence of a stagnant zone formed upstream of the wall and co-existing with an inertial zone above. The model is used to derive a physically-sound scaling law giving the pressure relative to the typical inertial force of the undisturbed flow as a function of the Froude number. Rheological properties of the granular flowing material such as the typical friction angles of the granular material as well as the restitution coefficient of granules are included in the proposed scaling law. With appropriate values of those rheological properties for flowing granular snow, the scaling law can be used to interpret existing pressure data from full-scale snow avalanches and can be cross-compared to classical approaches used in snow avalanche engineering.