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Evolution of flow velocities and basal stresses in finite-mass granular flows

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We present detailed velocity measurements in granular avalanches flowing down a flat chute together with shear and normal force measurements on the running surface. The chute is five meters long and half a meter wide. Granular material (glass beads or ballotini) with grain sizes between 0.1mm to 1.4 mm were used. The flow was recorded through a transparent side-wall by two high-speed cameras, which are able to capture 1825 pictures in a second. Due to the high frame rate of the cameras, several flow features can be observed with accuracy. By analysing the images with a pattern matching algorithm two dimensional velocity fields with high temporal and spatial resolution were obtained. The evolution of flow-normal velocity profiles, velocity fluctuation profiles and other flow characteristic such as the depth averaged velocity, the slip velocity, the surface velocity, shear rates or flow depth through the flow are tracked. By using two high-speed cameras at different downstream positions the evolution of the gradient of the velocities in downstream direction could also be studied. The shear and normal force plates were located at a camera's downstream position. The evolution of the basal forces and friction coefficients could therefore be analysed with respect to the flow characteristics mentioned above. The flow heights were recorded from the films as well as from two laser sensors located at the cameras downstream positions. We varied the roughness of the running surface by gluing sand paper of different grain-size and drawing paper on the wooden chute. The inclination angle was varied, from 20° to 40° degrees depending on the combination of material and running surface roughness. Together with the different sizes of the ballotini various flow conditions scenarios were carried out. As a result different flow structures could be observed and characterized including velocity profile with time varying slip condition, low to strong spreading flows, dilute to dense flow regions, displacement of maximal shear rate over the flow height.
For the general understanding of finite-mass granular flows, systematic testing of various flow conditions and material with according instrumentation is crucial and it represents the compulsory starting point for deterministic modelling of geophysical flows.