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Structure and behaviors of granular flows: simulations at the grain level and scaling laws

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Granular flows often involve multiple phases, for example in an avalanche the main bulk may be surrounded by a cloud of free grains. These multiphasic flows pose a real challenge for continuous representations, but they are still accessible on a small scale by simulations at the grain level. The existence of new flowing regimes is thus demonstrated even in a simple configuration such as the flat frictional inclined channel. These regimes emerge from the destabilization of unidirectional flows upon increase of mass holdup and inclination angle. They are characterized by non-trivial internal structures, including superposed rolls, a basal ordered layer topped by secondary flows, and states where a dense core is supported by a gaseous phase. Besides, the supported regimes exhibit striking behaviors at high mass holdup such as symmetry breaking leading to periodic oscillations of the dense core. Interestingly, these different regimes are shown to obey a universal scaling law for the mass flow rate as a function of the mass hold-up. These new states provide a unique set of 3D flow regimes on which granular rheological models can be tested and open perspectives for interpreting geophysical granular flows.