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Slope-scale dynamic states of rockfalls

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Rockfalls are common earth surface phenomena characterised by complex dynamics at the slope scale, depending on local block kinematics and slope geometry. We investigated the nature of this slope-scale dynamics by parametric 3D numerical modelling of rockfalls over synthetic slopes with different inclination, roughness and spatial resolution. Simulations were performed through an original code specifically designed for rockfall modeling, incorporating kinematic and hybrid algorithms with different damping functions available to model local energy loss by impact and pure rolling.
Modelling results in terms of average velocity profiles suggest that three dynamic regimes (i.e. decelerating, steady-state and accelerating), previously recognized in the literature through laboratory experiments on granular flows, can set up at the slope scale depending on slope average inclination and roughness. Sharp changes in rock fall kinematics, including motion type and lateral dispersion of trajectories, are associated to the transition among different regimes. Associated threshold conditions, portrayed in "phase diagrams" as slope-roughness critical lines, were analysed depending on block size, impact/rebound angles, velocity and energy, and model spatial resolution. Motion in regime B (i.e. steady state) is governed by a slope-scale "viscous friction" with average velocity linearly related to the sine of slope inclination. This suggest an analogy between rockfall motion in regime B and newtonian flow, whereas in regime C (i.e. accelerating) an analogy with a dilatant flow was observed. Thus, although local behavior of single falling blocks is well described by rigid body dynamics, the slope scale dynamics of rockfalls seem to statistically approach that of granular media. Possible outcomes of these findings include a discussion of the transition from rockfall to granular flow, the evaluation of the reliability of predictive models, and the implementation of criteria for a preliminary evaluation of hazard assessment and countermeasure planning.