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Connecting grain-scale physics to macroscopic granular flow behavior using discrete contact-dynamics simulations, centrifuge experiments, and continuum modeling

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A complete theoretical understanding of geophysical granular flow is essential to the reliable assessment of landslide and debris flow hazard and for the design of mitigation strategies, but several key challenges remain. Perhaps the most basic is a general treatment of the processes of internal energy dissipation, which dictate the runout velocity and the shape and scale of the affected area. Currently, dissipation is best described by macroscopic, empirical friction coefficients only indirectly related to the grain-scale physics. Another challenge is describing the forces exerted at the boundaries of the flow, which dictate the entrainment of further debris and the erosion of cohesive surfaces. While the granular effects on these boundary forces have been shown to be large compared to predictions from continuum approximations, the link between granular effects and erosion or entrainment rates has not been settled. Here we present preliminary results of a multi-disciplinary study aimed at improving our understanding of granular flow energy dissipation and boundary forces, through an effort to connect grain-scale physics to macroscopic behaviors. Insights into grain-scale force distributions and energy dissipation mechanisms are derived from discrete contact-dynamics simulations. Macroscopic erosion and flow behaviors are documented from a series of granular flow experiments, in which a rotating drum half-filled with grains is placed within a centrifuge payload, in order to drive effective gravity levels up to $\sim$100g and approach the forces present in natural systems. A continuum equation is used to characterize the flowing layer depth and velocity resulting from the force balance between the down-slope pull of gravity and the friction at the walls. In this presentation we will focus on the effect of granular-specific physics such as force chain networks and grain-grain collisions, derived from the contact dynamics simulations. We will describe our efforts to characterize both the convergence of these grain-scale parameters toward the empirical coefficients of the macroscopic descriptions, and the deviations from continuum model predictions caused by nonlocal granular effects for quantities such as erosion rate. We will also summarize the context and implications of our work for both granular physics theory and granular flow hazard risk assessment.