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Erosion by experimental debris flows: particle size effects

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Abstract

The mobilization of surface material by particle-laden flows involves phenomenology that cross multiple scales: particle-scale interactions and mesoscopic stresses have significant implications for landscape evolution and associated hazard mitigation issues. Here, we consider the problem of erosion of bed materials by debris flows – flows of boulders, gravel, sand, fine particles, and fluids – as they entrain soils and rocks from steep hillsides. In this paper we report results from laboratory experiments investigating the effect of changing coarse particle concentration in a dry "debris flow" on the erosion of a bed over which it flows. We find that increasing the fraction of coarse particles in the bed often increases the bed erosion. However, for some systems, the details are noisier and harder to discern. We associate the variable erosion and noisiness in part with the competing dynamics of small scale interactions, such as the coarse grain impacts, and larger scale details, such as those related to angles of repose. We also present preliminary results measuring instantaneous erosion rates and demonstrate that size dependence of the erosion rates can vary considerably from that of the net erosion. We conclude by summarizing some limitations of our experiments and ongoing next steps to address these limitations.

Keywords: debris flows, granular materials, erosion

1. Introduction

Debris flows are massive movers of sediment – boulders, gravel, and sand- and clay-sized particles – from mountainous regions and steep hillslopes to foothills, valleys, and river channels below (Hungr, McDougall, Jakob and Bovis, 2005). Along the way, they pose significant hazards to infrastructure and human life, and they determine important details of river channel dynamics to which they supply a substantial amount of sediment. There is significant evidence that changing land use and climate change are increasing debris flow magnitude and frequency (e.g., Stoffel and Beniston, 2006; Jakob and Friele, 2009; Jomelli et al., 2009).

Much of our understanding of debris-flow processes is drawn from experimental studies and limited natural examples. Changing environmental conditions, such as rainfall frequency and magnitude, and variable particle properties limit effectiveness of empirical models based primarily on previous debris flows. A solution to this problem may lie in a more physics-based understanding of the manner in which debris flow composition, interstitial fluid composition, and particles which can vary from one debris flow to the next can affect debris flow behaviors. Understanding the mechanisms that control the rate at which a particular debris flow entrains particles and grows in size is important for predicting their hazard (Godt and Coe, 2007).

In this paper, we focus on the effect of changing the concentration of large particles in an experimental debris flow on net erosion, the difference in bed mass before and after the flow, of a bed of erodible materials (loose

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