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Effect of particle entrainment on the runout of pyroclastic density currents

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Pyroclastic density currents (PDCs) can erode soil and bedrock, yet we currently lack a mechanistic understanding of particle entrainment that can be incorporated into models and used to understand how PDC bulking affects runout. Here we quantify how particle splash, the ejection of particles due to impact by a projectile, entrains particles into dilute PDCs. We use scaled laboratory experiments to measure the mass of sand ejected by impacts of pumice, wood, and nylon spheres. We then derive an expression for particle splash that we validate with our experimental results as well as results from seven other studies. We find that the number of ejected particles scales with the kinetic energy of the impactor and the depth of the crater generated by the impactor. Lastly, we use a 1D model of a dilute, compressible density current to examine how particle entrainment by splash affects PDC density and runout. Splash driven particle entrainment can increase the runout distance of dilute PDCs by an order of magnitude. Furthermore, the temperature of entrained particles greatly affects runout and PDCs that entrain ambient temperature particles runout farther than those that entrain hot particles. Particle entrainment by splash therefore not only increases the runout of dilute PDCs, but demonstrates that the temperature and composition of the lower boundary have consequences for PDC density, temperature, runout, as well as PDC hazards and depositional record.