ENTRAINMENT AND RUNOUT OF MARTIAN PYROCLASTIC DENSITY CURRENTS. D. Florez[1] and B.J. Andrews[2], [1]The University of Texas at Austin (dflorez@utexas.edu), [2]Smithsonian Institution (andrewsb@si.edu).

Introduction: Pyroclastic Density Currents (PDCs) are common on Earth, with deposits from individual eruptions sometimes extending for more than 100 km from the eruption vent. PDC deposits may also be present on Mars, forming, for example, the Medusae Fossae Formation (MFF; [*1-3*]). Here we present scaled analog experiments that measure air entrainment into dilute, heated, particle-laden density currents, and then apply those results to a numerical model to evaluate how PDC transport distances on Earth and Mars are affected by eruption rate, temperature, and entrainment rate.

PDCs are dense mixtures of rock and gas that travel laterally across the landscape when a volcano explosively erupts. These currents move because they are more dense than the ambient fluid, and their velocity is proportional to that difference in density and the current thickness. Importantly, density and thickness change during transport as currents sediment particle or entrain, or mix in, atmosphere; the latter process results in a decrease in current bulk density and an increase in current thickness. PDCs, unlike other density currents are hot and they travel through an expandable fluid, therefore when they entrain and heat atmosphere, that fluid expands, resulting in a further reduction in bulk density (and corresponding increase in current thickness or volume); ultimately this can result in a buoyancy reversal, where the PDC evolves into a buoyant plume and lifts off, terminating runout. Although turbulent entrainment into isothermal currents is reasonably well constrained, entrainment into PDCs is not well known. Entrainment is commonly defined as the ratio of entrainment velocity to characteristic velocity, with isothermal currents typically having values of ~0.1 [4], whereas entrainment in heated currents can exceed 0.5 [*5*]. 1D numerical models of dilute, entraining currents demonstrate that changing entrainment from 0.1 to 0.5 can produce an up to 5-fold reduction current transport distance.

Methods: We study transport and entrainment in PDCs using scaled experiments run at the Smithsonian Experimental Volcanology Laboratory, inside an air-filled chamber measuring 8.5×6×2.5 m [*5*]. Experimental currents comprise heated 20-μm talc particles turbulently suspended in air. Temperature within the experiments is monitored with an array of 0.001” thermocouples logged at 3 Hz. Experiments are illuminated with a laser sheet that sweeps the tank at 10 Hz and recorded with a high-speed camera at 1000 Hz. As the laser sheet moves substantially faster than the currents, each acquisition of 200 images captures a “snapshot” of the current, and from each “snapshot” we make a 3D reconstruction. Using those novel 3D reconstructions we measure current surface area and volume through time, and, accounting for thermal expansion and volume changes resulting from newly “erupted” material, calculate entrainment at each time.

Experimental Scaling: Experiments are scaled with attention to bulk and turbulent dynamic properties. Bulk properties include the Reynolds, Richardson, thermal Richardson, and Froude numbers. Turbulent properties include the Stokes and settling numbers. Experimental scaling is well within the range of natural dilute PDCs for all parameters except the Reynolds number, where the experimental scaling is several orders of magnitude less than for natural PDCs [5, 6]. Analysis of experimental currents shows, however, that the experiments are fully turbulent, thus the large scale dynamics of the experiments are dynamically similar to those of natural currents, and the large scale dynamics are what drive entrainment.

Experimental Results: Our experiments show that entrainment into dilute density currents is not constant, but instead fluctuates with a period similar to the integral turbulent time scale. Interestingly, entrainment is proportional to the thermal Richardson number (RiT), with hotter currents having systematically higher entrainment (up to 0.5) than cooler currents (0.1-0.2) (Figure 1). This suggests that thermal expansion of entrained atmosphere provides an additional driver of turbulent entrainment.

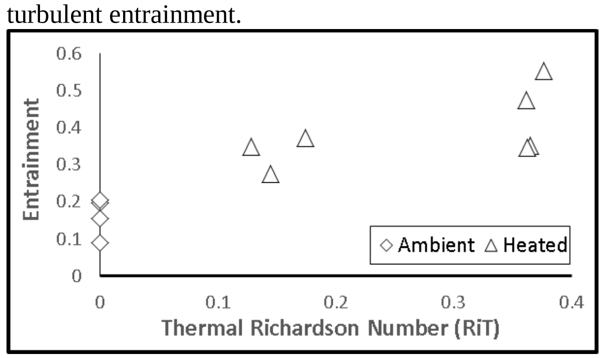

Figure 1. Entrainment increases with RiT from 0.1-0.2 for ambient temperature currents to >0.5 for heated currents.

Dilute PDC Transport Distance on Mars: 1D numerical modeling of entraining PDCs shows that entrainment and eruptive temperature exert first order controls on transport distance of PDCs. In a martian like atmosphere, a current erupted at a rate of 10^9 kg/s with entrainment rate of 0.2 and an eruptive temperature of 800° C should travel 97 km for an eruption lasting 1.6 hours. With an entrainment rate of 0.1 or 0.5, an eruption under similar conditions would travel to a distance of 152 km or 56 km before it lifts off, respectively. Likewise, a current with an entrainment rate of 0.2 and an eruptive temperature of 1000° C should travel 77 km. PDCs on Mars could reasonably be expected to travel up to ~200 km, with an eruptive temperature of 800° C, an entrainment rate of 0.1, and an eruption duration of 2 hours. Our results suggest it is unlikely that the MFF records deposition from a single, sustained PDC, but the MFF could be formed by PDC deposits erupted from a limited number of distributed vents.

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