THE DYNAMICS OF PYROCLASTIC DENSITY CURRENTS ON MARS: IMPLICATIONS FOR INTERPRETING MARTIAN SURFACE DEPOSITS. B. D. Brand[1] and A. B. Clarke[2], [1] Earth and Space Sciences, Box 351310, University of Washington, Seattle, WA (bbrand@u.washginton.edu); [2] School of Earth and Space Exploration, Arizona State University, Tempe, AZ (Amanda.clarke@asu.edu).

Introduction: The products of explosive volcanism have long been observed on the surface of Mars, and their corresponding dynamics, such as dike propagation, magma fragmentation, and eruption columns under Martian conditions, have been modeled with significant success [e.g. 1]. However, the dynamics of pyroclastic density currents (PDCs) under Martian conditions is still poorly constrained. Our increasing capability to image the surface at high resolution, both from orbit and from rovers, presents an opportunity for more rigorous deposit observations and descriptions. For example, observations and geologic mapping of highland Patera identify low-relief, friable flanks, interpreted as the deposits of PDCs, surrounding a well defined caldera [e.g., 1, 2]. High resolution CTX and HiRISE images reveal layering within the friable flanks, further supporting an interpretation of volcanoclastic deposits. In addition the bedded deposits identified by the Spirit rover at "Home Plate," an outcrop within the Columbia Hills in Gusev Crater, have been interpreted by many as the deposits of dilute PDCs [e.g. 3-4].

Understanding the role of atmospheric pressure, density and temperature on sedimentation in density-stratified currents allows us to explore the range of deposit characteristics expected on the surface of Mars (i.e., runout distance and deposit thickness, grain size distribution and dune wavelength). We strive to develop a model that predicts deposit characteristics; thereby improving our capability to interpret Martian features on both the outcrop (e.g., Home Plate) and regional scale (e.g., Apollinaris Patera).

Background: Concentrated PDCs are laminar mixtures of hot gases and unsorted pyroclastic material, are generally confined by topography, and can attain significant runout distances [e.g. 5]. Dilute PDCs differ in that they are turbulent, gas-pyroclast mixtures that are not confined by pre-existing topography, and typically occur as single pulses or series of pulses in which the kinetic energy rapidly decays [6-7]. Dilute PDCs often produce cross-stratified deposits, like those identified at Home Plate [e.g. 3-4], although planar to massive deposits are also common, reflecting the unsteady nature and variability in such currents [6-7]. Phreatomagmatic eruptions, thought to be a common trigger for explosive volcanism on Mars [1], frequently produce dilute PDCs. Thus their deposits may be prevelant around explosive volcanic centers on Mars.

Methods: We build on previous models [2, 8-10] to develop a quantitative, axi-symmetric model for flow of and sedimentation from a steady-state, vertically uniform dilute density current for application to PDCs on Earth and Mars. The conservation of mass, momentum, and energy are solved simultaneously, and include the effects of atmospheric entrainment, particle sedimentation, basal friction, temperature changes, and variations in current thickness and density. In addition we calculate the Rouse number and Brunt-Väisäla frequency to estimate the wavelength of internal gravity waves within the currents, which are thought be the primary control on deposit bedform wavelength and amplitude [9].

Preliminary Results:

Comparison of PDCs on Earth and Mars The roles of atmospheric density and gravity in controlling PDC dynamics and run out distance are explored by using identical initial conditions for Earth and Mars [Note: this simplified comparison does not capture predicted differences in vent dynamics between the two planets]. In both cases flow is supercritical and surge velocity initially increases due to thinning of the flow (Fig. 1). Note that the criticality of a given flow, thought to be a dominant control on bedform development and morphology [e.g. 9], is characterized by the non-dimensional densimetric Froude ratio $Fr_d = \frac{u}{\sqrt{g'h}}$, where u = velocity, h = flow thickness, and $g' = g\,\frac{\beta - \alpha}{\alpha}$ in which g = gravitatilan acceleration, β = bulk density of flow, α=ambient density. Values of $Fr_d>1$ are thin, fast supercritical flows, $Fr_d<1$ are thick, slow-moving subcritical flows.

Our preliminary results show that a Martian PDC will out distance an equivalent Earth PDC by roughly twice the distance, primarily due to slower sedimentation rates. Although this general conclusion is consistent with previous studies [e.g. 1-2, 10], the difference between the Earth and Mars cases is much less than previously published.

Figure 1c illustrates that we might expect longer dune wavelengths on Mars relative to Earth. This is likely due to slower sedimentation rates causing density stratification to develop over longer distances as a current travels away from source.

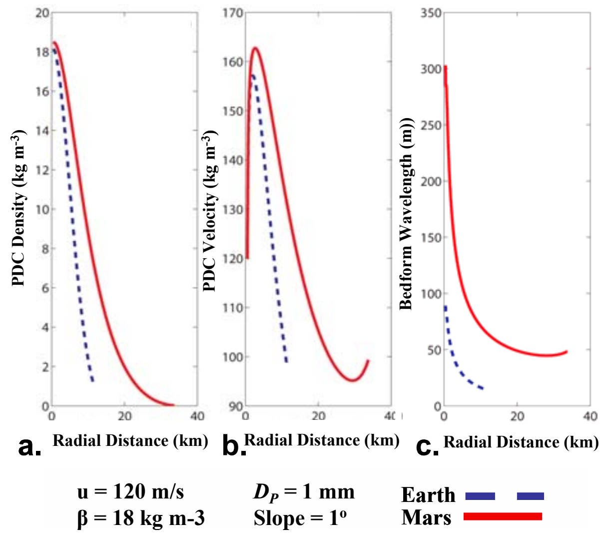

Fig. 1. Comparison of PDCs on Earth and Mars

Reconstruction of Flow Conditions from Early JModels Upon employing the Mars conditions proposed in [2], our models obtain run out distances of >400 km for PDCs generated at Hadriaca Patera (Fig. 2a), consistent with the previous models (red line; Fig. 2b-d). However, introducing entrainment of air slows the current more quickly (blue line), and adding sedimentation results in much shorter run out distances (<100 km; green line,). This discrepancy motivates further assessment and critical thinking about the depositional mechanisms for these deposits.

Conclusions and Future Work: Sedimentation of particles and atmospheric entrainment are important variables to include when modeling PDCs under Martian atmospheric conditions. Model results hold promise for predicting deposits features such as grain size distribution, thickness and bedform wavelength with distance from source for a set of initial conditions. Future work includes (1) introducing multiple grain sizes to the model, which will allow for a more accurate prediction of deposit thickness and grain size distribution with distance from source; (2) calculating a vertical concentration (density) profile, which will result in a more accurate estimate of internal wave frequency, and ultimately bedform wavelengths, with distance from source. We will also explore alternative interpretations for the extensive ash aprons around the Martian Patera by (1) assessing the dependence of atmospheric conditions on PDC transport by varying atmospheric density and pressure; (2) considering the dynamics of concentrated PDCs on the surface of Mars; and (3) reviewing new datasets (e.g., CTX, HiRISE, MER) as they become available to more closely observe and describe what have been interpreted as explosive volcanic centers (or deposits) on Mars.

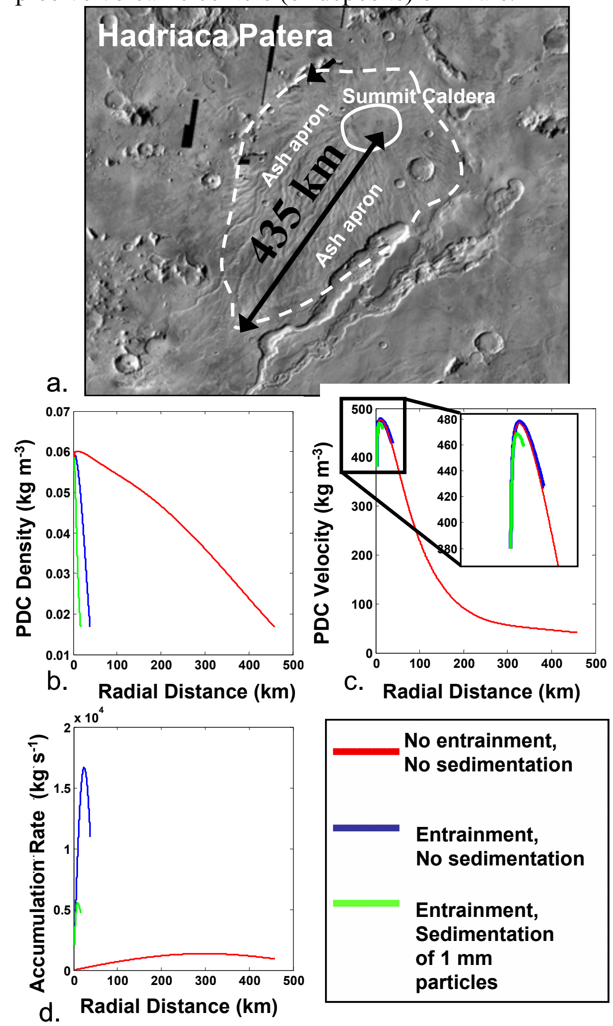

Fig. 2. Comparison of [9] results with our model, taking into account entrainment and sedimentation.

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