A WIND TUNNEL STUDY OF THE EFFECT OF INTERMEDIATE DENSITY RATIO ON SALTATION THRESHOLD.
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Introduction: An expression for saltation threshold – the minimum wind speed required to initially saltate particles – is necessary for modeling aeolian processes on Earth and other bodies. Analysis of a compilation of experimental data led to the conclusion that this threshold is a function of the ratio of the density of the particle to the density of the entraining fluid (ρ_p/ρ), and to a curve for the dimensionless threshold parameter, $A(\rho_p/\rho)$ [1]. Whereas data of low-density ratio conditions from flumes and of high-density ratio conditions from terrestrial and Martian wind tunnels show constant A values, data in the transitional region from the Venus Wind Tunnel (VWT) show a range of values.

Methods: To support modeling of aeolian processes under thicker-than-terrestrial atmospheres, we revisit this transitional portion of the curve using the Titan Wind Tunnel [(TWT; *Fig. 1*), 2]. Using this unique facility located the NASA Ames Research Center in Mountain View, CA, we collect new freestream threshold wind speed data for a range of grain densities and sizes and air pressures within the wind tunnel, yielding a range of intermediate density ratios. Although for previous TWT work, threshold was defined as ~50% of the center region of the bed in motion [3], we defined threshold in this work as the observation of patchy movement of grains, to be more consistent with the definition of threshold from the VWT work, namely, "the speed at which groups of grains began to saltate sporadically" [4]. The freestream threshold wind velocities were recorded by a stationary pitot tube within the freestream (i.e., above the boundary layer) (*Fig. 2*). To estimate roughness heights during each experiment, we also collected a limited number of wind profiles without sediment motion for fixed beds of different grain sizes and extrapolated the wind profiles to wind speeds of 0. With these roughness heights and the collected freestream wind threshold wind speed values, we calculated friction threshold wind speed using the law of the wall, namely,

$$u_\infty = \frac{u_*}{\kappa} ln \frac{\delta}{z_0} \qquad (1)$$

where u_∞ is freestream velocity, δ is the boundary layer thickness, κ is the von Kármán constant (0.41), and z_0 is the roughness height. From these friction threshold wind speeds, we calculated the dimensionless threshold wind speed, using the equation

$$u_{*t} = A\sqrt{\frac{\rho_p - \rho}{\rho} g D_p} \qquad (2)$$

where A is the dimensionless threshold parameter, ρ_p is the particle density, D_p is the mean particle diameter, and g is the gravitational acceleration ([5, see also 6)]). As $u = \sqrt{(\tau/\rho)}$, A is equivalent to the square root of the Shields criterion, $\theta = \tau/[(\rho_p-\rho)gDp]$, for the initiation of sediment motion in a fluid flow.

Results: The results (*Fig. 3*) show that the TWT-derived values do not coincide consistently with the VWT values. With the aggregated threshold data from both wind tunnels, we derive a new density ratio curve with the same form as the previous expression but new and different values for the parameters and including uncertainties. This updated curve of $A(\rho_p/\rho)$ confirms the slope in the transitional region between low- and high-density ratios, though giving slightly higher values for A.

This work offers an improved prediction of threshold wind speeds under thicker-than-terrestrial atmospheres on other solar or extrasolar planetary bodies, although the reason for the systematic offset between the VWT data and our TWT data is not known to us. As importantly, perhaps, is that this work provides a quantification of the uncertainties of the combined VWT and TWT results. The offset between these two data sets suggests possible challenges to accurate experimental simulation of aeolian transport under such transitional conditions with current facilities.

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References: [1] Iversen J.D. et al. (1987) *Sedimentology* 34: 699-706. [2] Burr D.M. et al. (2015) *Aeolian Res.* 18, 205-214. [3] Burr D.M. et al. (2015) *Nature* 517: 60-63. [4] Greeley, R. (1984) *Icarus* 57: 112-124. [5] Bagnold, R.A. (1941) *The Physics of Blown Sand and Desert Dunes*. [6] Kok, J.F., et al. (2012), Reports on Progress in Physics, doi:10.1088/0034-4885/75/10/106901.

Fig 1: (a) Photograph of the Titan Wind Tunnel. (b) Sectioned layout of the Titan Wind Tunnel. For clarity, only the downwind observational ports are labeled; the upwind port is visible in the photograph. Modified from [2].

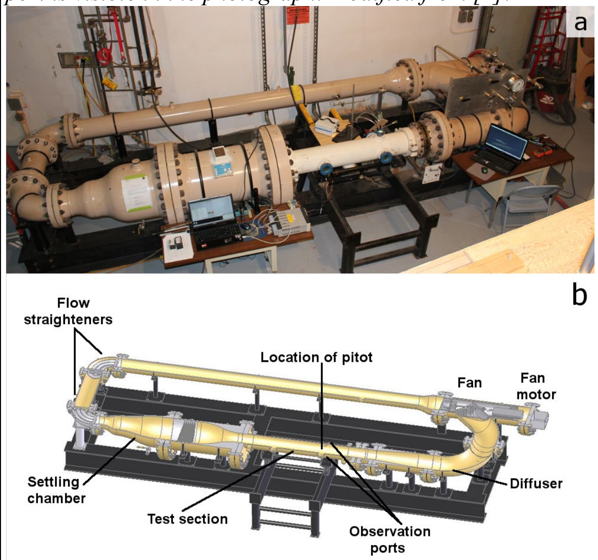

Fig 2: Experimental setup with the snake lights (rotated from their position in Fig. 2) used to illuminate the grains at the downwind observation port and position of high-speed video camera (showing zoom lens). Inset (lower left) shows view inside of the tunnel as seen by the camera.

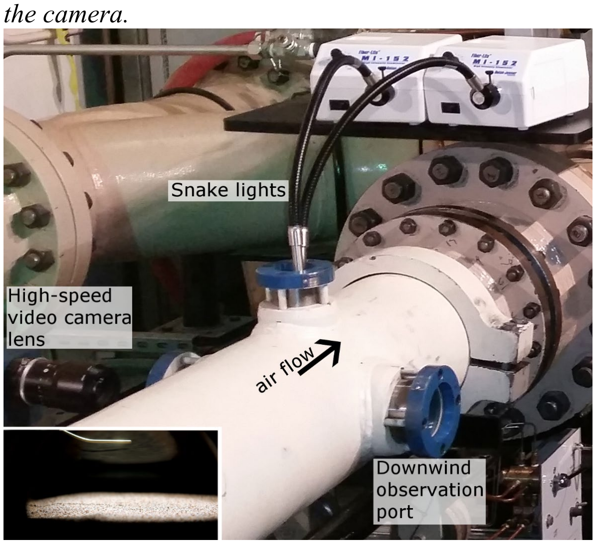

*Fig. 3: a) Threshold parameter A, from various sources [1] vs density ratio for Dp > 200 μm diameter and Re*t >10. Derivation of uncertainties is described in [6=Burr et al. in revision]. The colored points are the new TWT data presented here. The grey dashed line is the fit from [1]. The red dashed line is the new fit including the TWT data. The red dotted lines mark the uncertainty envelope represented by the 3-σ spread in the Monte Carlo fits. b) TWT data for a limited range of Reτ to further isolate density ratio dependence.*