Dust devils on Earth and Mars: Extension of particle threshold laboratory simulations

Conference or Workshop Item

DUST DEVILS ON EARTH AND MARS: EXTENSION OF PARTICLE THRESHOLD LABORATORY SIMULATIONS

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Introduction. Dust devils are proposed as effective mechanisms for lofting large quantities of dust into the martian atmosphere. Previous work [1] showed that vortices entrain dust more easily than simple boundary layer winds. However, these previous lab studies that used the *Arizona State University Vortex Generator* (ASUVG) were limited to vortices of 0.01 to 0.10 m in diameter. Utilizing a newer facility at Iowa State University, the Tornado/Microburst Simulator (ISUTMS)[2], allowed larger vortex sizes (0.60 to 1.20 m in diameter) to be studied. Natural dust devils on Earth are generally a few meters to 10s of meters in diameter and occasionally reach upwards of 100 m in size [3]. On Mars, however, dust devils expand to much larger sizes from <10 m to 500 m in diameter [4,5]. The goal of this study was to examine vortex particle threshold in the laboratory using the ISUTMS to study vortices with a range of diameters larger than was possible with the ASUVG and then apply the results to scaling aspects of terrestrial and martian dust devils.

The two vortex systems used in this study are designed differently yet provide similar Rankine-like vortices. The main observational difference is that the ASUVG vortex 'wanders' within an ~60cm-radius zone because the system is not confined as in the ISU case. The ISUTMS employs a recirculatory system resembling a Ward-model vortex generator [2] to produce an incredibly stable with almost no wander. This allows the system to be accelerated to tornadic conditions (i.e., $v > 27$ m/s).

Approach and Methods. Building on previous work [1], we investigated how dust devils lift sand at laboratory scales. We employed similar techniques outlined in [1] for determining threshold using the ASUVG and the ISUTMS. Threshold was designated as the point at which sediment begins to move under wind action. Movement can be designated as rolling, saltating, or suspended in the flow. Vortex action is different from boundary layer winds as small particles are more easily entrained, probably because of an added lift provided by the low pressure in the core of the vortex, which overcomes interparticle forces (e.g. cohesion, statics, etc.)[1].

For both systems, threshold values were determined by slowly ramping up the velocities until particles began to move on the test surface. Particle layers were thick (> 5mm) for each experiment to reduce testbed surface effects. The two mechanical systems behave differently because of differences in design. Therefore, threshold appears different in both cases, which could have an effect on the comparison of the data.

Results and Implications. The preliminary data show better-constrained values of threshold for the ISUTMS system (less scatter). The lower scatter is probably due to higher vortex stability in the ISUTMS experiments. Threshold values for the ISUTMS also display values that are lower than those published in [1]. This also might be due to the instability (wander) of the ASU vortices. Greeley et al. [1] noted that threshold is attained at two distinct points: "continuous threshold" where entrainment is approximately constant over time and a lower value deemed "intermittent" in which bursts of entrainment occur. Intermittent threshold coincides more with initial movement of particles on the test surface, which makes it a more likely analog to threshold determined with the ISUTMS. Due to the wander instability, "continuous" threshold is prohibited until higher velocities are attained potentially skewing the determination of the true threshold velocities.

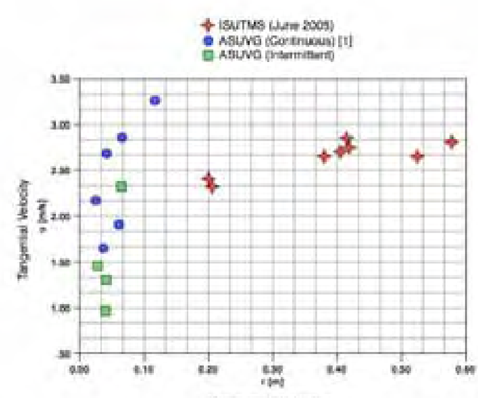

Figure 1. A plot showing the extension of threshold data for 125μm silica sand using the ASUVG "continuous" data (blue), the ASUVG "intermittent" data (green), and the ISUTMS data (red) collected last summer.

Extrapolating these results to martian conditions (also discussed in [1]), vortex threshold velocities should behave similarly. Figure 2, shows threshold velocities as a function of radius for both terrestrial and martian laboratory runs. These data are used to suggest where the ISUTMS data should plot if that system could be run at low ambient pressures.

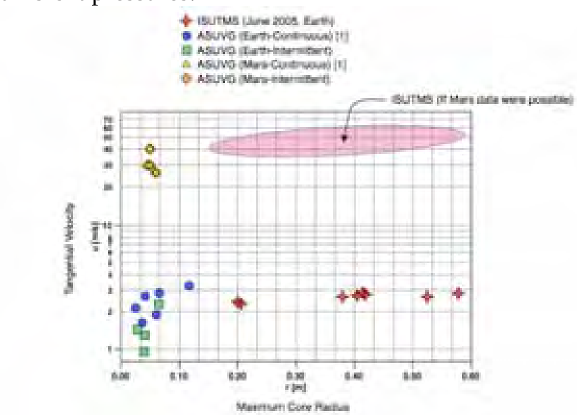

Figure 2. A plot showing ASUVG data plotted for both Earth and Mars cases, as well as the data collected from the ISUTMS in Summer 2005. The pink ellipse suggests where ISUTMS data would plot if that system could be run under martian conditions.

Future Work. Based on this preliminary work, threshold curves as a function of particle size and relative strength of the vortex (ΔP as a percentage of ambient) will be generated for both vortex generators. The relationship between ΔP and tangential velocity for the ASUVG was discussed in [6,7] and suggested that there could be a simple relationship between terrestrial and martian conditions, demonstrated in Figure 3. Intermittent ambient pressures could be used to simulate the appropriate ranges in ΔP (% ambient) for both terrestrial and martian cases. The efficiency of the ASUVG at low ambient pressures increases and allows stronger ΔPs to be investigated. Appropriate ranges as reported in [6,7] for natural dust devils are ~0.2-1.0% ambient for dust devils on Earth and Mars. Pressure wells from the ISUTMS are important to verify if velocities corroborate these relationships as vortex sizes approach those of natural dust devils. In conclusion, the ISUTMS has enabled the first extension of threshold laboratory data to natural dust devils and will be useful in the future for examining the intermediate ranges in vortex sizes between the laboratory and natural dust devils. Vortices at different ambient pressures appear to behave very similarly to each other suggesting that dust devil mechanics work the same for Earth and Mars. Future work with the ASUVG should focus on studying the range of ambient pressures that produce ΔP in the correct percentage range. Extrapolating ISUTMS data to martian dust devils suggests that larger vortices should display less variation in tangential velocity than what is observed over smaller ones. Overall this suggests that smaller, tightly wound dust devils are stronger and exhibit more variation that the larger ones.

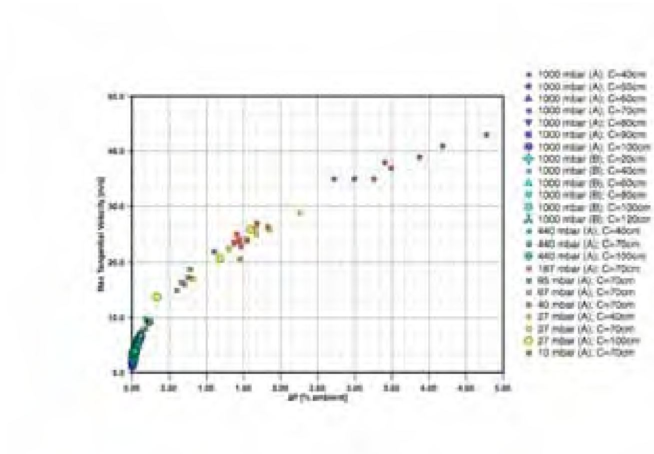

Figure 3. A plot showing all ASUVG data for all tested ambient pressures 10 to 1000 mbar. Maximum tangential velocities as dictated by the pressure wells are plotted showing the relationship with ΔP measured in percentage of ambient pressure. (after [6,7])

References. [1] Greeley et al. (2003) *J. Geophys. Res.*, *108(E5)*, 5041. [2] Sarkar et al., *10th Am. Conf. on Wind Eng*, (2005); [3] Sinclair (1966) PhD. [4] Metzger et al. (1999) *GRL*, *26(18)*, 2781-2784. [5] Fisher et al.,(2005) *JGR* 10.1029/2003JE002165. [6] Neakrase et al. (2005) *AGU Fall Mtg.*, #P11-0147 (Abstract). [7] Neakrase et al. (2006),*GRL in prep.*