Particle threshold as a function of surface type: Preliminary laboratory experiments

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Introduction: Boundary layer wind tunnel experiments were run to investigate the differences in static threshold for particles as a function of 1) particle composition, 2) particle spacing, and 3) surface on which they rested. *Static threshold* refers to the wind speed necessary to entrain particles from rest. Care was taken to not include particles in motion striking the samples. The objective of these experiments was to determine the differences in the threshold wind conditions as a function of these variables. The context for these experiments is for planetary protection, considering contaminants that survive current cleansing of spacecraft on Earth and could potentially contaminate astrobiology studies in upcoming missions on Mars, where typical spores could range from 1 to 1000μm in diameter.

Methodology: Particles used in these experiments included silica sand 500-600μm in diameter (2600 kgm^{-3}), crushed walnut shells (WS) 500-600μm in diameter (1300 kgm^{-3}), polystyrene beads 600-710μm in diameter (1050 kgm^{-3}), and Carbondale Red Clay (CRC) ~2μm in diameter (2650 kgm^{-3}). Two different experiments were run to compare differences in particle threshold, one to test effects of surface type and particle spacing, and the other to monitor effects of ambient relative humidity.

Threshold is determined by slowly increasing the free stream wind speed in the wind tunnel until the particles begin to move. Threshold can be subdivided into two distinct regimes, initial and sustained. Initial threshold corresponds to the removal of perched or otherwise easily moved particles (perhaps due to size, shape, or position). Sustained threshold refers to the active removal of a constant number of particles over time indicating that shear stress values necessary for full entrainment of the particles have been surpassed. Shear stress is related to the free stream velocity through a term called the *friction velocity*, u_*, which is a characterization of the boundary layer as a function of height and wind speed. Shear stress is most commonly described by:

$$\tau = \rho u_*^2,$$

where ρ is the atmospheric density.

Sediment was distributed in four different positions to study the effects of separated grains and surface material on static threshold (Figure 1). For the first position, a stylized lander model was employed to test the effect of vertical position within the boundary layer. The model was composed of a painted wood base mounted on pedestal legs and a glass top. Due to flow separation and vortices produced by the leading edge of the model, samples were placed on the downwind third of the model to minimize these effects. Particles were emplaced on the model so that individual grains were not in contact with any other grains. The second position utilized a glass microscope slide placed on the floor of the wind tunnel, with separated particles as in the lander model case. The third position used separated particles on the floor of the wind tunnel, which is comprised of 500-μm sand permanently affixed to the floor. The fourth position was a thicker bed of particles placed directly on the floor. Used as a control case, the fourth spot allowed comparison to previously published threshold values [1,2]. Each of the four sediment test cases was run twice for repeatability.

Results: Results showed distinct differences in threshold values for certain conditions (Table 1). In general, particles move at lower free stream velocities when they are separated and on smooth surfaces (i.e. glass), and more so when they are elevated on the deck of a spacecraft (being higher in the boundary layer). Threshold values for the thicker bed of material agree within 1-2% of previously published boundary layer threshold values for materials with similar sizes and densities. The observation that similarly sized particles move more easily when elevated on a spacecraft instrument or solar panel deck suggests that possible contaminants from Earth could be blown off spacecraft sent to Mars at lower wind speeds than are necessary for static threshold for surface materials. It should be noted that spacecraft components could shield surfaces from direct contact of surface winds and serve as particle "sinks" for both material sent from Earth and material collected once on Mars.

References: [1] Iversen J.D, J.B. Pollack, R. Greeley, B.R.White, *Icarus* 29, 1976; [2] Greeley and Iversen, *Wind as a Geological Process*, Cambridge, 1985.

Figure 1. An example of an experiment run setup. Particles were separated on the *Lander Model*, *Microscope Slide*, and the *Separated Patch*. *Thick Patch* was included as a comparison to previously published material.

Table 1. Comparison of free stream velocities for each sediment for the four different cases. Silica sand (SiO_2) 500-600μm in diameter (2600 kgm^{-3}), crushed walnut shells (WS) 500-600μm in diameter (1300 kgm^{-3}), polystyrene beads 600-710μm in diameter (1050 kgm^{-3}), and Carbondale Red Clay (CRC) ~2μm in diameter (2650 kgm^{-3}).

	Lander Initial	Sustained	Slide Initial	Sustained	Separated Initial	Sustained	Thick Initial	Sustained
SiO_2	4.19 m/s	4.93 m/s	5.26 m/s	6.46 m/s	6.26 m/s	7.97 m/s	7.26 m/s	9.12 m/s
WS	2.24 m/s	3.17 m/s	3.17 m/s	4.15 m/s	3.90 m/s	4.72 m/s	4.27 m/s	4.93 m/s
Polystyrene	1.20 m/s	1.71 m/s	2.24 m/s	2.85 m/s	3.48 m/s	4.70 m/s	4.92 m/s	5.94 m/s
CRC*	2.85 m/s	3.49 m/s	8.5 m/s	n/a	n/a	n/a	11.03 m/s	13.66 m/s

* CRC values were estimated as observation of 2μm particles were inferred