NUMERICAL STUDY OF ELECTROSTATIC DUST LOFTING VARIATION BY SURFACE PARAMETERS OVER THE LUNAR TERMINATOR REGION.

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Introduction: The lunar dust exosphere is sustained by the flux of interplanetary dust, impact ejecta and electrostatically transported dust particles (Figure 1). Even though laboratory experiments demonstrated dust lofting by electrostatic forces, there are several parameters to investigate through numerical studies as well as laboratory experiments. In our previous studies, a test bed has been developed to demonstrate the fundamental mechanism of the electrostatic dust transportation in the vacuum chamber, and the experimental results have been published for the initial launching velocities, launch angle distribution, lofted dust particle distribution, maximum heights, and acceleration profiles [1, 2, 3]. Even though the dust charging time is essentially controlled by the ambient plasma conditions, the charge magnitude requirement to launch a dust particle from the surface is mainly controlled by the regolith configuration. In this study, maximum altitudes for the lofting dust particles are simulated with launch angles from the measurements in the vacuum chamber experiments, variable contact forces considering surface cleanliness and multiple contact points, different micro-cavity sizes, and the gravity force parameter using mass densities of 1.00 kg/m^3-3.30 kg/m^3 considering agglutinate glass, basalt and regolith breccia.

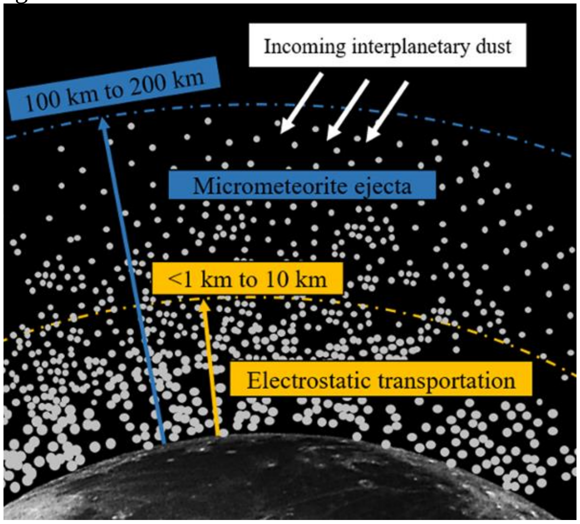

Figure 1: Dust transportation around the Moon

Electrostatic Dust Lofting: Laboratory experiments have demonstrated that dust grains can mobilize under the electron beam and/or UV lamp [1,3,4,5]. When a silica dust sample is compressed to decrease the number of micro-cavities (Figure 2), the dust activity under the same charging source reduces with the amount of the applied pressure [1]. It is the result of the enhanced contact forces with the applied pressure since the dust grains require building up stronger charges within the micro-cavities to detach from each other. In addition, the dust sample was placed between two parallel aluminum plates that were separated by a 5 cm distance and biased to 240 V. When the dust sample was exposed to the electron beam with 450 eV energy, negatively charged dust particles lofted in all directions (Figure 3). Therefore, it pointed out that electrostatic repulsion between the neighboring dust grains was significantly stronger than the external electric field applied by the aluminum plates.

Figure 2: Silica microspheres in vacuum chamber experiments

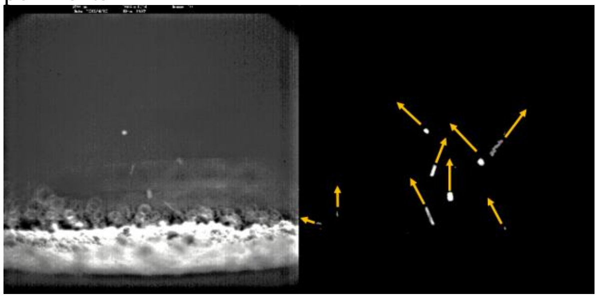

Figure 3: Lofting silica microspheres in the vacuum chamber captured by microscopic telescope (left) and processed recording (right)

A simulation code has been developed to estimate the initial charge magnitude for the lofted dust grains for solar wind conditions as well as the parameters related to the regolith. In addition, it also estimates the initial launching velocities of the particles, and the particle trajectories are calculated while updating the charging environment with 10^{-3} s time steps. For the initial set of simulations, the dust grains in the range of 0.1 – 5.0 micrometer in radius are investigated under the slow stream solar wind condition (Figure 4).

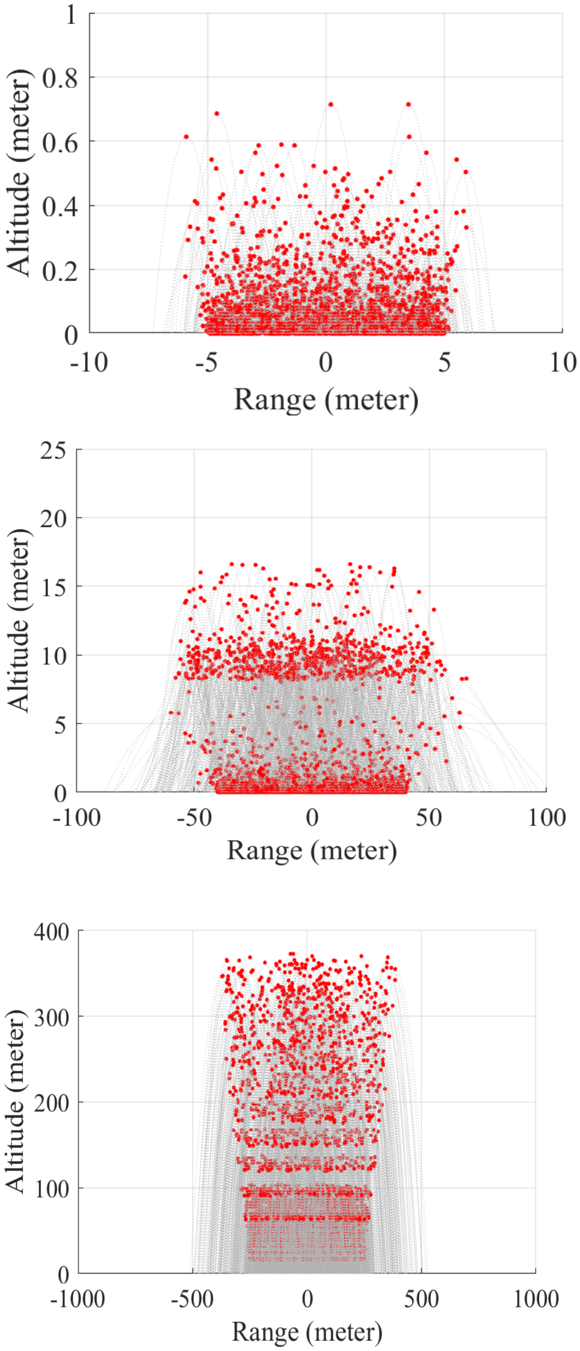

Figure 4: The simulation results for particle trajectories (gray lines) and the maximum altitudes (red points) for the dust grains with 5.0 micrometer (top), 1.0 micrometer (middle), 0.1 micrometer (bottom) radius

Discussion: The simulation results point out that the regolith configuration could significantly control dust lofting by electrostatic forces. Even though the near-surface electric field controls the particle motion after the detachment from the surface, the main mechanism is expected to be the repulsion between the adjacent charged dust particles. Therefore, the contact forces play a significant role in dust lofting since it determines the initial charge magnitude to initiate lofting. In addition, the characteristic size of the micro-cavities also plays a significant role since dust grains require smaller charges when the repulsive surfaces are in close proximity. These are important to consider for two reasons. First, the particles could attain higher launching velocities when stronger repulsive potential energy builds up within micro-cavities between the charging particles. Second, higher charge-to-mass ratios could allow particles to travel further by the near-surface electric field on the lunar terminator.

The dust grains with 0.1 micrometer radius have trajectories influenced by the surface electric field more than the other particles since they have higher charge-to-mass ratios. Even though no particles reached above 1-km altitude, the particles with high charge-to-mass ratios could be transported to higher altitudes near the regions with the enhanced electric field. As expected, there is a significant variation in the altitudes of lofted dust grains. We will discuss how these surface parameters control the dust lofting as well as the vertical dust profile.

References: [1] Orger et al., Adv. Space Res., 63(10), 3270-3288, 2019. [2] Orger et al., Adv. Space Res., 62(4), 896-911, 2018. [3] Orger et al., Adv. Space Res., 68(3), 1568-1581, 2021. [4] Wang et al., Geophys. Res. Lett., 43(12), 6103-6110, 2016. [5] Schwan et al., Geophys. Res. Lett., 44(7), 3059-3065, 2017.