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Electrostatically-Driven Dust Lofting and Migration on Small Bodies

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Electrostatic dust lofting may be a common occurrence on small bodies in the Solar System, whereby the upward electrostatic force on a grain overcomes the gravity and cohesion binding it to the surface. This phenomenon may redistribute and transport dust across the surface to produce features such as the dust ponds on Eros, or even to rid bodies of small particles completely. Classical models, which distribute charge evenly across a dust grain, predict electric field strengths which are insufficient to loft dust. However, recent studies have developed grain-scale charging models which assume unequal distribution of charge on a dust grain and account for the buildup of charge in the microcavities of regolith. These models predict electric field strengths orders of magnitude larger than classical models, which may explain how electrostatic dust lofting occurs.

This thesis extends the most recent experimental results and grain-scale simulations to a global, comprehensive small body environment to better understand the complex interactions affecting electrostatically-driven dust motion on small bodies. Specifically, this thesis develops a method of bounding initial grain parameters (charge and velocity) and surface conditions (regolith cohesion) which lead to electrostatic lofting using new grain-scale supercharging models. A survey of electrostatic lofting requirements and behaviors on asteroids such as Bennu, Itokawa, Ryugu, and Eros is performed using a three-dimensional small body environment model which accounts for a complex gravity field, solar radiation pressure, and electrostatics from the near-surface plasma sheath. Simulation results show that past periods of faster rotation may have depleted small particle populations from bodies such as Bennu and Ryugu. Additionally, there is a strong correlation of higher particle mobility and escape at lower solar elevation angles, implying that dustier times of day exist in the morning and evening near the terminator regions. Finally, we find a preferential loss of small particles on smaller rubble-pile asteroids such as Bennu, Itokawa, and Ryugu, contrasted with retainment of these same particles on larger bodies such as Eros. Overall, this work informs future efforts which aim to better understand, model, predict, and observe electrostatic dust behavior on small bodies in the Solar System.