ELECTRICAL EVOLUTION OF A DUST PLUME FROM A LOW ENERGY LUNAR IMPACT: A MODEL ANALOG TO LCROSS,

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Introduction: A Monte Carlo test particle model was developed that simulates the charge evolution of micron and sub-micron sized dust grains ejected upon low-energy impact of a moderate-size object onto a lunar polar crater floor. Our analog is the LCROSS impact into Cabeus crater. Our primary objective is to model grain discharging as the plume propagates upwards from shadowed crater into sunlight.

We assume ejected grains in the plume are initially seeded in a negative charged state consistent with previous lab studies of impacts and with grain-surface tribo-electric mixing. The vertically-moving negatively charged grains are then allowed to come into equilibrium with the surrounding solar wind plasma and photoelectron environment.

To mimic the plume dynamics we applied a simple formulation assuming equipartition of impact energy to the grains, such that particulate ejection velocity varied as ~ $(U/m_g)^{1/2}$ where U is assumed grain ejection energy and m_g is the grain mass. The ejection energy was modeled as having an average value, <U>, with a broad Gaussian spread, which was applied to individual grains in a random fashion. The mean value of <U> and standard deviation of the distribution of grain ejection energy was then adjusted to approximately replicate the LCROSS observations [1, 2].

The plasma environment is modeled as follows: The solar wind is propagating nearly horizontal to the polar surface. In the shadowed crater region (first ~800 meters [3]) we assume the presence of low density expanding plasma as modeled by [4]. Above the crater rim (> 800-m), the grains are directly exposed to both the horizontally flowing solar wind and solar radiation. The latter creates photo-electron emission at ~ 4 microA/m^2. The grain charge evolution, dQ/dt, is derived by summing the environmental currents (including associated retarding and enhancing factors [5]) as the grains propagate.

It is found (Fig 1) that as the plume propagates from shadow to sunlight, grains in ejecta cloud takes close to 100 seconds to reverse polarity to positive charge via photoelectron currents. The dissipation (i.e., polarity reversal) time is a function of grain size, with the smallest sub-micron grains at the leading edge of the ejecta cloud taking the longest time to reverse polarity. In this initial period (first 100 seconds), the system is not in equilibrium and a strong negative potential is expected at the shadow-sunlight boundary due to the presence of both negatively-charged grains and their photoelectrons.

During later stages in plume evolution, the plume grains ultimately dissipate the negative charge, reverse polarity, and finally come into equilibrium (dQ/dt approaches 0) with the plasma environment.

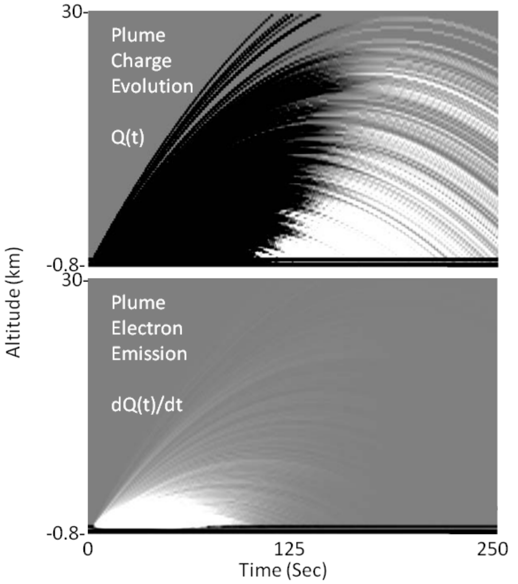

Figure 1- The evolution of charge (Q) and charge emissivity (dQ/dt) of a vertical particulate plume consisting of 5000 test grains ranging from 0.4 to ~6 microns in size. In the top panel, regions of negative polarity are black, and positive polarity are white (Black is < -0.1 fC; White is > 0.1 fC). In the bottom panel, the white regions indicate that the plume particulates are emitting electrons and hence charging increasingly positive (Black is < -.02 fA; White is > 0.2 fA). It takes close to 100 seconds for the grains to emit enough photoelectron current to reverse polarity from their initially negatively tribo-charged state.

References: [1] Colaprete, A. et al., Science, 330, 463, 2010. [2] Schultz, P. H., Science, 330, 468, 2010. [3] Stubbs, T. J., et al. (2010), LPSC XLI, 2410. [4] Farrell, W. M. et al., J. Geophys. Res., 115, E03004, 2010. [5] Goertz, C. K., Rev. Geophys., 27, 271, 1989.