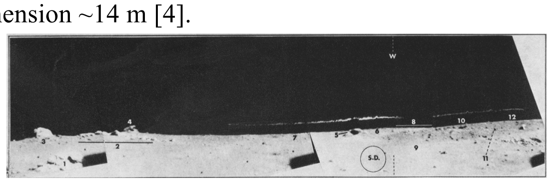
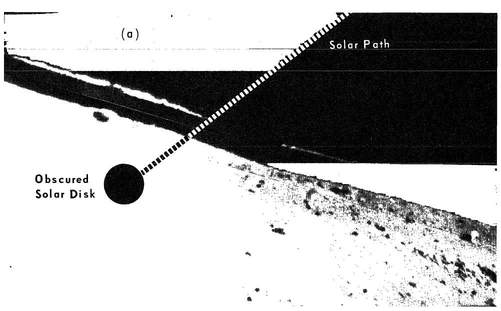
Modeling Dust Clouds on the Moon. J. Szalay[1,2] and M. Horanyi[1,2], [1]University of Colorado at Boulder Department of Physics (jamey.szalay@colorado.edu), [2]Coloardo Center for Lunar Dust and Atmospheric Studies

Introduction: The lunar environment is a complex and dynamic system. Without an appreciable atmosphere or large-scale magnetic field, with the exception of regions with strong magnetic anomalies, the solar wind freely reaches the lunar surfaces. Combined with photoemission from the lunar surface due to direct exposure to solar UV radiation, this can lead to surface charging, near-surface electric fields, and the mobilization and transport of the lunar soil [1].

Images taken by Surveyors 5, 6, & 7 have indicated the presence of lofted dust clouds along with estimates for their spatial extent and density [2]. A 1D hybrid code, treating electrons and ions as fluids and the dust grains as particles, has been developed to constrain the properties of these clouds. We will discuss the preliminary results of this model and compare its prediction to existing observations.

Horizon Glow: Surveyors 5, 6, and 7 captured the first evidence of dust transport on airless bodies with their television cameras (shown below) [2,3]. Just after sunset, a horizon glow was observed above the western horizon. This was interpreted to be forward scattered light from a cloud of dust particles with radii ~5 μm, vertical dimension ~3-30 cm, and horizontal dimension ~14 m [4].





Dust Levitation: Due to surface charging, like charged grains on the surface electrostatically repel each other. If this force overcomes gravity and cohesion forces, these grains can be lofted into the plasma sheath above the surface. In this model, grains are injected into the sheath with optimal velocities for levitation.

To model the plasma sheath, a two fluid approach is used with Boltzmann electrons and cold, drifting ions [4]:

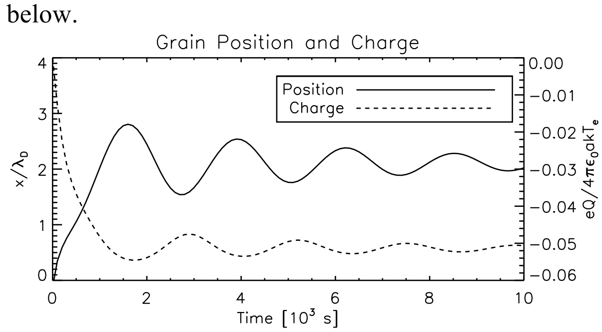
$$n_e = n_0 e^{e\varphi/kT_e} \qquad n_i = n_0 \left(1 - \frac{2e\varphi}{m_i v_{i,dr}^2}\right)^{-1/2}$$

As grains traverse the sheath, they charge according to charging currents dependent on the local plasma conditions and grain charge [5]:

$$I_e = -n_0 e \pi a^2 \sqrt{\frac{8kT_e}{\pi m_e}} \exp\left(\frac{e\varphi}{kT_e}\right) \exp\left(\frac{eQ}{4\pi\epsilon_0 a k T_e}\right)$$

$$I_i = n_0 e \pi a^2 \varphi_{i,dr} \left(1 - \frac{eQ}{2\pi\epsilon_0 a (v_{i,dr}^2 m_i - 2e\varphi)}\right)$$

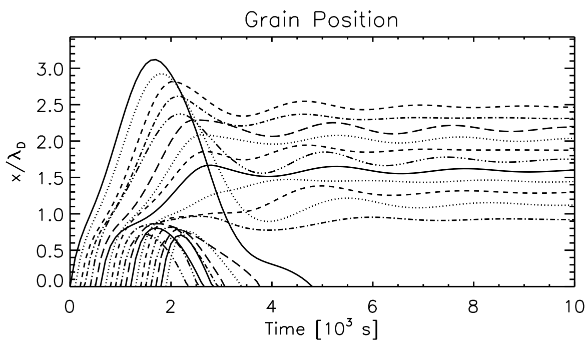
Given certain conditions such as initial velocity, grain size, and initial charge, grains have been shown to levitate in stable equilibria in the plasma sheath [4] as seen below.

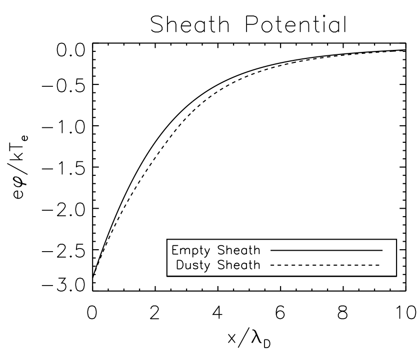


Simulation: If enough grains collect in the plasma sheath, the sheath potential profile can be significantly altered [1]. A 1D hybrid code has been developed with fluid plasma and particle dust grains to better understand this phenomena. Launching dust grains into the sheath, Poisson's equation shown below is solved at each time-step to determine the new potential, charging currents, and forces experienced by each grain.

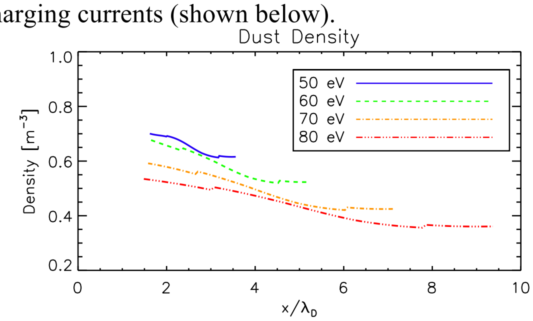
$$\frac{\partial^2\varphi}{\partial x^2} = \underbrace{\frac{en_0}{\epsilon_0} e^{e\varphi/kT_e}}_{\text{electrons}} - \underbrace{\frac{en_0}{\epsilon_0}\left(1 - \frac{2e\varphi}{m_i v_{i,dr}^2}\right)^{-1/2}}_{\text{ions}} - \underbrace{\frac{\rho_d(x)}{\epsilon_0}}_{\text{dust}}$$

Results: Identical particles are injected into the sheath at a given cadence. As more grains become suspended in the sheath, the sheath potential is modified and the electric field is weakened. At a critical dust density, the sheath becomes saturated and can no longer support the suspension of additional grains [1]. Shown below are the dust trajectories and sheath potential in a saturated dust sheath.





Looking at the characteristics of the sheath, the electron temperature was modified. In this run, the spatial extent of the dust sheath is found to vary as electron temperature varies due to different electron charging currents (shown below).



Conclusion: The model accurately reproduces the simulation results found in [1]. Additional layers of complexity will be added to the model to allow for different grain size distributions, alternate ion distributions, and 2D/3D simulations.

References: [1] Horanyi, M., Charged Dust Dynamics *Annu. Rev. Astron. Astrophys.,* 34 (1996) 383 [2] Rennilson, J. J., Criswell, D. R., 1974. Surveyor observations of lunar horizon-glow. The Moon 10(2), 121-142,doi:10.1007/BF00655715 [3] Criswell, D.R. Proc. Lunar Sci. Conf., 3rd, 1972 [4] Nitter, T.*, et al.,* IEEE Trans. Plasma Sci., **22,** 1994 [5] Nitter, T.*, et al.*, Earth, Moon and Planets, **56,** 1992 [6] Havnes, O., *et al*, J. Geophys. Res. **2**, 2281-2287