Simulating the LCROSS plume: improvements to water ice and vapor model

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The purpose of this work is to improve the previously developed LCROSS (Lunar Crater Observation and Sensing Satellite) impact plume model and provide greater insight into the presence of water in permanently shadowed craters on the moon. The impact plume is modeled as having a high angle spike and low angle cone component. Particles are modeled via two species: pure dirt and pure water ice grains. Previous work focused on constraining plume parameters using spectral observations. Once lofted into sunlight, water ice sublimes, and the vapor may photo dissociate or ionize. The present work focuses on improving the sublimation and photodissociation models.

Ice grain sublimation rates are defined by energy balance, where solar energy absorbed is balanced by energy lost due to blackbody emission and sublimation. To accurately replicate this process, it is necessary to account for the optical properties of ice grains and their variance with grain size. These properties have an impact on energy absorbed as well as energy lost through blackbody emission. Mie scattering theory was utilized to compute the wavelength-dependent grain absorption coefficient for a range of grain radii. Integrating the product of absorption coefficient and solar irradiance over wavelength yielded the energy absorbed as a function of grain radius. Similarly, integrating the product of absorption coefficient and Planck's Law (for a range of temperatures) over wavelength yielded the energy emitted as a function of grain radius and temperature. Sharp gradients are present in energy emitted with respect to grain radius, a feature not present in the previous calculation (using $\varepsilon\sigma T^4$). We calculated lifetimes for ice grains in sunlight using these two results and we found that ice grains last much longer than the LCROSS observation timescale.

Calculated lifetimes of pure water ice do not agree with observed water ice spectra. This implies that lofted water ice is not pure, but instead has inclusions of some dark material that increases its absorption and reduces the grain lifetime. Further work will attempt to constrain the fraction of dirt present, providing some indicators as to how ice accumulated over time in this region of the moon.

Previously, photodissociation was modeled using a reaction rate based on observations. However, this did not account for the excess energy of the dissociating photon. Of particular interest for this investigation is the fraction of excess energy added to the kinetic energy of product molecules, since this directly impacts the shape and size of the resulting cloud of OH. Through a review of the literature, a 5 path model for water dissociation (with different kinetic energy additions) was implemented. A large fraction of the water is dissociated into OH by Lyman-alpha (121.6 nm) photons, and have recoil velocities of 1.01 km/s with respect to the original water molecule. This improvement will allow for more accurate constraints on causes of observed OH spectra.