Abstract

Innovative experiments and models are used to explore the behavior of subsurface ice on Mars. Through communication with the atmosphere, the porous regolith of Mars hosts significant quantities of ice which grow, evolve, and are lost in response to climate changes. As a controlling property of rate of ice response to a changing equilibrium state, the diffusive properties of several regolith simulants are measured in Mars-like environments. Ice loss through a variety of particle sizes, particle size distributions, packing densities, and salt contents are examined and reveal that many unconsolidated media exhibit diffusion coefficients in the range of 2–6 cm^2 s^{-1}, indicating a response time on the order of several thousand years for ice within the upper meter of the regolith. Only high salt contents or mechanically packed micron-sized dust are observed to exhibit substantially lower coefficients, suggesting that strong diffusive barriers may not form as readily as previously invoked.

The growth of ice directly from vapor under diffusive control is reproduced for Mars-like environmental conditions in the absence of the liquid phase. As predicted, ice deposits preferentially at grain contact points and the ice table interface is sharp and strongly controlled by near-surface temperature perturbations. The quantity of ice deposited as a function of depth and time accords well with new numerical models of vapor diffusion and ice deposition, though constriction of the pore space reduces the diffusion coefficient faster than originally expected.

A numerical model incorporating a fast solution to subsurface ice growth predicts near-surface ice contents for the last 300,000 years of Mars' history at high latitude locations, including specifically the Phoenix landing site. Several parameterizations of constriction developed from laboratory observations of ice growth are employed and compared. The thickness of the ice-free layer above the ice table has the strongest effect on the quantity of ice accumulated, though subsurface massive ice sheets and ice-free porosities also affect the ice profile. If predicted ice loss events have emptied the upper 0.5–1.0 m of regolith prior to 300,000 years ago, pore ice formed through diffusive processes will have been unable to fill the most rapidly accumulating depths with ice in this time unless ice-saturated regolith exists within ∼0.5 m of the surface. Predictions of these experiments and models will be tested by the imminent arrival of the Phoenix Mars Lander and future Mars missions.