

ICE TABLE DEPTH VARIABILITY NEAR SMALL ROCKS AT THE PHOENIX LANDING SITE. H. G. Sizemore¹, M. P. Golombek², and M. T. Mellon¹; ¹Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, CO 80309 (hanna.sizemore@colorado.edu); ²Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109.

Introduction: A major objective of the Mars Scout mission Phoenix is to investigate both shallow subsurface ground ice and overlying dry soil in the martian high latitudes [1]. The Phoenix mission will provide the first in situ tests of the theoretical understanding of ground ice developed over the past four decades. The mission will also provide the first opportunity to examine the structure and chemistry of soils in a “wet” martian environment. In light of these goals, a landing site was sought where ice is shallow enough in the current climate to allow sampling of ice-rich material by the Robotic Arm, but deep enough to permit examination of loose soils [2].

The depth of the ice table (the boundary between dry and ice-cemented soil) at the Phoenix landing site has been estimated using a variety of orbital data sets and analysis techniques. Current depth estimates range from <2 cm to ~6 cm [3], but local slopes, variations in soil texture, and surface rocks might cause depth variations of a few to 10s of cm within the spacecraft’s digging area [4]. Anticipating and capitalizing on ice table depth variations within the digging area may be key to realizing the dual goals of investigating both ice and soil. Sampling ice will be easiest where the ice table is shallowest. Sampling dry soils will be optimized in areas where the ice table is deeper. Moderate-sized rocks will be particularly valuable to soil investigations because they can depress the ice table by several cm while simultaneously protecting dry soil from descent engine exhaust dispersal.

Here, we present new 2- and 3-dimensional thermal simulations of ground ice stability near rocks specific to the Phoenix landing site. We make statistical predictions of the ice table depth variability caused by small rocks within the 3.8 m² area accessible to the Robotic Arm. We discuss implications for soil collection and highlight spatial configurations of surface rocks that Phoenix might exploit to optimize investigations of soil.

Methods: We simulated the thermal behavior of the martian subsurface near rocks from 5 cm to 3 m in diameter using the multi-dimensional radiative-conductive thermal model described by [4]. We defined key model parameters to closely reflect conditions expected at the Phoenix landing site, assuming a rock thermal inertia of 2300 J m⁻² K⁻¹ s^{-1/2}, a soil thermal inertia of 200 J m⁻² K⁻¹ s^{-1/2}, and an albedo of 0.2 at latitude 68° N. To determine the depth of the ice table we assumed the ice to be in equilibrium with 20 pr μm of atmospheric water

vapor, yielding a depth of ~4 cm in rock-free soil -- consistent with estimates from orbital data sets [3].

We combined the results of these simulations with statistical estimates of the number of small rocks expected in the area accessible to the Robotic Arm [5]. This allowed us to predict the fraction of the surface area available for excavation that might overlie ice depressed by the thermal influence of rocks (Fig. 1). We estimated the total abundance of small rocks at the landing site by extrapolating rock size-frequency distributions measured in HiRISE images of the landing ellipse to small diameters, as described by [5]. This method of estimating the total number of rocks assumes that model size-frequency distributions based on fracture and fragmentation theory apply at the Phoenix landing site and that the surface distribution of rocks is homogeneous. The former assumption is likely valid and will be testable upon landing [5]. We discuss some implications of the latter assumption below.

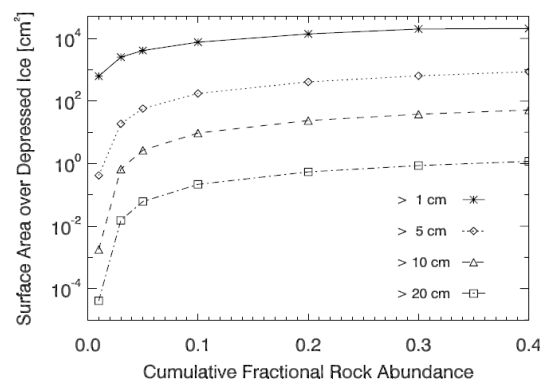


Figure 1. Total accessible surface area overlying ice depressed by the thermal influence of rocks in the 3.8 m² excavation region. For reference, the Robotic Arm scoop is 10 cm wide. See additional discussion in text.

Results: Numerical simulations indicate that rocks act as heat sources in the soil, forcing the ice table to greater than average depth in their vicinity [4]. At the high latitude of the Phoenix landing site rocks of ~5 cm diameter and larger will likely be associated with depressions in the ice table and an annulus of deeper than average ice-free soil. The lateral extent of the ice table depression associated with a given rock is comparable to the rock’s radius and the depth of the depression is controlled primarily by the depth to which the rock penetrates beneath the soil surface.

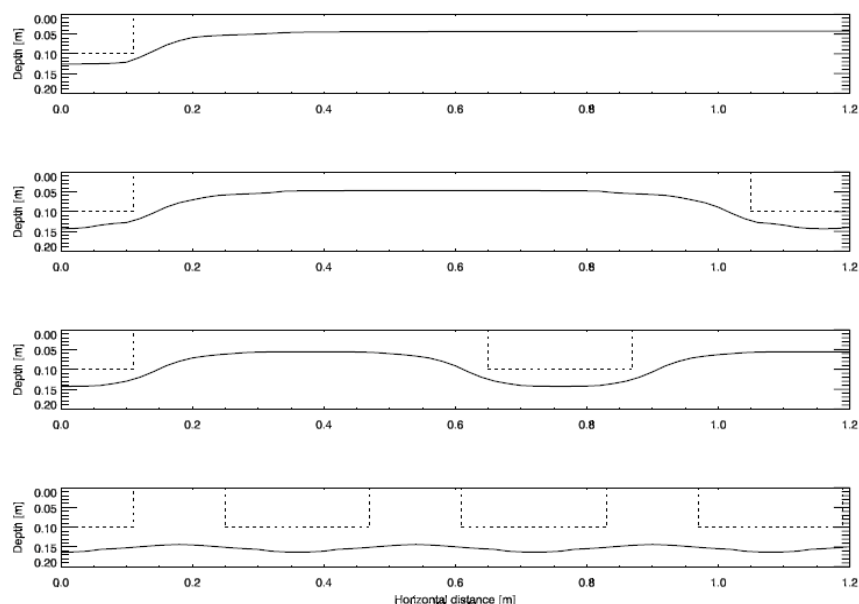


Figure 2. The ice table (solid lines) is depressed to progressively greater depths as lateral separation between rocks (dashed lines) is decreased.

Fig. 1 shows the total surface area accessible to the Robotic Arm under which the ice table is likely to be depressed by > 1 cm, > 5 cm, > 10 cm, and > 20 cm below its average depth in rock-free soil. For regions of the landing ellipse where the cumulative fractional rock abundance is 10% or higher, $> 10^4$ cm² or $\sim 1/3$ of the area accessible to the arm will likely overlie ice depressed by > 1 cm below its average depth. For rock abundances $< 10\%$, smaller fractions of the digging area will overlie ice depressed to this degree, but observing undulations at the one to two cm level seems very likely everywhere inside the landing ellipse. In the same rock abundance range, less than 100 cm² ($\sim 0.25\%$ of the digging area) will overlie ice depressed by more than 5 cm. Although this area is a small fraction of the region available for excavation, it is comparable to the area of the Robotic Arm scoop, indicating that Phoenix may have the opportunity to excavate soils as deep as twice the average depth of the ice table. The data in Fig. 1 also indicate that Phoenix is unlikely to encounter ice depressed by more than 10 cm below its average depth.

The forgoing results are predicated on the assumption that rocks are homogeneously distributed on the surface and that their regions of thermal influence do not overlap. However, thermal contraction polygons (ubiquitous in HiRISE images

of the landing ellipse) affect the spatial distribution of surface rocks, segregating them in polygon troughs and rubble piles [5,6]. Periglacial clustering of rocks may provide opportunities to sample dry soil at depths > 10 cm below average. Fig. 2 compares the ice table near a single thermally isolated rock to the ice table near groups of rocks with decreasing degrees of lateral separation. As the distance between rocks decreases both the maximum and minimum ice table depth increase (Fig. 3). These results indicate that a serendipitous landing near a polygon trough might optimize soil collection opportunities for Phoenix. Closely associated pairs of rocks in polygon centers could also provide opportunities to acquire deep soil.

Excavation near any rocks in the size range 5 cm to 1 m will provide opportunities to make detailed tests of our current theoretical understanding of ground ice stability, while simultaneously maximizing the volume and acquisition depth of soil samples.

References: [1] Smith P. et al., LPSC XXXV (2004); [2] Arvidson R., et al., JGR-Planets, Phoenix special issue (2008); [3] Mellon M.T. et al., JGR-Planets, Phoenix special issue (2008a); [4] Sizemore H. G. & Mellon M.T., Icarus 185, 358-369 (2006); [5] Golombek M. P. et al., JGR-Planets, Phoenix special issue (2008); [6] Mellon M. T. et al., Phoenix special issue (2008b).

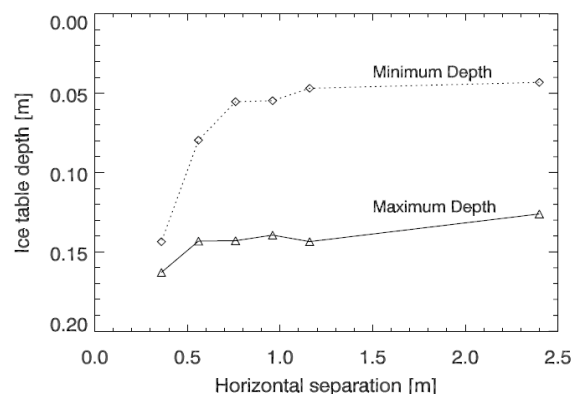


Figure 3. Maximum and minimum ice table depth as a function of lateral separation between rocks depicted in Fig. 2.