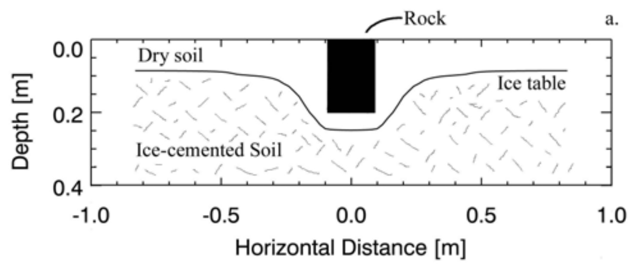
EFFECTS OF ROCKS ON MARTIAN GROUND ICE AND NEUTRON FLUX. H. G. Sizemore and M. T. Mellon, Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, CO 80309 (hanna.sizemore@colorado.edu).

Introduction: Recently, a remarkably consistent picture of the global distribution of near-surface ground ice on Mars has emerged from both observation and theory. Leakage neutron and gamma ray emission data from the Gamma-Ray Spectrometer (GRS) onboard Mars Odyssey indicate the presence of an ice-rich subsurface soil layer extending throughout the mid- to high-latitudes in both Martian hemispheres [1]. A variety of theoretical studies have predicted the occurrence of shallowly buried ground-ice in the same geographic regions indicated by GRS data [2 & references therein]. We present numerical simulations of the three-dimensional distribution of ground ice in a heterogeneous soil and discuss the implications of our results for the interpretation of GRS neutron data.

Background: Despite good geographic correlation between GRS data and theory, observational estimates of the depth to ground ice are larger than theoretical predictions by roughly a factor of two. Mellon *et al.* [2] attributed this discrepancy to two major factors. First, the spatial resolution of the data from which theoretical maps of ground ice are derived differs significantly from the spatial resolution of the GRS. Secondly, theoretical and observational estimates of the depth to ice rely on a common, incorrect assumption – that the "ice-table" (the depth boundary between dry and ice-cemented soil) is uniform over horizontal scales of many kilometers. In reality, the ice-table should exhibit complex, undulating topography due to the presence of rocks, slopes and variations in soil type on spatial scales of meters to centimeters.

Ice Stability. In the current cold, dry martian environment, stable ground ice is in diffusive equilibrium with atmospheric water vapor. The ice-table occurs at the depth where average water vapor density in the soil pore spaces is equal to the mean atmospheric vapor density on annual time scales. Temperatures in the martian subsurface (and thus pore space vapor density) are controlled primarily by the thermophysical properties of surface and subsurface materials (Table 1).

Neutrons. All GRS sub-instruments indicate the presence of ice under a layer of dry material at high latitudes [1]. Neutrons and gamma rays are not sensistive to the geometric depth of this dry layer but to the column mass [g/cm^2] of the material containted in the layer. Current interpretations of ice-table depth based on neutron data have been predicted to over-estimate depths for two reasons [2]. First, the relationship between dry column mass and epithermal neutron count rate is highly non-linear. This non-linearity will cause sub-pixel areas in which the ice-table is depressed to dominate the neutron signal for a given region, skewing depth estimates deeper than the true regional average. Second, if sub-pixel areas of ice depression are caused by the presence of rocks, estimated ice depths will be skewed still deeper, because the high density of rock will add to the apparent thickness of the dry soil above the ice-table when a uniform soil density is assumed.



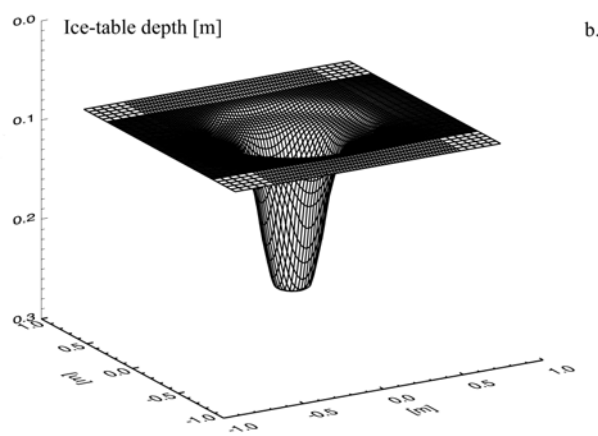


Figure 1. (a) Profile of the ice-table near a cylindrical rock embedded in a typical (I=200) martian soil (60^o N Latitude; Elevation ~ 0 km). (b) Three-dimensional rendering of ice-table shown in (a).

Landed missions. The upcoming Mars Scout Mission, Phoenix, which will land in the northern high latitudes and attempt to excavate to ground ice, illustrates the importance of quantifying local variability in ice-table depth. Before a Phoenix landing sight is selected, current orbital observations must be interpreted correctly to estimate the average geometric depth to ice over large areas of the martian surface. Once Phoenix has landed, a detailed understanding of the configuration of ice near local obstacles will be necessary to aid decisions about where the lander will dig and place tailings [3].

Methodology: We used a radiative-conductive thermal model of the martian atmosphere and regolith to quantify the effects of heterogeneous surfaces on ice-table geometry and GRS observations. The model can operate in one-,two-, and three-dimensional modes. In each case, the thermophysical properties of the regolith can be varied spatially to represent the presence of rocks and a variety of soil types (e.g., Table 1). We typically model surface regions of 1 to 2 m^2 containing a single rock or other heterogeneity.

Results and Discussion:

Ice Geometry. We modeled the effects of cylindrical rocks and dust inclusions in uniform soil on the ice-table. We also considered the effects of patches of high and low albedo at the surface of uniform soil. We found that rocks and regions of low albedo locally heat the soil and depress the ice table, while dust and patches of high albedo cool the soil and locally enhance ice stability, causing the ice-table to deflect upward. Rocks and dust inclusions both affect ice stability on lateral length scales comparable to their own dimensions (10's of centimeters for a cylindrical rock of radius r = 9 cm; Figure 1). Albedo patches alone have less significant effects than the thermal properties of rocks or dust, but will tend to amplify the effects of dark rocks and bright dust on the real martian surface.

Implications for neutrons. Large portions of the martian surface are known to be rocky. Rock abundances ranged from 15 – 20% at the Viking and Mars Pathfinder landing sites, and may be as high as 35% in some areas of Mars [4]. For this reason, we focused on rocks when considering the effects of surface heterogeneities on GRS data.

Figure 2 shows the column mass of dry material above the ice-table from Figure 1. The presence of the rock and the resultant deflection of the ice-table increases the dry column mass above the ice-table by more than a factor of four at length scales significant for neutron moderation. In current one-dimensional neutron transport codes, this four-fold increase in dry column mass corresponds to an increase of several neutron counts per second. For rocky regions of Mars, local areas of elevated neutron count rate can dominate the integrated neutron signal received by GRS. We will present: 1) theoretical ice tables associated with rocky soil; 2) analysis of the neutron signal produced by rocks and theoretical ice table topography; and 3) implications for geometric ice table depths inferred from GRS data.

References: [1] Boynton W.V. et al. (2002), Science, 297, 81-85. [2] Mellon M.T. et al. (2004), Icarus, 169, 324-340. [3] Mellon M.T. et al. (2004) *LPSC XXXV*, 1900. [4] Golombek et al. (2003), JGR 108.

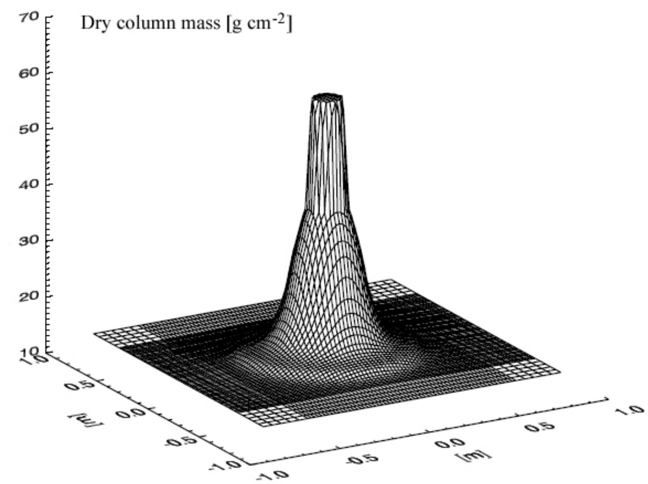


Figure 2. Column mass of dry material overlying the ice-table shown in Figure 1. The high density of the rock and the greater depth to the ice-table both contribute to the elevated column density at the center of the modeled region.

	k [W/m/K]	ρ [kg/m^3]	c [J/kg/K]	I [J/m^2/s$^{1/2}$/K]
Icy Soil	2.5	2018	1040	2290
Soil	0.029	1650	837	200
Rock	2.5	2600	837	2333
Dust	0.001	1000	837	29

Table 1. Representative thermophysical properties for "typical" Martian soil, rock, dust and ice-cemented ground. All values assume 1) basaltic minerology, 2) 40% porosity in soil and dust, and 3) complete saturation of soil and dust pore spaces to form ice-cemented ground.