THE HISTORY OF ICE AT THE PHOENIX MARS LANDING SITE. Norbert Schorghofer, *Institute for Astronomy, University of Hawaii, 2680 Woodlawn Drive, Honolulu, HI 96822 (norbert@hawaii.edu).*

Introduction: The Phoenix Lander is en-route to Mars and scheduled to touch down in 2008 at the high northern latitudes, where the Mars Odyssey Gamma Ray Spectrometer Instrument Suite observes shallow ground ice [1] and equilibrium models predict the presence of ice beneath a layer of dry soil [2, 3]. Two mechanisms for the emplacement of the ice have been proposed: (i) Precipitation with subsequent burial [4, 5, 6] and (ii) deposition from atmospherically derived water vapor that diffuses through the soil [2, 3, 7]. A precipitated massive ice sheet and interstitial pore-ice can be present simultaneously at the same location but different depths [8].

Equilibrium calculations can provide estimates for the geographic distribution and depth of the ice [2, 3, 9, 10] and they apply to both emplacement mechanisms, but they cannot predict the amount of ice. A few estimates for the burial depth of the ice, using existing models [3], are presented in Fig. 2, but the exact answer depends on parameters that are not fully constraint.

Model: To determine the vertical distribution and age of ground ice, it is necessary to consider the history of the ice since the last precipitation. A model of the evolution of subsurface ice layers, described in more detail in Ref. [8], is applied at the approximate latitude of the proposed Phoenix Landing site [11]. The model solves the time-averaged transport equations for (i) the growth of interstitial pore-ice, (ii) recession of interstitial pore-ice, and (iii) the retreat of an ice sheet. It can integrate millions of years of Mars history with varying orbital elements [12], while still resolving diurnal temperature oscillations.

(Various assumed parameters are listed in Table 1. The atmospheric humidity for the variable humidity scenario [15] depends mainly on obliquity and to a lesser degree on eccentricity and the longitude of Mars' perihelion. The model assumes an exposed north polar cap of the same size as today's and no other sources of atmospheric water vapor. The initial ice sheet is 20 m thick, but the behavior in the upper meter of the surface depends little on the total sheet thickness.)

Results: Figure 2 shows the time variation of ice table depths for a climate scenario where the last ice sheet formed 5640 ka ago at an obliquity of $\sim 47^\circ$, which has not been exceeded since, such that the last precipitation dates from a different obliquity epoch [6, 13]. The top interface (green) is that between ice-free soil and pore-ice. The lower ice table (blue) is the top of the ice sheet, which consists mainly of ice and a small fraction of dust. There are as many as three layers: dry soil, pore-ice, and the ice sheet. During dry periods (at low obliquity) interstitial pore-ice recedes, and after all pore-ice is lost, the ice sheet retreats to greater depth. During humid periods (at high obliquity) pore-ice forms, while the ice sheet remains at constant depth. Note that the uppermost ice of today is comparatively young [8]. It is barely discernible in the figure that the ice has been at slightly shallower depths than today many times over the past few million years.

It is not reliably known when the last massive ice sheet formed [14, 5, 6] or how humidity varies with time. In total, four climate scenarios are simulated: Precipitation 5640 ka ago and 632 ka ago (the most recent obliquity maximum with $\sim 35^\circ$) with constant humidity and time-varying humidity.

Figure 3 shows preliminary model results for the vertical ice profile, if the last ice sheet formed 632 ka ago. The massive ice sheet is much closer to the surface than it would be had it last formed millions of years ago. Note that the pores are completely full in the pore-ice layer. The model allows pores to be completely filled with ice, such that the volumetric ice fraction can be as high as the porosity of the ice-free soil. Diffusive infilling decelerates, because of the constriction caused by the ice, but deposition since the last obliquity excursion was sufficiently fast to lead to high ice content.

For the two climate scenarios with constant humidity (not shown), the depth to the ice sheet turns out to be much less than with variable humidity, since they lack the dry periods that lead to retreat of the ice sheet. Still, there is pore-ice on top of the ice sheet.

For all four climate scenarios considered here, the following is true: (i) Nearest the surface is interstitial pore-ice instead of a massive ice sheet [8], and (ii) The pore filling fraction is close to its maximum.

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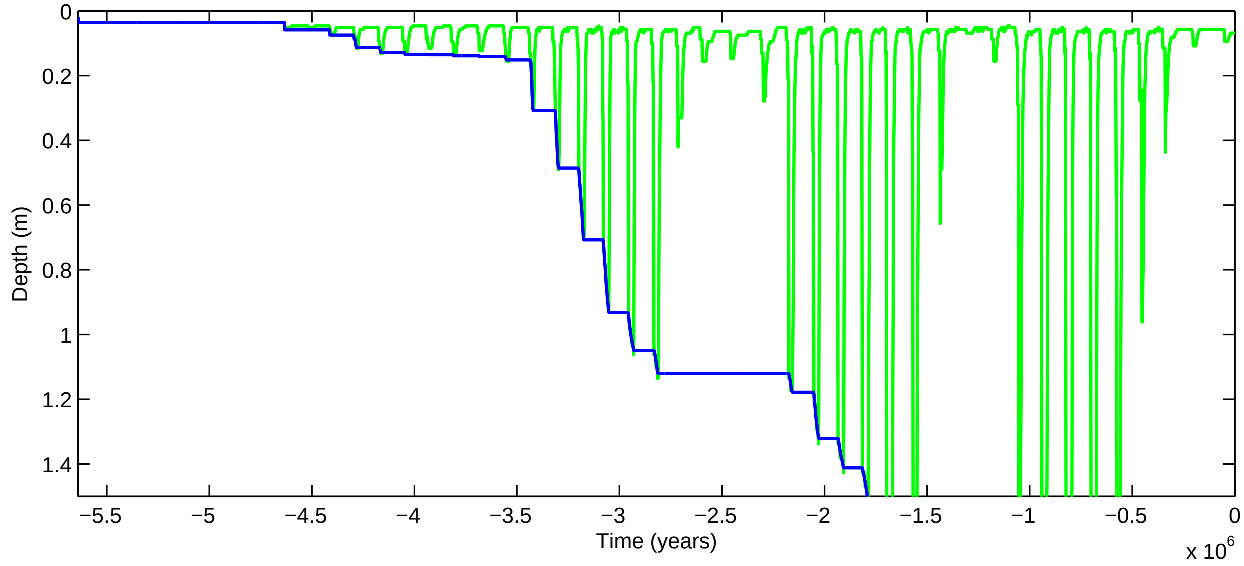

Figure 1: Burial depth of pore ice (green) and the massive ice sheet (blue) as a function of time for a climate scenario where the ice sheet formed 5.640 Ma ago, and atmospheric humidity varied strongly. The final depth of the massive ice sheet is $\sim$1.9 m.

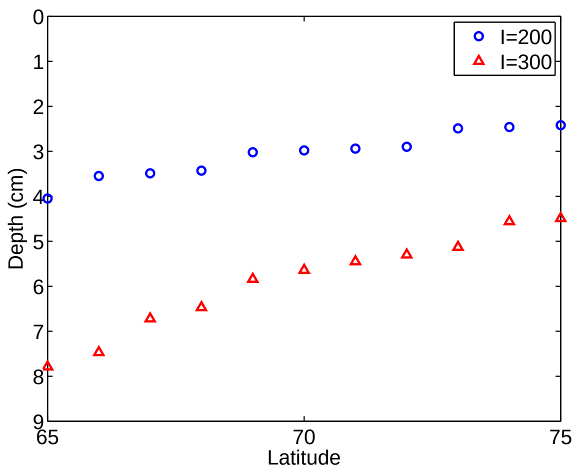

Figure 2: Equilibrium burial depths for two different thermal inertias. The frost point temperature is 201K (0.19 Pa). Other parameters are listed in Table 1. The Phoenix landing site will be between 65° and 72°N [11].

Latitude	68°N
Albedo	0.2
Thermal inertia of ice-free soil	200 $\mathrm{J\,m^{-2}K^{-1}s^{-\frac{1}{2}}}$
Porosity of ice-free soil	40%
Dust content of ice sheet	15%
density of ice-free soil	1480 $\mathrm{kg\,m^{-3}}$
heat capacity of ice-free soil	800 $\mathrm{J\,kg^{-1}K^{-1}}$
max. therm. cond. of ice-filled soil	3.08 $\mathrm{Wm^{-1}K^{-1}}$
atmospheric absorption	4% in zenith

Table 1: Model parameters used for all climate scenarios and in Fig. 2, unless mentioned otherwise.

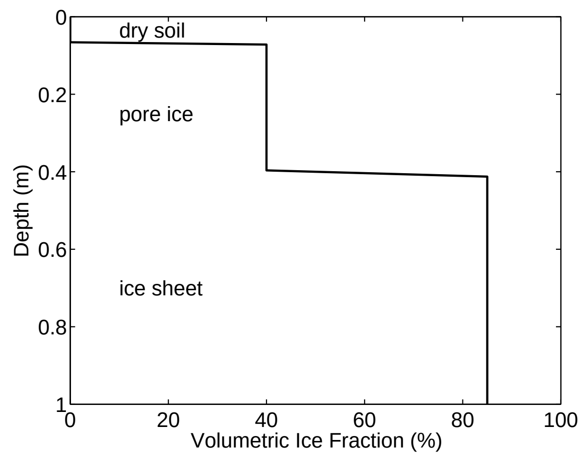

Figure 3: Vertical distribution of ice for a climate scenario where the ice sheet formed 632 ka ago and humidity varied strongly with time.