The Distribution and Behavior of Martian Ground Ice During Past and Present Epochs; Michael T. Mellon [1,2,4] and Bruce M. Jakosky [1,3]; [1] Laboratory for Atmospheric and Space Physics, [2] Department of Astrophysical, Planetary, and Atmospheric Sciences, [3] Department of Geological Sciences, University of Colorado, Boulder, CO 80309. [4] Now at NASA Ames Research Center, Moffett Field, CA 94035.

Introduction: Mars undergoes significant oscillations in its orbit due to gravitational interactions with the sun and other planets. Similar, but smaller, oscillations in the Earth's orbit are known to influence its climate, producing ice ages. Therefore, it is possible that orbitally-induced changes in the martian climate, and in particular the behavior of subsurface water ice, are considerably more impressive. Previous studies have shown that in the current martian climate ground ice is stable poleward of the mid-latitude regions and that the molecular diffusion of water vapor is capable of transporting atmospheric water into the regolith of short time scales. The question remains as to whether during favorable climate conditions the diffusion of water vapor can populate the near-surface regolith (top few meters) with ice before the climate changes toward more unfavorable conditions. To address this question we explore and map the behavior of ice in the near-surface regolith over the past 1 million years. We find that the past behavior differs significantly from that at the present epoch.

Background: Changes in the obliquity (tilt of the spin axis relative to the orbital plane), eccentricity, and L_S of perihelion (the areocentric longitude of the sun, or season, at which perihelion occurs) will affect the distribution of solar radiation on the planets surface and impact the climate and the behavior of ground ice in two ways. Firstly, the surface temperature is affected primarily by oscillations in the obliquity. For example, at an obliquity higher than the present (25°) more solar energy will be deposited in the polar regions raising the annual mean temperature, while less energy reaches the mid-latitude and equatorial regions resulting in lower annual mean temperatures. The situation is reversed during times of lower obliquity. Precession of the L_S of perihelion and oscillations in the eccentricity change the seasonal distribution of solar energy between the northern and southern hemispheres. Although these parameters are less important, they nontheless have an effect.

Secondly, changes in the polar surface temperature will affect the summertime sublimation of the residual water-ice polar cap. During times of higher obliquity when mean polar surface temperatures are warmer, summertime sublimation will greatly increase and ultimately raise the mean atmospheric water content. These changes will not only impact the atmospheric frost point (the temperature at which the atmosphere saturates with respect to water ice) but also the rate of diffusion on water vapor into and out of the regolith.

To investigate the behavior of ground ice and map its distribution as a function of time we employ a model of the diffusive exchange of water vapor between the regolith and the atmosphere, coupled with a model of the martian orbital evolution during the past 1 million years. This model includes all the relevant physics of molecular diffusion, including ordinary and Knudsen diffusion and the choking effects of ice filling the soil pore space. The effects of martian orbital evolution on the surface temperature and atmospheric water abundance are also included.

Martian Ground Ice During Past Epochs: Michael T. Mellon and Bruce M. Jakosky

Conclusions: The following conclusions have been reached from the results of our numerical model:

1) Obliquity oscillations can cause marked changes in the atmospheric water content and surface temperatures on Mars as to effect a significant global change in the stability of ground ice. Variations in the L_S of perihelion and eccentricity have lesser but noticeable effects.

2) The process of molecular diffusion of atmospheric water is rapid enough on orbital time scales to produce cyclic saturation and dessication of the top 1 to 2 meters of the regolith.

3) At obliquities of only 32° ground ice is stable and likely present in the near surface regolith, globally. This is significantly different from the current epoch where ice stability is restricted to regions poleward of approximately 40° latitude, accounting for only about 1/3 of the martian surface.

4) In some regions a long-term buildup of permanent ice is expected below the depth of dessication (1 to 2 meters). This ice will extend to a depth where the seasonal thermal oscillations die out (less than 10 meters); deeper ice will require non-atmospheric sources or burial of near-surface deposits. Permanent ice may persist to the current epoch in regions where ground ice is unstable.

5) The quantity of water exchanged between the regolith and polar caps during an obliquity cycle is variable with location and maximum obliquity. Typically, for maximum obliquities exceeding 32° an average of about 40 g/cm^2 of water is exchanged with the global regolith, and is capable of creating a deposit about 29 meters thick on both poles. This thickness is consistent with observations of polar-layered-deposit layer thicknesses.

6) Cyclic saturation and dessication may have a pronounced effect on the geomorphic character of the surface. Features might form, such as solifluction lobes, hummocky terrain, sorted stones, and frost- and sand-wedge polygons. These features should have small horizontal scale owing to the small vertical scale of the saturation and dessication cycles. Future high resolution images of such features might provide the best test of the models presented here.