THE LONG-TERM EFFECTS OF SURFACE FROSTS, SEASONAL ATMOSPHERIC WATER VARIATION AND ICE FRACTION-DEPENDENT THERMAL CONDUCTIVITY ON MARTIAN GROUND ICE. Jonathan Bapst and Stephen E. Wood, Department of Earth and Space Sciences, University of Washington, Box 351310, Seattle, WA 98195. (jnbapst@uw.edu)

Introduction: Observations from the Mars Odyssey Neutron Spectrometer (MONS) suggest substantial water ice exists beneath the Martian surface (in the upper meter or so) extending from the polar regions to mid-latitudes in both hemispheres [1,2]. The boundary between regions with ground ice and those without appears to be abrupt, as predicted [3].

More recently, HiRISE images of fresh, shallow (~1 m excavation) impact craters indicate mid-latitude ground ice that resides outside the theoretical stability boundary (i.e. prone to sublimation and removal; [4]). Theoretical models have shown near-surface ice equilibrates with climate relatively quickly and the location where these craters lie is expected to be mostly dessicated [5]. This inconsistency needs investigation. The survivability of subsurface ice is important for understanding past and present distribution of water ice on Mars.

Theoretical [3,5] and experimental [7] studies predict that the geographic extent of ground ice is quite sensitive to changes in climate, most notably the atmospheric water abundance. Furthermore, previous studies have shown that changes in Mars' orbit, primarily obliquity, lead to variation in atmospheric water abundance due to fluctuating levels of insolation at the water-rich polar caps [8,9]. Due to the cyclical nature of orbital variation, the stable regions of ground ice will advance and retreat, accordingly [5,6,10].

Methodology: This work aims to isolate and quantify the long-term (>100 kyr) effects on ground ice evolution of some known processes that occur on Mars. Three processes are considered and detailed below. We incorporate a 1-D time-dependent vapor diffusion model for this investigation.

Seasonal Carbon Dioxide Frost: Winter seasons on Mars, past and present, are of interest, especially in the mid to high latitudes where subsurface ice is located. The surface temperatures fall to the point where carbon dioxide (major constituent of the atmosphere) will condense onto the surface as frost. This will change the subsurface temperature regime due to frost setting the surface temperature equal to the frost point of atmospheric CO_2 (about 148 K in Mars' present atmosphere). The frost will also restrict diffusion of vapor between the atmosphere and subsurface. The latitudinal extent of seasonal carbon dioxide is highest during high obliquity (Figure 2).

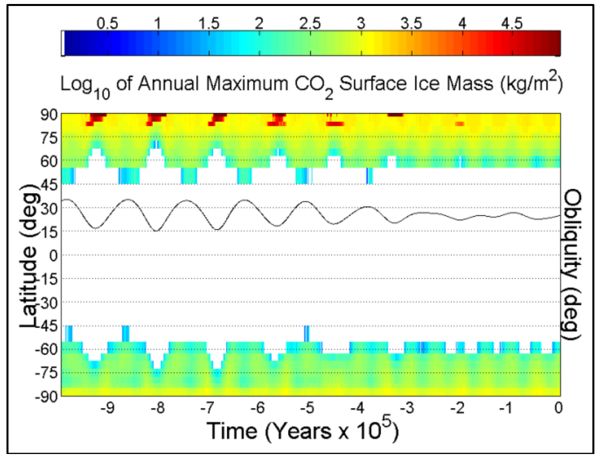

Figure 1 Latitudinal extent and annual maximum mass of seasonal CO_2 over the past 1 Myr. Assumed CO_2 frost albedo of 0.60. Obliquity data from [11].

Performing a simple frost/no frost comparison is not valid. The reason is that without CO_2 frost formation the surface temperature is able to drop well below what is possible under conditions with an atmosphere. Instead, we lower the albedo of CO_2 frost to establish a minimum temperature while avoiding the effects of (normal) high albedo frost. This also provides insight into the sensitivity of CO_2 frost albedo and its affect on the thermal environment and therefore ground ice.

Seasonal Atmospheric Water Cycle: The seasonal water cycle of Mars has been observed by multiple instruments [12,13] and is relatively well replicated by general circulation models [14]. Previous time-dependent ground ice studies used an annual average atmospheric water abundance throughout the year which is unrealistic but is likely acceptable for short term investigations. We introduce a variable vapor density depending on the time of year, to match the observed water cycle and determine its consequences in the long term using our time-dependent model.

Ice Fraction-Dependent Thermal Conductivity: The difference in thermal conductivity between ice free and ice filled regolith can be orders of magnitude. Because of this effect, ice rich regolith dampens thermal oscillations and extends the acceptable conditions for stability [15]. New theoretical work [16] shows that small volume fractions of ice can enhance the conductivity. We investigate the consequences of this effect in the long-term evolution of ground ice.

Discussion: Specifics vary from run to run although to be consistent we will try to keep certain parameters identical (e.g. our regolith is initially ice free for all runs). Other initial conditions will be addressed in future work. Various latitudes are considered but with emphasis on mid latitudes since this is where stability comes and goes over the past 1 Myr and one of our goals is to see how these effects alter, if at all, the window of stability.

We compare two endmember cases in order to understand the potential they have in affecting ice growth and retreat (e.g. CO_2 frost albedos; Figure 2). Conceptually speaking, many of these have both positive and negative influences on ice stability. For example, CO_2 frost acts to lower the average temperature (see Figure 3), favoring ice stability but detracts from it at the same time by preventing diffusion from the regolith to the atmosphere (although this would be helpful if the subsurface ice is unstable during the winter).

Coming back to the observation of icy mid-latitude craters, is it possible that some of these previously never studied processes contribute to the persistence of ground ice? Retreat rates are key in determining the lifetime for ice in the upper meter in the mid latitudes where the craters were observed but can be convoluted due to the complex changes in climate and thermal environments over long timescales (see Figure 4)). These various mechanisms could play a part in reducing retreat rates of unstable subsurface ice. Our work should shed some light on these issues.

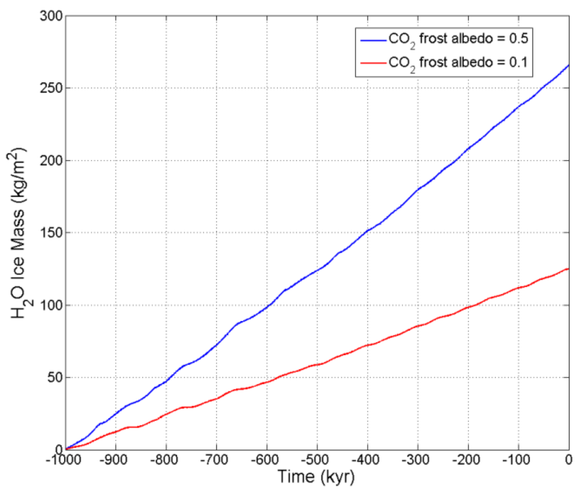

Figure 2 Column integrated water ice mass over 1 Myr for two different cases of CO_2 frost albedo at 55°N. CO_2 frost appears to improve growth of ground ice at this latitude perhaps due to cooling effects (see Figure 3).

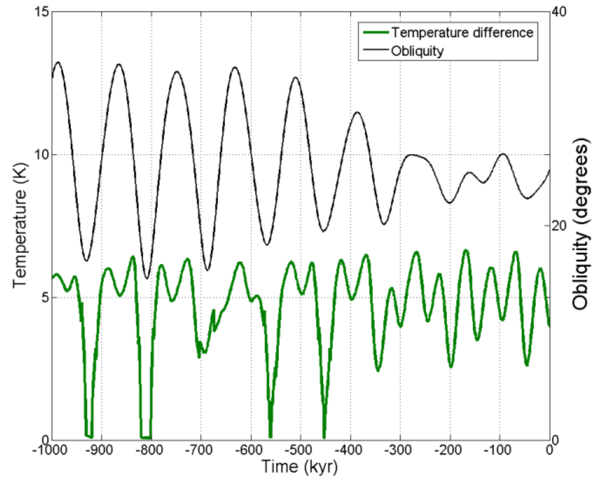

Figure 3 Annual average surface temperature difference between low albedo (0.1) CO_2 frost and high albedo (0.5) CO_2 frost cases at 55°N. Obliquity data from [11].

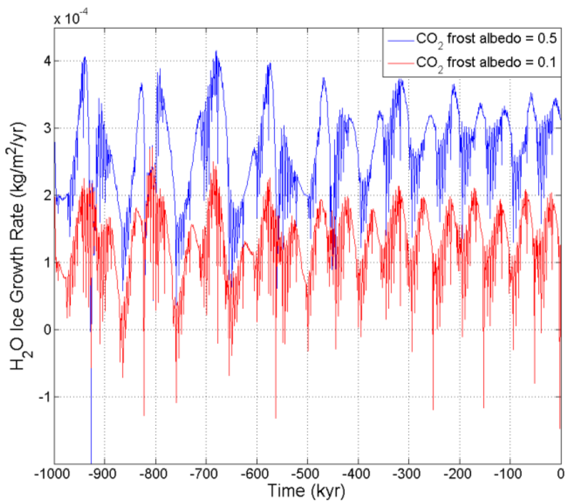

Figure 4 Rates of ice growth (negative equals retreat) for two cases mentioned previously.

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