THERMOPHYSICAL PROPERTIES OF EXPOSED SOUTH POLAR WATER ICE.

J. Bapst[1] and S. Piqueux[1], [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA, jonathan.bapst@jpl.nasa.gov

Introduction: Comprising the vast majority of Mars' known water inventory are large deposits of water ice at the poles, the polar layered deposits [1]. The history of these deposits is not well understood, including their recent evolution and present mass balance. Mars' orbital elements vary in a cyclical fashion [2,3]. The resulting changes in solar flux over time (Figure 1) will drive the exchange of water ice between the polar regions and lower latitudes. Substantial geologic evidence exists for this exchange (e.g., [4]), and the process is also predicted by climate models (e.g., [5,6]).

In general, ice is stable at the poles during periods of low obliquity and is unstable during high obliquity. Over the past 200–300 kyr, the expected changes in obliquity are small relative to preceding fluctuations (Figure 1). What does this mean for the current state of the climate? Is there net-transport of water ice to the poles or away from the poles to lower latitudes? This work addresses the above questions and brings us closer to understanding the current water cycle. Extrapolating to climates under different orbital configurations is impossible if we cannot understand the behavior at present.

Although recent obliquity changes have been muted, water ice is sensitive to small changes in insolation as its vapor pressure is exponentially dependent on temperature (i.e., the Clausius-Clapeyron relationship). Climate models [7] and thermophysical properties of exposed ice [8] support both accumulation and ablation occurring across the north polar at present or in the geologically-recent past.

Here, we focus our efforts on characterizing thermophysical properties at the southern pole of Mars. The southern polar region is much more limited regarding water-ice exposures when compared to the north (Figure 2; [9]). Based on climate model simulations, recent accumulation has been invoked as a source for a large fraction of this exposed water ice [10]. However, no test of its thermophysical properties has been made to establish consistency with that hypothesis. In addition, we can directly compare derived properties in the south to water ice properties in the north, in order to test for systematic differences [8].

Methods: To examine whether water is being transported to the pole (i.e., net accumulation), or to low latitudes (i.e., net ablation), we characterize the physical properties of exposed water ice deposits. Accumulation of water ice can be inferred by the presence of porous ice at the surface. Porous ice at the surface will densify over time [11] and therefore old ice should exhibit low porosities. The absence of porosity is compatible with

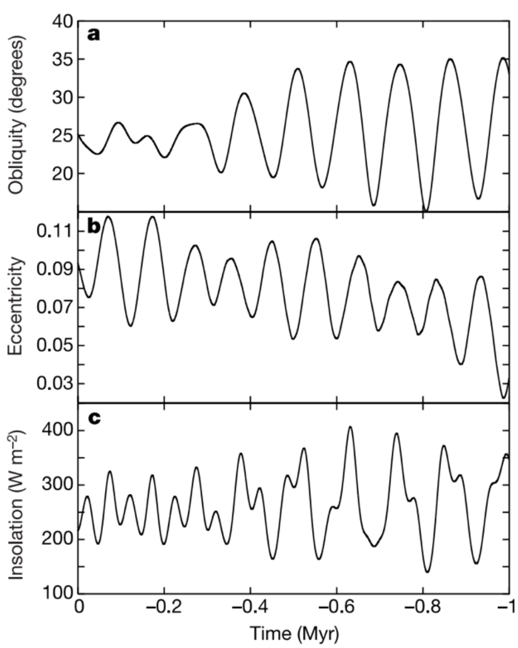

Figure 1. The past 1 Myr of Mars (a) obliquity or axial tilt, (b) eccentricity, and (c) insolation at the north pole at summer solstice (L_S=90°). From [2].

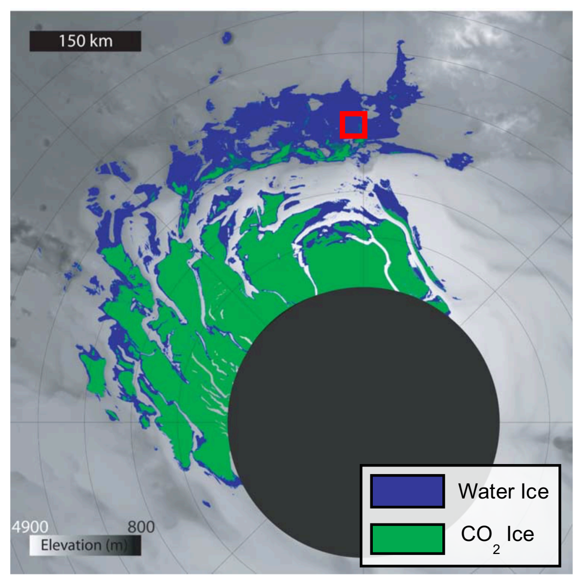

Figure 2. Exposed south polar ices in summertime, discriminated by measured surface temperature from the Thermal Emission Imaging System (reproduced from [9]). Surface temperature data within the red square is shown in Figure 3.

both accumulation and ablation as modeled under martian conditions [12], but other lines of evidence are used to support/reject ablation, such as geographic location and the surface albedo relative to other exposures. It is along these lines we assess the youthfulness of exposed ice in the southern polar region.

Deriving thermophysical properties is accomplished by testing a series of simulated surface temperatures against those measured from orbit. Three datasets of surface temperature will be analyzed: Thermal Emission Spectrometer (TES; [13]) bolometer- and spectrometer-derived surface temperature as well as surface temperature measured by Mars Climate Sounder (MCS; [14]).

Modeled temperatures are produced using KRC [15], a well-established and validated 1-D thermal model with many capabilities that are of use to the broader planetary science and engineering communities (see http://krc.mars.asu.edu for additional information). KRC has primarily been used for studies concerning Mars and is well suited for analysis of temperatures from the aforementioned datasets. We first test homogeneous models of thermal inertia (TI) ranging from ~50–2000 J m^{-2} K^{-1} $s^{-1/2}$. Fits between the model and observed sets of temperature will be evaluated by their RMS error.

Preliminary Results: A preliminary analysis is given here, focusing on a single example concerning a small patch within the exposed water ice mapped by [9]. At the meeting, the analysis of surface properties will be expanded for water ice exposures south of 65°S.

The region of exposed water ice investigated here (see red box in Figure 2) includes sufficient numbers of observations from each dataset, in order to interpret and compare against modeled cases (Figure 3). A qualitatively-derived model fit for a prescribed TI = 500 J m^{-2} K^{-1} $s^{-1/2}$ and albedo = 0.45 provides good agreement. These properties imply 10s of cm-thick water ice of significant porosity (>40%; [8]) which is consistent as being a product of recent accumulation.

Discussion and Future Work: Significant porosity is suggested by our preliminary fitting of temperature data, implying recent accumulation, in line with [10]. This has important implications for the current trend in climate and the water cycle. Our findings affect related areas of research, such as impact crater density at the south pole [16].

The behavior of temperatures prior to defrosting (L_S~300°) is indicative of dust loading in the atmosphere. To avoid erroneous fits this must be removed from our analyses and fitting procedure (similar to [8]).

Lastly, a number of layered models will be tested which may reveal a vertically-heterogeneous deposit. This line of evidence would support cycles of accumulation, where a porous water-ice layer at the surface represents only the latest episode.

Acknowledgement: Part of this work was performed at the Jet Propulsion Laboratory, under a contract with NASA. US Government support acknowledged.

References: [**1**] Byrne, S. (2009) *Annu. Rev. Earth Planet. Sci.* **37,** 535–560 [**2**] Laskar, J., et al. (2002) *Nature* **419,** 375–377. [**3**] Laskar, J. *et al*. (2004) *Icarus* **170**, 343–364. [**4**] Head, J. W. *et al.* (2003) *Nature* **426**, 797–802. [**5**] Levrard, B. *et al*. (2004) *Nature* **431**, 1072–1075. [**6**] Levrard, B., et al. (2007) *JGR Planets* **112,** 1–18. [**7**] Tyler, D., & Barnes, J. R. (2014) *Icarus* **237**, 388–414. [**8**] Bapst, J. et al. (2019) *JGR Planets* **124**, 1315– 1330. [**9**] Piqueux, S *et al*. (2008) *JGR Planets* **113**, E08014. [**10**] Montmessin, F. *et al*. (2007) *JGR Planets* **112**. [**11**] Herron, M. M., & Langway, C. C. (1980) *J. Glaciology* **25**, 373–385. [**12**] Arthern, R. J., et al. (2000) *Icarus* **144,** 367–381. [**13**] Christensen, P. R. *et al.* (2001) *JGR Planets* **106,** 23823–23871. [**14**] McCleese, D. J. *et al.* (2007) *JGR Planets* **112**, E05S06. [**15**] Kieffer H. H (2013) *JGR Planets* **118***,* 451–470. [16] Koutnik, M. *et al*. (2002) *JGR Planets* **107**, 5100.

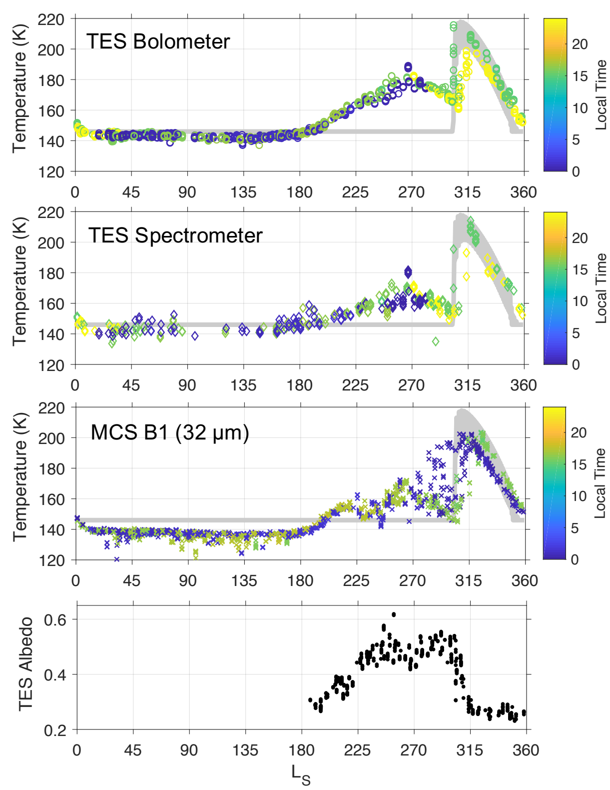

Figure 3. The top three panels show surface temperatures for the region in red from Figure 1, with each dataset listed. The large squares in the plot with MCS temperatures represent atmospherically-corrected surface temperature while other points are uncorrected brightness temperature at 32 μm. Our model fit to the data is shown in gray.