THERMOPHYSICAL EVIDENCE FOR RECENT ACCUMULATION AND ABLATION OF WATER ICE AT THE NORTH POLE OF MARS. J. Bapst1,2, S. Byrne2, J. L. Bandfield3, P. O. Hayne4 and S. Piqueux1, 1Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA, jonathan.bapst@jpl.nasa.gov, 2Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, 3Space Science Institute, Boulder, CO, 4Astrophysical and Planetary Sciences, University of Colorado, Boulder, CO.

Introduction: The polar regions of Mars host Polar Layered Deposits (abbreviated as NPLD for the north) that are up to ~3 km-thick sequences of water ice with varying degrees of dust [1]. The spatial extent of the NPLD is substantial, extending equatorward from the pole to roughly 80ºN, at all longitudes. Both PLDs are thought to have formed over the recent geologic past (~10⁶–10⁷ yr; [2-6]), where climate change is expected to be driven by changes in orbital elements [7].

The northern residual cap (NRC) spans a large fraction of the NPLD extent. The NRC is composed of water ice and is on the order of a meter thick, though likely exhibits some regional heterogeneity [8]. Several studies have analyzed NRC albedo, composition and morphology; yet comparably few have addressed its thermophysical state (e.g., [9]) and none have addressed how its properties change with depth.

The focus of this study is the physical nature of the NRC, or what we consider the most-recent and potentially-active layer of the NPLD. We investigate how relevant properties (e.g., density, albedo) vary, both laterally, and vertically into the subsurface. The NRC interacts strongly with the current climate, e.g., supplying almost all atmospheric water vapor in summer [10]. Past residual caps (now layers within the NPLD) were also likely influenced by past climates. Thus, understanding the thermal properties of the NRC can inform us of the potential link between climate and polar geology.

Methods: Constraining the thermophysical properties of today’s NRC is achieved using observed temperatures and a number of thermal model simulations (sensitive to depths <5 m). Many studies have used observed temperatures and thermal modeling to derive depth-dependent properties [11-17]. Here use derived temperatures acquired by the Thermal Emission Spectrometer (TES) aboard Mars Global Surveyor (MGS). MGS was operational over four Mars Years (MY), specifically MY24-28. MGS’s primary science orbit was inclined approximately 93º, which resulted in high data density near the poles, useful for the study of polar surface properties. Unfortunately, this also resulted in a region of low-to-zero data density poleward of 87ºN. Queried data are separated into 10 by 10 km bins for fitting. We ignored bins with less <100 observations. Almost all bins are above this threshold, and many near the pole have >1000 observations per bin.

Best-fit properties are determined by minimizing the RMS error between the observed and model temperatures. All observations within a single bin are fit simultaneously, but is restricted by a prescribed seasonal window (here Ls=110–180º). This window is necessary to avoid springtime data which can result in erroneous derivations.

Depth-density Relationships: How density varies with depth constrains key conditions (e.g., ice accumulation rate), and thus aids in understanding how climate affects polar stratigraphy. Predicted depth-density profiles are especially sensitive to the accumulation rate [20]. In addition to a homogeneous case (constant properties with depth), we explore three relationships of depth versus density, in order to compare the near-surface structure of the NRC with predicted profiles of accumulating ice on Mars. The three depth-density relationships explored are abrupt changes in density (e.g., ice table), and exponentially- and linearly-increasing density with depth. For depth-dependent cases the value of porosity is prescribed at the surface and varies with depth.

Results: Because our model is customized to retrieve the thermal properties of porous ice, results over regolith-covered surfaces should be ignored. Bins with derived thermal inertia (TI) <1000 J m² K⁻¹ s¹/² from homogeneous fits are masked out in Figure 1. For the homogeneous case, derived TI is relatively high (≥1400 J m² K⁻¹ s¹/²) across the NRC and its outliers (Figure 1). Derived albedo of the NRC is consistent with the pattern of observed albedo across the NRC from TES [18].

Figure 1. Derived albedo and TI for the north polar region of Mars above 70ºN for the depth-homogeneous case.
derived properties are layered and similarly high albedo). The edges of the residual cap exhibit small or zero improvements over the homogeneous model, indicating denser ice with derived porosities of <40% and lower albedo.

Conclusions: Here, we investigated the thermo-physical nature of the upper-most layer of the NPLD, the NRC, and its icy outliers, with emphasis on depth-density relationships within the subsurface (up to depths of a few meters). We find the strongest evidence for layering associated with Gemina Lingula and the icy outliers (i.e., a more-porous layer of ice overlying a denser layer). We interpret this as a result of recent accumulation. This change in density occurs typically within 0.5 m of the surface. At the edges of the NRC we derive a more-homogeneous subsurface that is denser, and likely older, ice. We interpret this ice as having undergone recent ablation, which is consistent with and may help explain its lower albedo.

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