MODELING NORTH POLAR RESIDUAL CAP SURFACE TEXTURE AND RECENT RESURFACING.
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Introduction: The Martian North Polar Residual Cap (NPRC) is a water ice deposit that overlies most of the North Polar Layered Deposits (NPLD). The NPRC is thought to be the topmost layer of the NPLD and the portion of the NPLD that is currently interacting with the atmosphere [1]. The present-day mass balance of the NPRC is not known, nor is it clear if it is in a current state of net accumulation or ablation. Observations of the NPRC surface have shown evidence for both accumulation and ablation, which may vary depending on region and time of year [2,3]. Landis et al. (2016) estimated the surface age of the NPRC to be ~1.5 ka, and suggested that this age likely corresponds to a recent resurfacing event [4].

The surface texture of the NPRC may hold clues as to its current mass balance and age. The NPRC surface is characterized by depressions and mounds that have dominant spatial wavelengths on the order of ~10 m and heights of ~1 m [5]. This texture has been compared to sublimation hollows observed on terrestrial snow/ice sheets, suggesting it may indicate net ablation [6]. We model the evolution of this surface texture in time and explore its utility as evidence of net accumulation or ablation. We investigate the timescales over which these features form and suggest that the characteristic wavelengths of surface features on the NPRC may be indicative of the exposure ages of those surfaces.

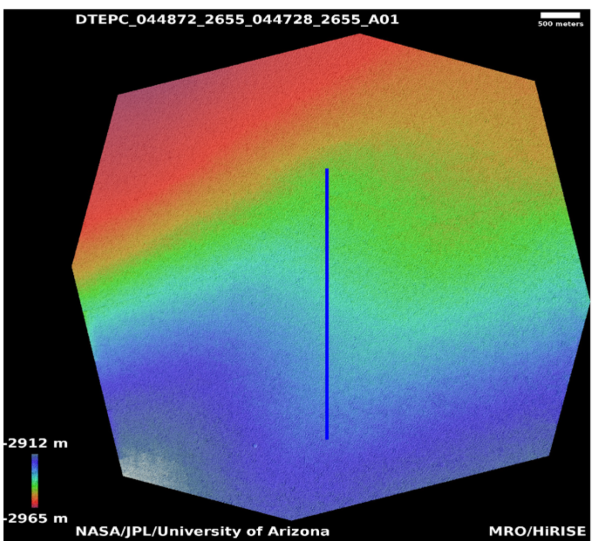

Figure 1 HiRISE DTM of the NPRC surface. Color represents elevation. The blue vertical line denotes the transect along which a cross-section was taken. The power spectra of this cross-section is shown in Figure 3, along with that of a modeled cross-section. (DTEPC_044872_2655_044728_2655_A01) (NASA/JPL/University of Arizona)

Methods: We use a 1D coupled thermal and atmospheric model to calculate ice fluxes on a perennial NPRC ice surface. The thermal model balances incident energy due to solar radiation adjusted for atmospheric effects, reradiated and reflected energy from nearby surfaces, vertical heat conduction, and latent heat exchange, with infrared emission from the surface in order to calculate surface temperatures. The model also takes into account shadowing from topography and the seasonal accumulation/sublimation of CO_2 frost due to the advance and retreat of the Martian seasonal CO_2 caps. The thermal model is validated using data from the Mars Climate Sounder (MCS) instrument onboard the Mars Reconnaissance Orbiter (MRO) [7]. The atmospheric model mixes water vapor in a 1D vertical column above the surface and calculates water vapor densities directly above the surface, similar to [8]. The upper boundary of the atmospheric model is constrained using water mixing ratio estimates obtained from the Mars Climate Database [9]. Surface temperatures and water vapor densities are used to calculate ice accumulation or ablation that occurs at the surface.

The 1D thermal and atmospheric model is applied to each point on a 2D (height and length) surface. The surface is initialized with small scale (~1 mm) vertical roughness and a uniform power distribution across all wavelengths. The model is run for one Mars-year, after which each point on the surface is adjusted in position based on the ice flux calculated at each point. The model is then multi-stepped over ~10s of Mars-years to decrease computation time, before it is run again. In this manner, the surface is allowed to evolve in time.

We compare the evolved model surface to a Digital Terrain Model (DTM) of the NPRC surface (Fig. 1) derived from a stereo pair of images acquired by the High Resolution Imaging Science Experiment (HiRISE) instrument onboard MRO [10]. We take a cross-section of the DTM (blue line in Fig. 1), subtract out the strong north-south slope of the DTM, and then compare the power spectra of the DTM cross-section with that of the model cross-section.

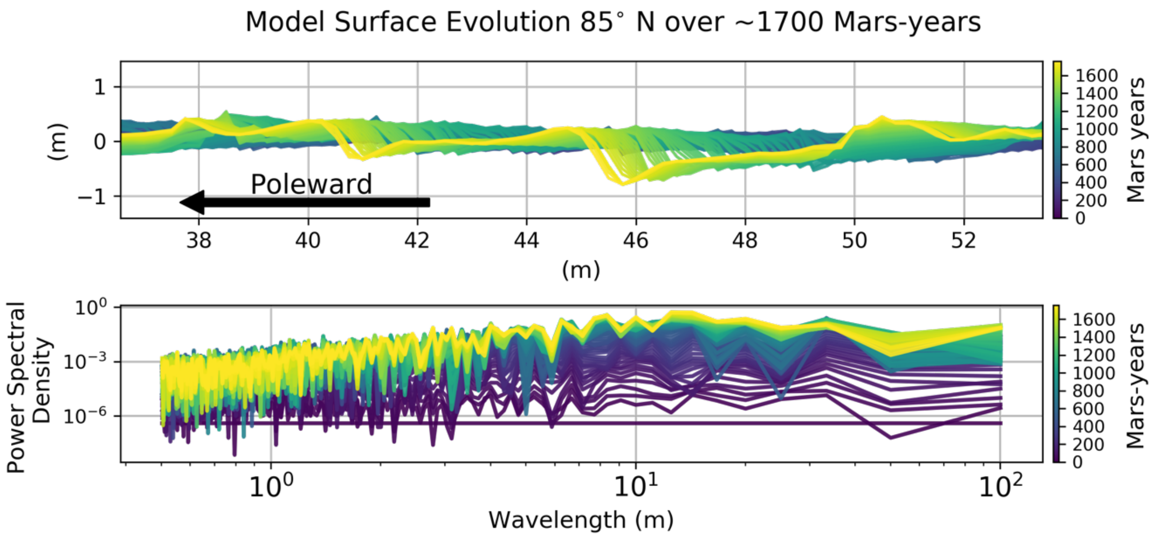

Figure 2 An example of a surface evolution model run for a period of ~1700 Mars-years. The top plot shows a ~15 m long section of a 100 m long surface at each stage of its evolution. The color corresponds to time after the beginning of the model run, with initial surface in purple and the final surface in yellow. The bottom plot shows the PSD of the entire surface versus wavelength at each stage of its evolution.

Results and Discussion: Figure 2 demonstrates the ability of our insolation-driven accumulation/ablation model to grow surface topography over time. Small perturbations to the virtually flat initial surface give rise to depressions and mounds that tend to have steep south-facing slopes and lower angle north-facing slopes, both of which migrate pole-ward with time. The growth of surface topography occurs for both cases of net accumulation and net ablation of ice. This suggests that the NPRC surface texture is not necessarily indicative of net accumulation or ablation.

We use the power spectral density (PSD) of the surface to analyze the wavelengths of the dominant features of the surface over time (Fig. 2). The PSD comes to an equilibrium at shorter wavelengths that manifests as a roughly linear trend in log-log space.

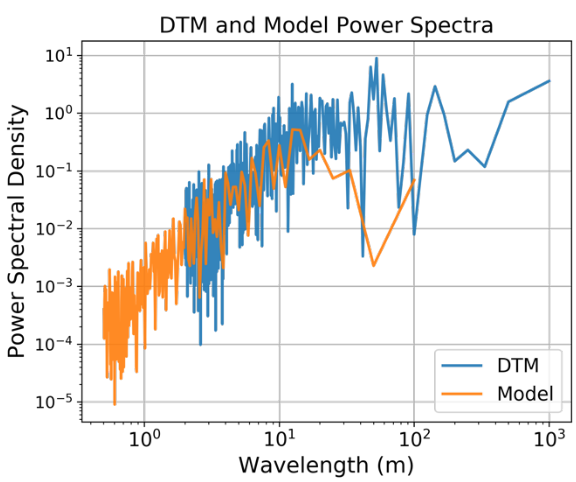

Figure 3 PSD of the DTM cross-section shown in Fig. 1 compared with the PSD of the final modeled surface shown in Fig. 2.

We define the characteristic wavelength of the surface to be the wavelength of topographic features for which peak power occurs in the PSD. This characteristic wavelength increases over time as surface features grow, suggesting that the characteristic wavelengths of surface features on the NPRC may reflect how long those surfaces have been exposed. Figure 3 shows a comparison of the PSD of a cross-section taken of the DTM in Figure 1 and that of the final surface in the model run shown in Figure 2. The exponential trend in power versus wavelength is shared by both spectra at shorter wavelengths. Both spectra diverge from this trend close to their peak power (i.e. characteristic wavelength). Both cross-sections have characteristic wavelengths on the order of 10 m, as is typical of NPRC surface topography. Our model forms surface topography with characteristic wavelengths on the order of 10 m over ~1000s of Mars-years. This is a comparable timescale to the most recent NPRC surface age estimates made by [4] of ~1.5 ka, and supports the idea of relatively recent resurfacing of the NPRC.

References: [1] Tanaka K. L. (2005) *Nature*, 437(7061), 991-994. [2] Langevin Y. et al. (2005) *Science,* 307, 1581-1584. [3] Brown A. J. et al. (2016) *Icarus*, 277, 401-415. [4] Landis M. E. (2016) *GRL,* 43, 3060-3068. [5] Milkovich S. M. et al. (2012) LPSC 43, #2226. [6] Milkovich S. M. and Head J. W. (2006) *Mars,* 2, 21-45. [7] McCleese D. J. et al. (2007), *JGR*, *112*(E5). [8] Bapst J. et al. (2018) Icarus, 308, 15-26. [9] Navarro T. et al. (2014) JGR, 119(7), 1479-1495. [10] McEwen A. S. et al. (2007) *JGR*, 112(E5).