MASS BALANCE AND SURFACE TEXTURE OF THE MARTIAN NORTH POLAR RESIDUAL CAP.

A. X. Wilcoski and P. O. Hayne, Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder CO 80309 (andrew.wilcoski@lasp.colorado.edu).

Introduction: The North Polar Residual Cap (NPRC) of Mars is a predominantly water-ice deposit that overlies the majority of the North Polar Layered Deposits (NPLD). Together they represent a large portion of the water-ice reservoir on Mars. The NPLD consists of many layers of ice with differing dust concentrations, the formation of which is likely linked to climatic oscillations over the last 4-5 Myr of Martian history [1]. Therefore, the NPLD may serve as a record of the recent climate of Mars that can be deciphered once the mechanisms that control its formation are better understood. The NPRC has been postulated to be simply the uppermost layer of the NPLD, as opposed to an entirely separate deposit [2]. As such, an understanding of the processes that shape the NPRC will be useful in the interpretation of layers within the NPLD.

The surface of the NPRC is characterized by hummocky, pitted terrain that often forms linear chains of mounds and depressions (Fig 1.). These mounds are typically ~1 m in height and tens of meters in width. The dominant wavelengths of these features have some dependence on elevation and latitude [3,4], suggesting that insolation may have some role in their formation. A number of mechanisms to explain the patterned morphology of the NPRC surface have been suggested, including combinations of wind-driven erosion/deposition, insolation-driven sublimation/accumulation, and re-orientation due to ice flow [4,5]. However, it is unclear to what degree each of these processes controls the surface texture, and over what timescales these features form.

We investigate the evolution of the NPRC surface under the assumption that the surface morphology is dominated by the effects of insolation on the accumulation and sublimation of ice. We explore the reproducibility of the observed dominant wavelengths in the NPRC surface. In addition, we probe the timescales over which the development of these surface features occurs. This work gives insight into the plausibility of insolation as the dominant formation mechanism for these features while also providing constraints on their ages.

Methods: We use a coupled thermal and vapor diffusion model to determine the evolution of a 2D (height and length) surface driven purely by insolation and the subsequent accumulation or ablation of water ice. The model uses solar flux modified by atmospheric effects, reradiated and reemitted solar and infrared radiation from nearby surfaces, and 1D vertical heat conduction to determine the surface temperature and

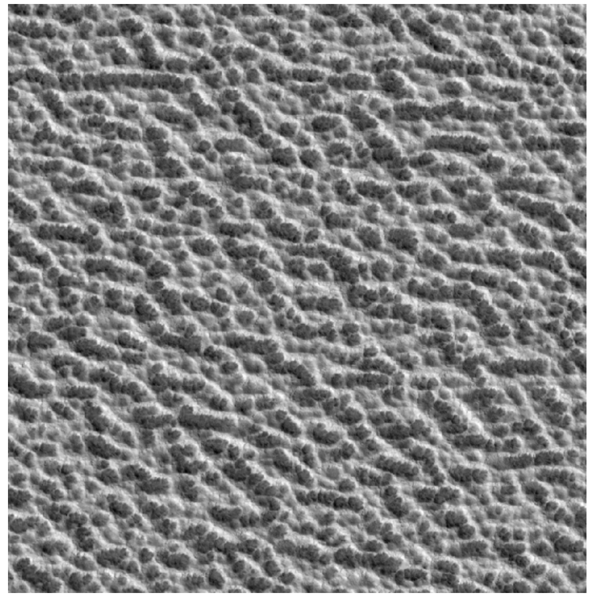

Figure 1. *An example of North Polar Residual Cap surface texture. Image shows a roughly 0.5 km by 0.5 km area at ~87° N latitude. HiRISE image ESP_019030_2725 (NASA/JPL/University of Arizona).*

ice mass flux over time at each point on a given 2D surface, similar to [6]. The model also accounts for the accumulation and ablation of CO_2 frost, the effects of shadowing from nearby surface maxima on the incident energy flux at any point on the surface, and slope-dependent insolation.

The model is initialized with a relatively flat 2D surface with a randomly generated small-scale roughness. A 2D surface (height and length) was chosen for the sake of computational simplicity and more efficient computation time. The surface is oriented from north to south so that each point on the surface has a slope with no east or west component. The model is then run for one Mars-year and the cumulative ice mass flux at each point on the surface is calculated. This mass flux is used to calculate the advance or retreat of each point on the model surface and generate a new surface accordingly. In order to decrease computation time, it is assumed that the calculated mass flux at each point remains constant over ~10 Mars-year periods, and therefore the mass fluxes can be increased by a factor of 10 and the model advanced in 10 Mars-year increments. Once the surface texture

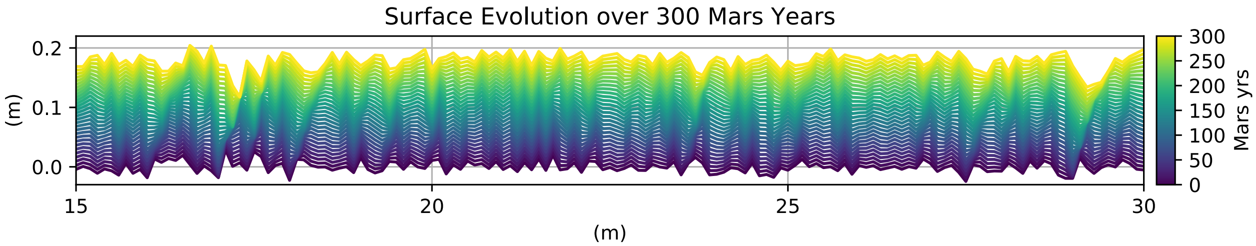

Figure 2. *Evolution of a surface over a 300 Mars-year model run in the accumulation regime. A 15 m section of a 40 m long surface at 85° N latitude is shown. The length of the surface is oriented from north to south, so slopes facing in the positive x-direction are south facing. The color gradient represents the time evolution of the surface, with the dark blue being the original surface and yellow being the final surface after the model has been advanced for 300 Mars-years. Large wavelength features are difficult to see (see Fig. 3), but some shorter wavelength depressions have deepened noticeably over the model run.*

has been updated, we run the model for another Mars-year and the same process is repeated.

Results: The amount of ice mass flux into or out of the model surface depends strongly on the assumed water vapor partial pressure above the surface. We use modeled water vapor content from the Mars Climate Database [7] in order to approximate the seasonal variation in vapor pressure. In the majority of model runs at high latitudes (~85° N), the model predicts net accumulation of ice. In these cases, accumulation occurs for all slope angles regardless orientation poleward or equatorward. However, the amount of accumulation is still dependent on slope, with steeper slopes experiencing less accumulation and equator-facing slopes experiencing slightly less accumulation than pole-facing slopes.

Figure 2 shows the development of a section of a 40 m long surface over a 300 Mars-year model run. This is an earlier iteration of the model where shadowing effects were not included. However, the depressions developed in the model run are not sufficiently deep for shadowing to have a large effect. In this case, the surface is located at 85° N latitude and experiences net accumulation at a rate of ~0.6 mm/yr. While this simulation was not run for long enough for the emergence of any distinct wavelengths to be immediately apparent to the eye, a comparison of the power spectral density (PSD) of the original surface and the final surface shows an increase in power at several longer wavelengths (Fig. 3). The appearance of longer wavelength signals that were not originally present demonstrates that these wavelengths can be produced by differential accumulation controlled by insolation.

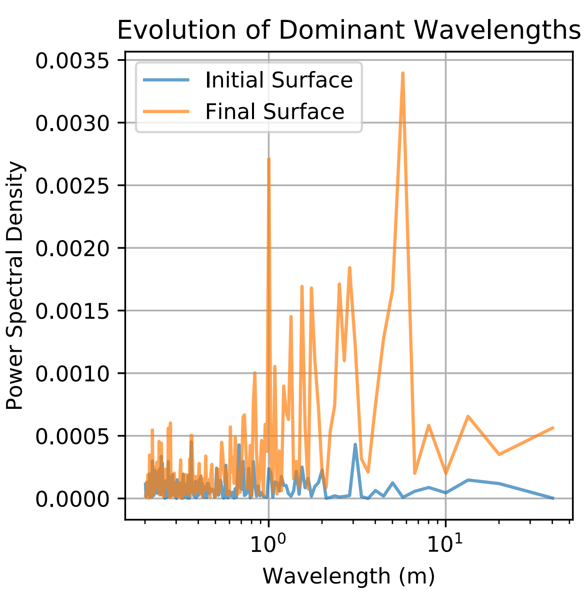

Figure 3. *Power spectral density of both the initial and final surfaces of the 300 Mars-year model run depicted in Fig. 2. The final surface shows an increase in power relative to the initial surface at wavelengths of 1 and ~6 meters.*

Future Work: We plan to utilize data from the Mars Climate Sounder onboard the Mars Reconnaissance Orbiter [8], to constrain the thermal model using surface temperatures and atmospheric profiles of temperature and aerosol opacity. Using these new constraints, we will continue to explore the evolution of a 2D surface on timescales long enough to recreate the observed wavelengths and amplitudes of NPRC topography. This will allow us to estimate the timescales required to form such terrain. We will also investigate the parameters that may be controlling the wavelengths of these features, such as latitude and atmospheric water vapor content. Eventually, this model will be extended to 3D in order to more realistically reproduce NPRC surface textures.

References: [1] Levrard B. et al. (2007) JGR, 112, E06012. [2] Tanaka K. L. (2005) Nature, 437(7061), 991-994. [3] Parra S. A. et al. (2018) LPSC XXXXIX, Abstract #2272. [4] Milkovich S. M. et al. (2012) LPSC XXXXIII, Abstract #2226. [5] Fisher D. A. et al. (2002) Icarus, 159, 39-52. [6] Dundas C. M. and Byrne S. (2010) Icarus, 206, 716-728.

[7] Navarro T. et al. (2014) JGR, 119(7), 1479-1495. [8] McCleese D. J. et al. (2007), *JGR*, *112*(E5).