VARIATIONS IN TEXTURE OF THE NORTH POLAR RESIDUAL CAP OF MARS.

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Introduction: The North Polar Residual Cap (NPRC) of Mars is primarily a water ice deposit with a rough textured surface composed of semi-regular depressions and mounds on the scale of tens of meters [1]. These dark pits and bright mounds form a quasi-linenar texture in visible imagery with a characteristic wavelength and orientation (Fig 1). According to spectral data, the surface of the NPRC is composed of large-grained (evidencing older) water ice, the presence of which seems to suggest that the NPRC is in a current state of net loss [2]; this result must however be considered alongside impact craters statistics, which suggest rapid ongoing deposition and resurfacing within the past 1.5kyr [3].

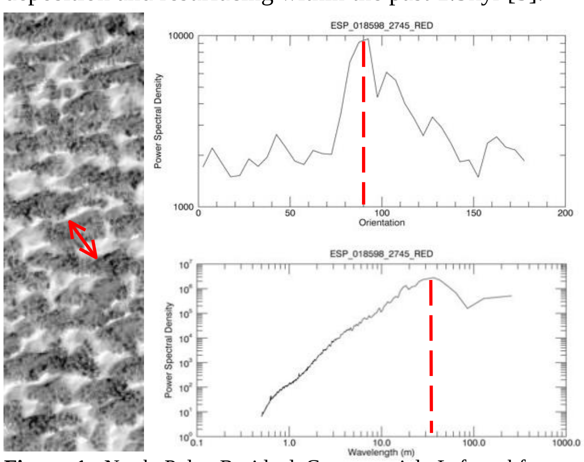

Figure 1: North Polar Residual Cap material. Left: subframe of HiRISE image ESP_018598_2745. Red arrow indicates the orientation and wavelength results of FFT analysis. Upper right: result of orientation analysis; dotted line indicates dominant orientation. Lower right: result of wavelength analysis; dotted line indicates dominant wavelength.

The NPRC is thus able to provide a connection between the current Martian climate and the past climate as recorded in the varied layers of the North Polar Layered Deposits beneath. In the characterization and mapping of the NPRC's surface texture, we seek to understand the seasonal and regional factors that are not just currently involved in reshaping the deposit, but that may also have been involved in the shaping of the layers beneath.

We expand upon previous work [4,5] analyzing images taken by the High Resolution Imaging Science Experiment (HiRISE) onboard Mars Reconaissance Orbiter (MRO) via 2D FFT for trends in dominant wavelength and orientation of the NPRC surface texture. Additionally, we include results from HiRISE Digital Terrain Models (DTMs) examined via wavelet analysis to determine the existence of a dominant periodicity.

Methods: Search parameters for HiRISE coverage of the NPRC were expanded from a selection of 25 cm/pixel resolution images in [5] to include images at 50 cm/pixel within a geographic bracket of 80°-90° N. In total, 836 HiRISE were selected for analysis, including the 579 images analyzed in [5]. From these 836 images, 1024 x 1024 pixel subframes including the textures to be analyzed were manually extracted from the 25 cm/pixel images, and 512 x 512 pixel subframes were extracted from the 50 cm/pixel images so that both subframe types covered a 256 x 256m area.

Co-located subframes from [5] indicating the presence of a monitored site were readjusted and aligned manually. 15 monitored sites were ultimately covered in the final data set, encompassing 105 images in total. Images with DTMs in the HiRISE catalog were also replaced with subframes taken from the parent orthorectified image (orthoimage) for comparison with results from DTM wavelet analysis. The DTMs used have a horizontal scale of ~1m, and an estimated vertical precision of 1–2 m [6], where the orthoimages that match the DTMs are produced at each site and represent a "map-view" of the surface, with topographic and camera distortions removed.

2D Fourier Analysis. Because of the semi-regular nature of the NPRC texture, a quantitative, automated approach via two dimensional Fourier analysis taken in [4,5] was chosen to continue extraction of the characteristic wavelengths and orientations for the 256 m x 256 m region in each subframe. 2D FFT analysis reconstructs an image via sinusoidal functions of varying wavelengths and power. Matching wavelengths and orientations within the subframe analyzed therefore correspond to a higher power. The dominant wavelength of the resulting peak power spectrum corresponds to the average size of a pitknob pair in the image, and as such serves as a proxy for the scale of the texture's roughness. The surface texture's dominant orientation reflects the trend of pits and mounds encompassing this dominant wavelength, as seen in Fig 1.

DTM Wavelet Analysis. Similar to FFT, the wavelet analysis method decomposes a function into its periodic components in time-frequency space, but unlike FFT, it also shows the variation of the dominant periodicities with time [7]. Instead of a time dimension in this case, the variation of periodicities are studied along a single specified direction on the surface. Given uniform periodicities in texture, variability in the dominant wavelength with distance is subsequently expected to be minor.

Based on the availability of HiRISE data, seven sites were selected for analysis (Fig 2a). From each of these sites, five adjacent and parallel linear elevation profiles were extracted along the surface (Fig 2b, c) before local, resolution-scale slopes were calculated by taking the first derivative of the elevation profile (Fig. 2d). The five slope profiles were then aligned via cross-correlation and averaged in order to reduce noise. Subequently each location shown in Fig 2a has one noise-averaged profile of local surface slope of the NPRC. Wavelet analysis relies on the 'wavelet transform', calculated through the convolution of the linear slope profile with a wavelet function. This wavelet can differ depending on the specific analysis performed; here, a Morlet wavelet was chosen for its higher resolution in wavelength. The wavelet power spectrum (WPS) is the square of the real portion of the transform and is plotted as a 2-D image.

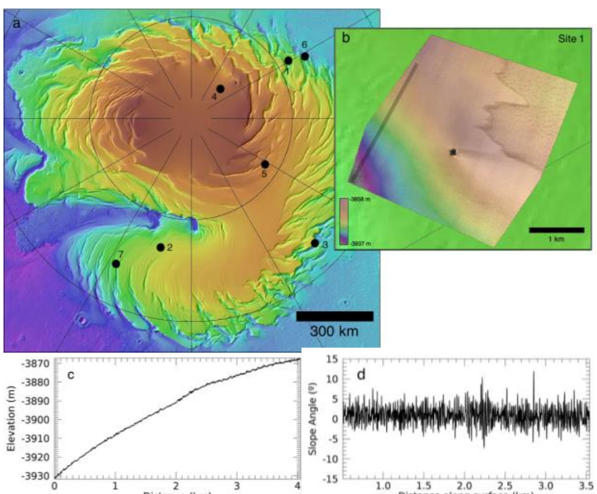

Figure 2: (a) MOLA topographic map of the North Polar region of Mars showing the locations of the DTMs studied. (b) HiRISE DTM and orthoimage of site 1: a typical 'flat' area on the NPRC. The black lines indicate the profile tracks. (c) Elevation profile from one of the tracks shown in (c). (d) Local slope calculated from the first derivative of (c).

Results: *2D Fourier Analysis Results.* While no observable trends were noticed in comparing wavelengths to incidence angle and subsolar azimuth, the larger data subset seems to support the broad positive trend previously noted by [4] for wavelength and elevation and thus wavelength and latitude (given that elevation and latitude are highly correlated on Planum Boreum). This trend suggests that ablational processes may play a role in controlling the size and spacing of the NPRC surface texture. Concerning seasonal monitoring, one site was examined in particular, at 82˚N, 20˚E. The surface texture wavelength shortens as the site transitions from spring into summer (Fig 3). This may indicate that seasonal CO_2 frost covers the surface selectively, changing the apparent wavelength of the surface texture by filling in the smallest-wavelength (likely the shallowest) hollows. While no temporal trends in orientation have been observed, visible trends may correspond to adiabatic wind patterns at the NPRC, as noted by [4].

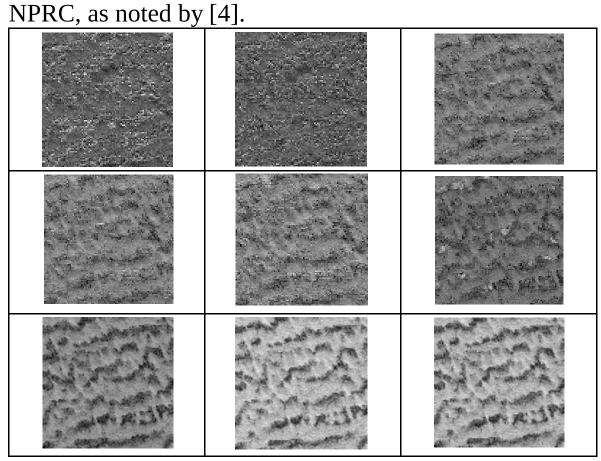

Figure 3: Subframes from monitored site, 82˚N, 20˚E. The subframes cover the same location across Ls 24.8 to 136.4 Chronological order is left to right, top to bottom.

DTM Wavelet Analysis Results. The complete WPS of the site 1 profile with 95% confidence contours is shown in Fig 4. For all profiles, the most dominant wavelengths were found to range between 5 and 15 m, and they are uniformly found throughout the length of the profiles for nearly all cases. These results also align with the predominant wavelengths found through 2D FFT analysis, which exhibit a similar range.

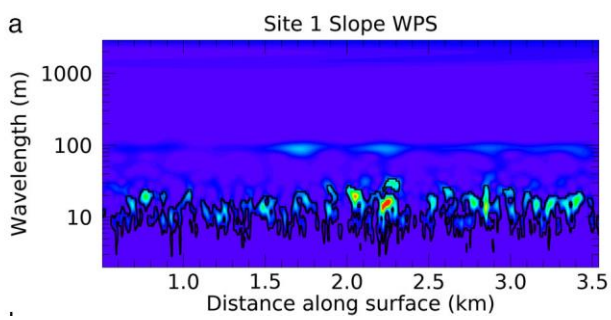

Figure 4: Wavelet Power Spectrum (WPS) of the site 1 profile shown in Fig. 2d. Warmer colors indicate higher power. The black contours delineate the 95% confidence curves above red noise.

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