VISIBLE AND TOPOGRAPHIC TEXTURE OF THE NORTH POLAR RESIDUAL CAP OF MARS. P.S. Russell[1], S.A. Parra[2], S.M. Milkovich[3], P. Becerra[4], and S. Byrne[5], [1]Department of Earth, Planetary, and Space Sciences, University of California, Los Angeles, patrick.russell@epss.ucla.edu, [2]Georgia Institute of Technology, sparra95@gatech.edu, [3]Jet Propulsion Laboratory, California Institute of Technology, [4]Physikalisches Institut, Univerität Bern, Switzerland, [5]Lunar and Planetary Laboratory, University of Arizona.

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 generally dark pits and bright mounds often appear to form a quasi-linear 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 suggests that the NPRC is in a current state of net loss [2]. However, impact craters statistics, suggest rapid ongoing deposition and resurfacing within the past 1.5kyr [3].

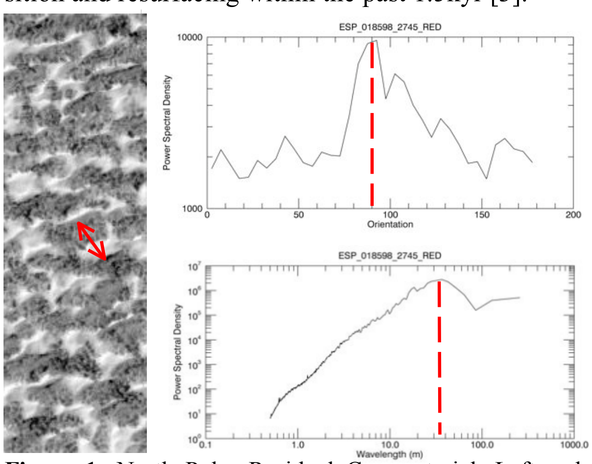

Figure 1: North Polar Residual Cap material. Left: subframe of HiRISE image ESP_018598_2745. Red arrow indicates the orientation and wavelength results of FFT analysis. Upper right: result of orientation analysis; dotted line indicates dominant orientation. Lower right: result of wavelength analysis; 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. We seek to take advantage of patterns in the NPRC's surface texture, through quantitative characterization and mapping, to understand the seasonal and regional factors currently involved in re/shaping the NPRC. As the uppermost layer above a thick deposit of many layers, the evolution of the NPRC may yield clues into the deposition & modification environments that produced the layers beneath.

We expand upon previous work [4,5] analyzing images taken by the High Resolution Imaging Science Experiment (HiRISE) onboard Mars Reconnaissance Orbiter (MRO) with 2D FFT for trends and dominant frequency of wavelength and orientation of the NPRC surface texture. Additionally, we include results from analogous 2D FFT analysis of HiRISE Digital Terrain Models (DTMs) as well as wavelet analysis of DTMs.

Methods: HiRISE RDR images between 80°-90° N and at both 25 cm and 50 cm resolutions were used. In total, 836 HiRISE were selected, including the 579 images analyzed in [5]. From each image, 1024 x 1024 pixel and 512 x 512 pixel subframes were manually extracted from the 25 cm/pixel and 50 cm/pixel images, respectively, so that all subframes covered a 256 x 256 m area.

At sites with existing HiRISE DTMs, subframes co-located with the RDR subframes were extracted from the corresponding orthoimage, in order to better compare FFT results directly with topographic & wavelet results run on the DTM. It should be noted that HiRISE DTMs have a horizontal resolution of ~1 m, and an estimated vertical precision of 1–2 m [6], which is coarser than the visible images and may influence results.

2D Fourier Analysis of Images. Because of the semi-regular nature of the NPRC texture, a quantitative, automated approach of two dimensional Fourier analysis was chosen to extract characteristic wavelengths and orientations within each subframe [4,5]. In this 2D FFT analysis, the dominant wavelength corresponding to the peak of the power spectrum is the characteristic width of a dark/bright alternation of the NPRC surface in the image (Fig. 1). This dominant wavelength serves as a proxy for the characteristic scale of the texture's pit/knob-pair widths, i.e., the scale of the texture's roughness. The surface texture's dominant orientation describes how this wavelength trend is oriented azimuthally w.r.t. North.

Topographic Analysis of DTMs. Extraction of topographic profiles from DTMs can quickly give an impression of the regularity and magnitude of topographic patterns in the texture (Fig. 2), and 1D Fourier analysis quantifies this. Our goal is to capture the characteristic wavelengths and orientations of topography in order to compare with those gleaned from visible imagery. However, individual profiles are only in a single orientation, a fundamental reason for choosing 2D FFT in the visible image analysis. Also, the 1D profile results are not directly analogous or most directly comparable to the 2D results. Therefore, we use DTM subframes co-located with image subframes to run an analogous 2D FFT on topography/height of the surface .

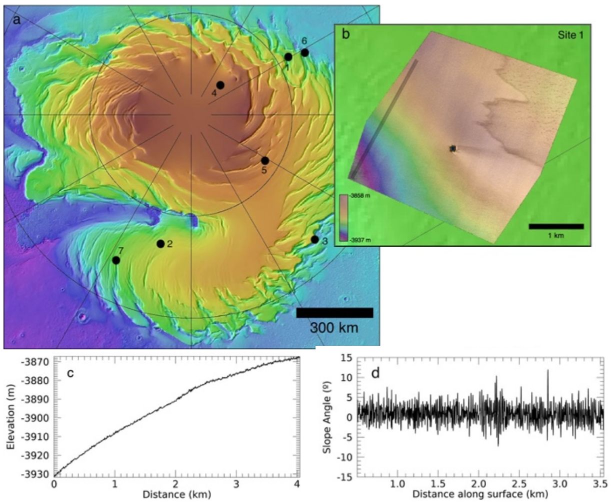

Figure 2: (a) MOLA topographic map of the North Polar region of Mars showing the locations of the DTMs studied. (b) HiRISE DTM and orthoimage of site 1: a typical 'flat' area on the NPRC. Black lines indicate the profile tracks. (c) Elevation profile from one of the tracks shown in (b). (d) Local slope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

Similar to FFT analysis, wavelet analysis of a topographic profile decomposes a function into its periodic components in time-frequency space, but unlike FFT, it also shows the variation of the dominant periodicities with *distance along the profile* [7]. However, because periodicities in texture appear to be regular, variability in the dominant wavelength over distance is expected to be minor.

Based on the availability of HiRISE DTMs, seven sites were selected for topographic analysis (Fig. 2a). From each, five adjacent and parallel linear elevation profiles were extracted along the surface (Fig. 2b, c). 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. Thus, each location has one noise-averaged profile of local surface slope (an alternative to height) of the NPRC texture. 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 is the square of the real portion of the transform and is plotted as a 2-D image.

Results: *2D Fourier Analysis of Image Results.* Dominant wavelengths of NPRC surface texture tend to cluster between 5-15 m. No observable trends of characteristic wavelengths with incidence angle or subsolar azimuth of the imagery, which excludes observation conditions as the major control on apparent wavelength. There is a broad positive trend [noted by 4] of characteristic wavelength with elevation, and hence latitude (which are highly correlated on Planum Boreum (Fig. 2)). This trend suggests that ablational processes may play a role in controlling the size and spacing of the NPRC surface texture.

2D Fourier Analysis of DTM Results. This is the main advance in contribution to this study as a whole beyond [5]. Extraction of DTM frames exactly co-located with image frames was more challenging than anticipated, largely because the extent of the parent images/DTMs are not the same and the surface is extremely uniform to the eye. However, this uniformity also forgives slight misalignments of the analysis subframe. We will present results of all 7 DTM sites, and compare them with respective image analysis results.

1D Wavelet Analysis of DTM Results. The complete wavelet power spectrum of the site 1 profile shown in Figure 2d is shown in Figure 3, with 95% confidence contours. For all profiles, the most dominant wavelengths were found to range between 5 and 15 m. They are uniformly found throughout the length of the profiles for nearly all cases (as expected). These results also align with the predominant wavelengths found through 2D FFT analysis, which exhibit a similar range.

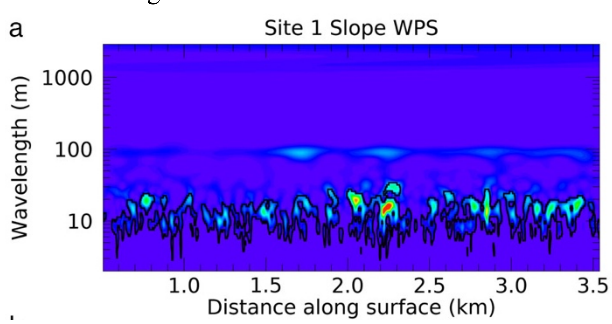

Figure 3: Wavelet Power Spectrum (WPS) of the site 1 profile shown in Fig. 2d. Warmer colors indicate higher power. The black contours delineate the 95% confidence curves above red noise.

References: [1] Thomas P. C., et al. (2000) *Nature* 404, 161-164. [2] Langevin Y., et al. (2005) *Science* 307, 5715, 1581-1584. [3] Landis M., et al., (2016) *GRL*. [4] Milkovich S. M., et al. (2012) *LPSC XXXXIII*, Abstract #2226. [5] Parra S. A., et al. (2017) *LPSC XXXXVIII,* Abstract #1719. [6] Sutton S., et al. (2015) *LPSC XXXXVI*, Abstract #3010. [7] Torrence, C., and G. P. Compo (1998) *Bull. Am. Meteorol. Soc.*, 79(1), 61.