FREQUENCY ANALYSIS OF SHARAD REFLECTORS WITHIN THE NORTH POLAR LAYERED DEPOSITS, MARS AND IMPLICATIONS FOR THE LINK BETWEEN RADAR AND OPTICAL DATA.

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Introduction: Characteristic wavelengths detected in albedo profiles of the north polar layered deposits (NPLD) of Mars [1, 2] have received attention as a potential record of orbital climate forcing [3]. While thought to result from the vertical separation between morphologically distinct marker beds [4, 5], a unique solution to using these wavelengths to constrain deposit age or to correlate layer sequences with orbital parameters has not yet been produced [1, 6] and is unlikely to be easily discovered [7]. Similar complications have arisen when attempting to correlate radar reflectors to orbital parameters [8, 9], suggesting that each of these data sets is unable to uniquely resolve a record of orbital climate forcing.

Recent evidence of a genetic link between radar reflectors and visible layers [10], however, provides the opportunity to increase stratigraphic information through the integration of radar and optical data, which may help to resolve these difficulties. As part of the study addressing the feasibility of such an integration [10], the statistical relationship between the vertical distance between subjacent radar reflectors and vertical separations between marker beds has been explored. While results of the clustering analyses correspond closely, both rely on visually-interpreted radar and optical stratigraphic sections. In order to verify that echoes in the uninterpreted radar data contain signals at frequencies similar to those recorded in albedo, and by extension, visible layering, we have performed Fourier analyses on representative radar returns at two sites (site A: 87.2ºN, 97.8ºE; site B: 86.9ºN, 8.5ºE) where albedo frequency analyses were previously undertaken (Fig. 1) [1].

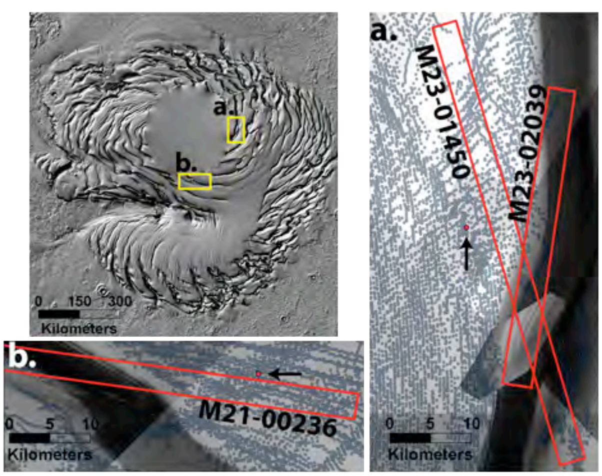


Figure 1. Sites of radar and albedo [1] frequency analyses. (a) Site A with locations of MOC images used in albedo analyses [1] and a HiRISE DEM [7] used in the radar-optical integration study [10]. Representative radar trace (red point) chosen from possible first-return locations (blue points). (c) Location of frequency analysis at site B.

Methods: Using amplitude data returned by NASA's Shallow Radar (SHARAD) [11], vertical samples of radar returns, or traces, representing user-defined areas of the deposit can be constructed. Taking into account the influence of surface slopes on surface echo locations (Fig. 1) [12], the time-delay echo data of all first-return locations within 0.03 km² (about .5% the area of one Fresenel zone [11]) of a center trace are identified, typically resulting in the selection of 8-16 traces. The traces are then aligned by the highest amplitude return, which is assumed to be the first surface echo, and averaged together. Because the surface echo is not representative of internal boundaries due to the greater dielectric contrast between ice and free space, surface effects must be minimized by the exclusion of bins with data exhibiting high amplitudes related to the surface return, corresponding to depths up to ~120 m.

The resultant trace is then de-trended to remove the effects of attenuation with depth, and the 500 m section subjacent to the zone influenced by the surface (Fig. 2) is isolated and analyzed using a fast Fourier transform. The accuracy of the resulting wavelengths is reliable down to the vertical resolution of SHARAD in water ice, or ~9 m [11].

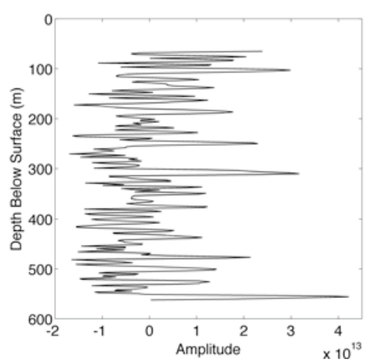
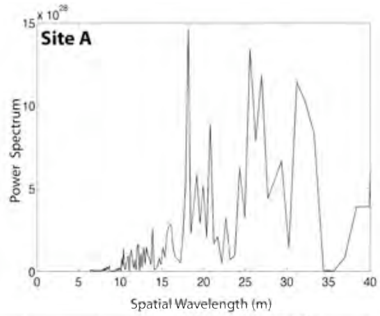


Figure 2. Averaged, de-trended radar response (trace) with surface effects removed. Trace corresponds to the upper 570 m of the NPLD at site A.

Results: The Fourier analysis at site A returned peak values at 31.2, 20.8, 18.1 and 16.1 m, with broader maximums around 24.3-29.3 m (Fig. 3a).

Figure 3a. (top) Results of Fourier analysis on radar trace at site A. (bottom) Fourier analysis for a MOC image at the same site [1].



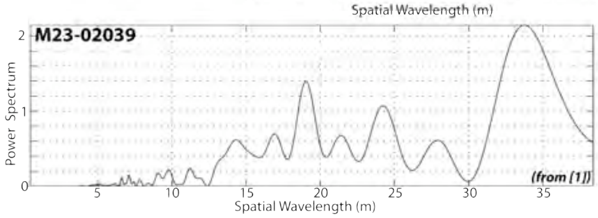
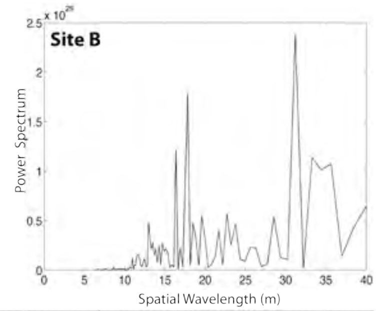
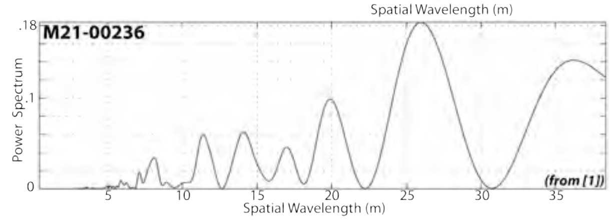


Figure 3b. (top) Results of Fourier analysis on radar trace at site B. (bottom) Fourier analysis for a MOC image at the same site [1].





These wavelengths strongly agree with prominent wavelengths of ~27, ~24, ~18 and ~15 m apparent in one of the analyzed images from the same site (Fig. 3a) [1]. Notably, the smaller peaks in visible wavelength at ~21 and ~ 12 m correspond to cluster means from the statistical analysis of a high resolution stratigraphic section at the same site [5], notably the 21.0 and 12.5 m results [4]. Similarly, peak radar wavelengths in the uninterpreted signal agree closely with statistical cluster means of 27.9, 20.3, 15.8 and 11.8 m recently produced from radar stratigraphy for an extended correlation study site [13]. In all analyses the 30-35 m wavelength is prominent (results for site A summarized in Table 1).

At site B, the radar signal is dominated by major peaks at 31.2, 17.8 and 16.4 m (Fig. 3b). Agreement with the corresponding image [1] is less apparent, however, the image wavelength peaks between 15 and 18 m are similar to those in the radar signal, as is the ~ 35 m wavelength in both signals.

Conclusions: Preliminary results of radar return frequency analysis from two sites in the NPLD suggest

Radar Clusters [13]	Radar Freq.	Visible Clusters [4]	Visible Freq. [1]
31.2 m	35.3 m	30.7 m	~33 m
24.3 - 29.3 m	27.9 m	-	~24 m
20.8 m	20.3 m	21.0 m	-
16.1 m	15.8 m	-	~15-18 m
13.9 m	11.8 m	12.5 m	-

Table 1. Summary of results from radar and visible statistical and frequency analyses at site A.

that not only are similar frequencies present in the uninterpreted optical and radar data, but also there is consistency between radar wavelengths and statistical results from the interpreted data. This additional verification of concurrence between radar reflectance and optical layering continues to demonstrate the fundamental similarities between these phenomena. Additionally, this technique potentially provides a basic method to quantitatively assess the geographic variation of accumulation over specific intervals of NPLD history, especially if combined with detailed "ground truth" studies at specific sites where both radar and optical data can be assessed. Our results also improve confidence when co-analyzing SHARAD data with visible layer properties for the purpose of studying NPLD composition [14].

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