MOLA-DERIVED ROUGHNESS DATA USED TO PREDICT SURFACE SCATTERING FOR MARS SUBSURFACE RADAR SOUNDING.

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Introduction: The Mars Express orbiter, to be launched by the European Space Agency in 2003, will carry a low-frequency radar sounding instrument, MARSIS (Mars Advanced Radar for Subsurface and Ionospheric Sounding). The primary goal of MARSIS is to map the distribution of water, both solid and (if present) liquid, in the upper several km of the martian crust. Detecting discontinuities in the crust, such as an ice-water transition, presents many challenges for a Mars orbital radar sounder. One challenge that must be overcome is the presence of radar scattering (echoes) from the surface of Mars, expected to be detected by the sounder antennas at the same time as any echoes arising from subsurface interfaces. As the transmitted spherical wavefront spreads within the crust of Mars,. it also interacts with surface topography at off-nadir positions, creating a "clutter" signal that can mask the subsurface echoes. The MARSIS instrument will utilize Doppler filtering to limit the off-nadir clutter in the along-track direction, and a nadir-null secondary antenna to identify strong off-nadir clutter from the cross-track direction. To evaluate the effects of off-nadir surface clutter and the capability of these schemes to reduce the clutter, it is necessary to predict the range of scattering behavior that may be expected from martian surface topography. In this paper, we utilize Mars Orbital Laser Altimeter (MOLA) data from the current Mars Global Surveyor mission to characterize the topographic roughness of a variety of martian terrain types, at scales relevant to the MARSIS clutter problem. Segments of MOLA altimetry profiles are reduced to the topographic parameters rms slope and fractal dimension, which then are used as inputs to a near-nadir radar scattering model to predict the strength of the clutter signal.

Approach: The MARSIS sounder operates in the frequency range of 1.3 to 5.3 MHz, which corresponds to wavelengths from 56 to 230 m. For this analysis, we consider the effects of the topography on a radar signal of 100 m wavelength, which is an intermediate value within the MARSIS wavelength range. The MOLA data used here are from the first release of MGS data, acquired during the capture orbit and aerobraking hiatus phases of the mission. Topographic samples are taken at spacings of 300-500 m. To obtain acceptable statistics, we analyzed MOLA segments 100-200 km in length (Figure 1), each of which lies wholly within a geologic unit from the maps of [1]. Data were reduced to topographic parameters using the methodology of [2]. Profile segments were first detrended to remove regional slope effects. Point-to-point slopes were calculated for adjacent points, and at all baselines up to one-half the profile length, and the standard deviation of the slopes ("rms slope") was calculated at all scales. The resulting slope functions (rms slope as a function of baseline length, or "lag") were analyzed to determine the fractal dimension. This is obtained simply by fitting a power law to the slope function at the smallest scales, where a power law is observed to hold (Figure 2). Some profile segments displayed power-law (fractal) behavior at scales from ~300 m to 10 km or more, while many segments departed from fractal behavior at lag distances of less than 1 km (Figure 2). This behavior has been noted in an analysis of median (adirectional) slope at selected scales [3].

Results: We focused our initial study on four members of the Vastitas Borealis Formation (Hv) of [2], a northern plains assemblage of possible sedimentary origin, and for comparison, several segments of an ancient cratered highlands unit Npld (dissected unit of the Noachian plateau sequence). Of the four Hv members, rms slope values at scales of 700-1000 m were remarkably clustered, in the range of 0.005-0.015 (0.3-0.9 deg.). Fractal dimension values were also clustered, in the range of 1.1-1.3, with the exception of the "grooved" member of the Formation (Hvg), which had values from 1.4-1.6. In contrast, the highlands unit was significantly rougher, with rms slope values at the 700-1000m scale of 0.035-0.08 (2.0-4.5 deg.). Interestingly, the fractal dimension for the rough highland areas was very similar to that of most of the Hv plains units (1.1-1.3). Unit Hvg was the only one to deviate significantly from this narrow range in fractal dimension. As suggested by [2], a surface displaying self-affine (fractal) behavior at a range of scales may be expected to display that behavior somewhat beyond the scale measured. We extrapolated the rms slope using the observed power law behavior at point-to-point (300-500 m) MOLA scales and larger, down to the 100 m scale to assess the scattering behavior of a radar signal of 100 m wavelength. Using the near-nadir radar scattering model of [4], which is based on a treatment of wavelets interacting with self-affine topography, we generated predicted scattering "laws" for a subset of the MOLA topographic segments. We utilized a range of Fresnel reflectivity values from numerous ground-based radar observations of Mars. Results indicate that northern martian plains surfaces such as the Hv Formation will produce off-nadir scattering that drops off very rapidly with incidence angle, and therefore will not be a significant source of "clutter" for the detection and interpretation of subsurface interfaces. Highland units, on the other hand, with 100-m scale rms slope values of 5 degrees or more, will continue to scatter at larger angles from nadir, requiring utilization of clutter cancellation strategies.

References: [1] Tanaka K., Scott D.H., Greeley R. and Guest J.E., USGS maps I-1802-A, -B. -C. [2] Shepard M.K. et al. (1995) *JGR, 100,* 11709-11718. [3] Kreslavsky M.A. and Head J.W. (1999) *LPSC XXX*. [4] Shepard M.K. and Campbell B.A. (1999) in press.

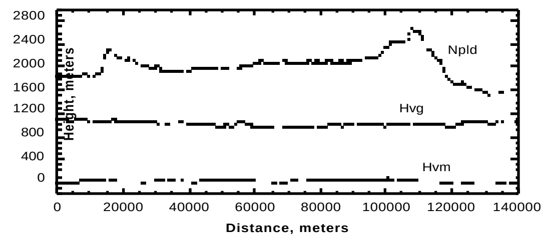

Figure 1. Three topographic profiles from MOLA data, offset to arbitrary elevations for clarity. Three geologic units sampled are from maps of [1]; Npld is a highlands unit, Hvg and Hvm are northern plains.

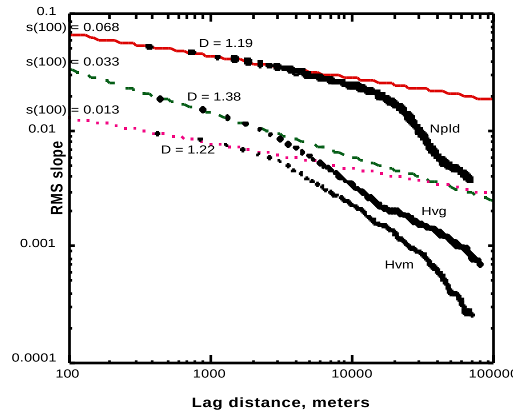

Figure 2. RMS slope as a function of length scale ("lag distance") for the three profiles shown in Figure 1. Best-fit power law slopes for the left side (linear segment in log-log) of each curve gives the fractal dimension (D). Fits are extrapolated to 100 m to give RMS slope at MARSIS wavelength scale.