SURFACE ROUGHNESS MAPS OF MARS BASED ON SHARAD ECHOES. B. A. Campbell[1], N. E. Putzig[2]. [1]Center for Earth and Planetary Studies, Smithsonian Institution, MRC 315, Washington, DC 20013-7012, campbellb@si.edu. [2]Department of Space Studies, Southwest Research Institute, 1050 Walnut St #300, Boulder, CO 80302.

Introduction: The Shallow Radar (SHARAD) instrument on the Mars Reconnaissance Orbiter was designed to capture echoes from subsurface geologic layering with dielectric contrasts, but significant information on topographic roughness properties can also be recovered through analysis of the amplitude and time-delay characteristics of the initial surface echo. We derive a parameter related to the rms surface slope on scales of meters to tens of meters, complementing MOLA pulse width measurements of meter-scale roughness [1], few-meter-scale image-derived stereo altimetry [2], and MOLA point-to-point roughness studies [3].

SHARAD Data Processing: SHARAD transmits a linear chirp from 15 to 25 MHz with a total duration of 85 μs and records at a sampling interval of 0.0375 μs. The received signal is correlated with the chirp waveform to recover a range resolution in vacuum of 15 m. Focused synthetic-aperture processing increases the coherent gain and narrows the along-track lateral resolution [4]. For all of the data analyzed here, we employ a fixed suite of processing parameters, such as aperture length and windowing function, to permit comparisons between tracks collected over several years.

SHARAD echoes also contain information on the roughness and dielectric properties of the Martian surface, the range between the spacecraft and surface, and the total electron content of the intervening ionosphere [5]. The range measurements may be useful for filling gaps in topographic datasets for Mars, but here we focus on the recovery of surface physical properties from the peak power and delay width of the SHARAD echoes.

Roughness Estimation from Near-Nadir Echoes: Model-dependent estimates of physical parameters from near-nadir or "quasi-specular" echoes have a long heritage in Earth-based studies of the Moon and Mars [6, 7], orbital studies of Venus [8], and terrestrial ocean and ice altimetry. Radar backscatter at low incidence angles (within a few degrees of normal incidence) is dominated by mirror-like reflections from topographic features that are smooth on horizontal scales at least a few times the illuminating wavelength and are tilted toward the sensor. Echoes from these facet-like features are typically assumed to sum incoherently, so the angular scattering behavior depends only on the Fresnel normal reflectivity ρ and a roughness parameter, often represented as the rms slope s, that captures the angular width of the tilt distribution. The horizontal scale over which estimates of radar-derived roughness apply is loosely defined, from a few times the radar wavelength to scales comparable to the illuminated footprint.

There are numerous models for the incoherent scattering properties of a statistical surface at small incidence angles. These scattering models share two attributes that are useful in extracting actual surface properties. First, the peak power at normal incidence depends linearly on the Fresnel normal reflectivity and the inverse square of the roughness parameter s. Second, the ratio of power integrated over a range of incidence angles to the peak power is independent of reflectivity and thus modulated only by the surface roughness. We exploit the second attribute to estimate relative values of surface roughness on horizontal scales relevant to the SHARAD center wavelength of 15 m. The first attribute could then, in principle, be used to recover information on surface dielectric variations, but only in conjunction with careful calibration of SHARAD measurements over time.

Initial Geologic Results: Our proxy for roughness at the few-meter to few-hundred-meter scale exhibits some strong correlations with the 600-m-scale roughness values drawn from MOLA profiles [3]. For example, SHARAD roughness values are high in the Olympia Planum dune field, which shows clear runout of echo power to significant delays (Figs. 1 and 2) and corresponds geographically with an arcuate region of high 600-m rms slope [3]. Both approaches map a patch of very low roughness between about 170^0E and 240^0E in the south polar deposits - the unit Apl "smooth plateau" in [3].

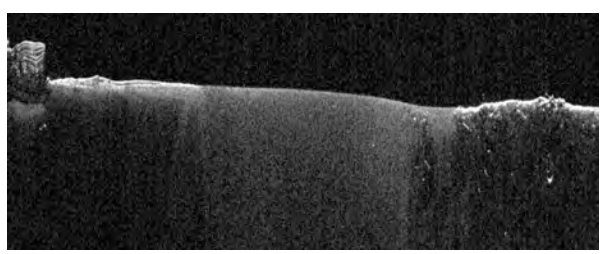

Fig. 1. SHARAD view of the Olympia Planum region, with margin of NPLD units at left. Note the long delay runout of echo power due to scattering from dune fields. Portion of track 1301702.

Across the northern plains and younger volcanic units such as those in Amazonis and Elysium Planitiae, the SHARAD-inferred roughness again generally tracks with the smallest length scale of MOLA-derived rms slope. There are local deviations from this correlation, which are of particular interest where the SHARAD results initially suggest a more rugged surface. It is possible for such discrepancies to arise instead from (1) shallow reflectors which are not well discriminated from the sidelobes of the surface return, or (2) strong volume scattering due to blocky or fractured material in the upper few tens of meters. We continue to reprocess additional SHARAD data with the same set of synthetic-aperture parameters, and to examine in detail those locations where the radar properties differ from the MOLA-derived roughness.

References: [1] Neumann et al., GRL 30 #11, 1561, 2003. [2] Beyer et al., LPSC XXXIX, 2485, 2008. [3] Kreslavsky, M.A., and J.W. Head, JGR, 105, 26,695-26,711, 2000. [4] Seu, R., et al., JGR, doi:10.1029/2006JE002475, 2007. [5] Campbell, B.A., L.M. Carter, N.E. Putzig, and R.J. Phillips, IEEE-GRSL, submitted, 2010. [6] Hagfors, T., JGR, 69, 3779-3784, 1964. [7] Simpson, R.A., et al., in Mars, Univ. of Arizona Press, 1992. [8] Ford, P.G., and G.H. Pettengill, JGR, 97, 13,102-13,114, 1992.

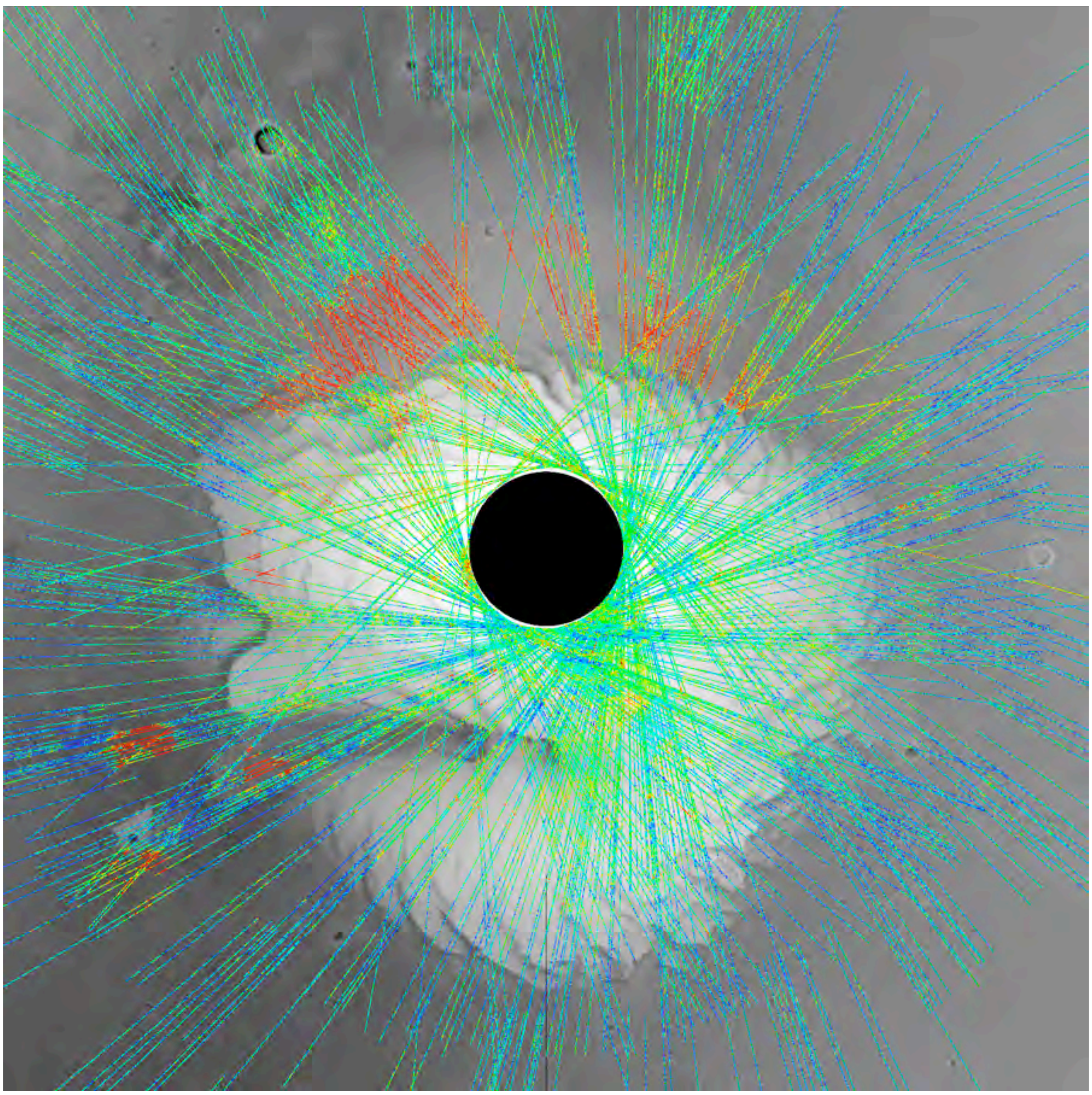

Fig. 2. SHARAD-derived roughness map of the north polar region of Mars. Red tones indicate rough terrain at meter to tens-of-meters scale. Blue tones indicate smooth terrain. The arcuate red area at center top and patches at lower left correspond with dune fields in Olympia Planum, Hyperborea Lingula, and Hyperboreus Labyrinthus identified as rough at the 600-m scale in [3].