SLOPES AND STOCHASTIC PROPERTIES OF THE NORTHERN HEMISPHERE OF MARS FROM MOLA ALTIMETRY.

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Introduction. Analysis of slope and macroscale roughness provides useful information on the nature and evolution of geologic surfaces. As a first step toward understanding the surface evolution of the northern hemisphere of Mars, we have analyzed measurements made by the Mars Orbiter Laser Altimeter (MOLA) [1], an instrument on the Mars Global Surveyor spacecraft (MGS) [2] to determine surface slopes and the statistical character of the topography by stochastic modeling.

Data and Measurements. The data were collected during orbital periapses 3 through 36, which resulted in 17 near-polar inclination MOLA passes in the approximate latitude range 80°N and 12°S. The profiles are characterized by ~300-m along-track spacing, 40 cm-range resolution and ~1-10 m range precision over slopes of up to 30° [3]. This performance combined with absolute vertical measurement accuracy of 50-100 m [4] (driven the MGS orbital knowledge), dictates that the MOLA data is well suited for quantitative analysis of topographic variation over a broad wavelength spectrum. Surface slopes were obtained on a variety of length scales: ~150 m from the instrument's return pulse shape, ~600 m from a 3-point Lagrange slope formula applied along track, and > 100 km from fitting to a set of points along a track. These techniques respectively correspond to the transition from local roughness through regional slopes, to global shape. While the first involves various ambiguities, the second and last methods have been applied and contrasted with other solid bodies in the solar system [5, 6, 7]. Fig. 1 shows slopes computed for all 18 profiles over 10-km baselines.

Slope Distributions. All profiles show the northern latitudes outside of the Tharsis rise (Passes 24, 26, 33 and 35 in Fig. 1), to be extremely flat or sloping gently upwards to the south [3, 8]. This flatness of the upper latitudes of the northern hemisphere extends across all longitudes and for over 2000 km in north-south extent. Along the 17 continuous tracks the topography varies by only ±50 m to ±400 m about a mean sloping surface. Mars exhibits a pole-to-equator mean topographic slope of 0.056°, which is a result of the separation of the planet's center of mass from the center of figure along the polar axis [9] and the Tharsis rise that effectively increases the mean equatorial radius by ~1 km. Pass 24, which crosses the Olympus Mons volcano at 18°N, -136°E, slopes upward to the south from the layered terrain at about 0.08° for a distance of 2500 km, and has an rms deviation of only 61 m from a flat sloping surface. The hemispheric dichotomy boundary region, which separates the low, volcanically resurfaced northern hemisphere from the older, heavily cratered and topographically higher southern hemisphere [10], has the highest regional slopes. Over tens of km baselines (Fig. 1) slopes are generally in the range 1°-3°. Slopes over hundreds of meter length scales, which are indicative of surface modificational processes [11] and perhaps some relic primary structure, can be locally steep, occasionally exceeding 20°.

Stochastic properties. Statistical analysis of the topography provides further quantification of macroscale roughness properties. The topographic profiles can be decomposed into three components [12] a "deterministic" component, *i.e.* a regional slope, a quasi-stochastic component, with power-law spectral behavior, and erratic components. The latter consists of outliers, representing for example small craters, false returns, and instrument noise, with no point-to-point correlation. The stochastic component has a fractal-like roughness, characterized by a point-to-point correlation length scale *l* and a root-mean-square (rms) roughness *h*. Inversion schemes to determine these parameters [13, 14]. require estimation of either the autocorrelation function or the local slope distribution, as well as instrumental parameters.

We have performed an inversion that resolves a distinct population in *h-l* space corresponding to the smooth plains of Amazonis, crossed by Pass 31, and neighboring regions crossed by adjacent tracks (as can also be seen in Fig. 1). The model that best fits the MOLA stochastic component includes about 50 cm of rms noise due to instrument and pulse width jitter. The model rms height, on a 60 km (1°) baseline varies from a minimum of 1.5 m over the Amazonis basin and a region to the southeast, to nearly 10 km in the Olympus Mons area. The correlation scale is constrained by an *apriori* 10 km length, but varies from about 2 km to several hundred km. Taken together, these scales resolve 3 arrays of surface type: 1) plains with about 25 m rms roughness and 8 km correlation scale length; 2) highlands with > 50 m roughness and > 10 km scale; and 3) a low, smooth region with about 2 m roughness, with a 20 km scale.

Analysis is underway to correlate these distributions with mapped geologic units [15] and with results from similar topographical analyses of surfaces on the Earth, Moon and Venus. Preliminary results show Amazonis to be comparably rough to the Earth's oceanic abyssal plains and smoother than the Sahara Desert. Further systematic study is planned to correlate the topographic properties with the processes that shape planetary surfaces.

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Figure 1. Slopes on 10-km length scales determined from MOLA topography. Numbers above the profiles on the left are MGS orbit numbers and numbers on the right are areocentric longitudes at the equator measured positive east.