REFLECTED SIGNAL ANALYSIS AND SURFACE ALBEDO IN THE MARS ORBITER LASER ALTIMETER (MOLA) INVESTIGATION.

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Introduction

Mars Orbiter Laser Altimeter (MOLA) is an instrument on the Mars Global Surveyor spacecraft. A general description of the instrument can be found in [8]. The laser operates at the wavelength of 1.064 μm , emitting 8-nsec-long pulses. MOLA measures topography, surface reflectivity and returned pulse width. First tracks of data, were acquired during the contingency orbits in September-November of 1997. Later, many more data were acquired during the Science Phasing and Mapping Orbits. The results from the mapping orbits data are discussed in [5]. Currently, data are available for more than 9 month of continuous observations.

In this presentation we concentrate on one of the primary scientific objectives of the MOLA investigation : compilation of a map of normal surface albedo at the MOLA wavelength. Albedo can be calculated from the reflectivity measurement. Reflectivity (R) is a ratio of returned laser energy to the emitted laser energy, adjusted for distance and the Lambert reflection law. It is affected by the albedo (A) of the underlying terrain and extinction of the photons from the laser beam by atmospheric aerosols and can be expressed as $R{=}A * e^{-2\tau}$, where τ is a total atmospheric opacity. MOLA monitors the emitted power and measures the reflected energy from the ground and the returned pulse width. However, small deviations from the Lambert law are expected.

MOLA detector was constructed to be very sensitive to the incoming signal. When on Mars, it turned out that incoming signal was much stronger than expected. As a result energy measurements are saturated in about 60% of the mapping data. Later in the mission, the laser energy decreased slightly ($\approx$ 10%) and the average atmospheric opacity has increased. Currently, unsaturated reflectivity data are available for about 80% of the Martian surface. Figure 1 displays reflectivity map, compiled from data taken during the dust storm period. Data over the brightest areas such as Tharsis region and seasonal ice cap are still saturated. Unsaturated reflectivity data are also obtained when the ground is obscured with non-reflective clouds.

Opacity or albedo can be inferred from the reflectivity measurement, if one of them is known from some external dataset. Here we present an algorithm to calculate the normal albedo of Mars at the MOLA wavelength using the MGS Thermal Emission Spectrometer (TES) 9μm opacity measurement [6].

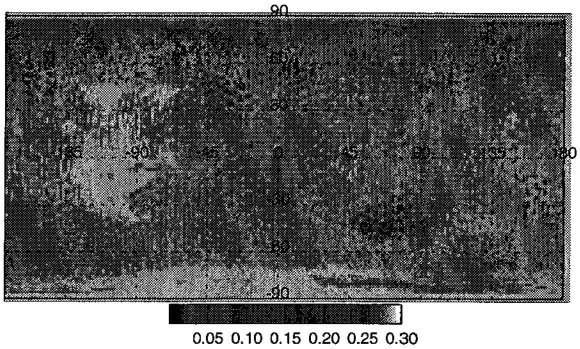

Figure 1: Sample map of the MOLA reflectivity data. Compiled from data taken during the dust storm season period (L_s=220.5° – 240.5°). White areas (Tharsis region, South Polar region) are saturated data. Cylindrical projection from 90°S to 90°N.

Calculation of albedo

To calculate the surface albedo from the reflectivity measurement, we have to remove the atmospheric attenuation. Opacity in the MOLA experiment is primarily due to the extinction of photons from the laser beam. MOLA albedo is calculated from the Beer's law :

$$A_{MOLA}{=}\left(R * e^{2*\tau}\right)/Op \ ,$$

where R - is the measured reflectivity, τ - extinction atmospheric opacity at 1.064μm , Op - returned signal enhancement due to the opposition effect ([2]). To calculate the opacity at the MOLA wavelength we propose to use the opacity calculated from the depth of the 9μm dust absorption band ([6]). A visible-to-IR opacity scaling factor can be used to infer opacity at the MOLA wavelength from the 9μm dust opacity, measured by the TES instrument. The scaling of the dust opacity in the infrared compared to the MOLA wavelength is very important for the determination of albedo. It may contribute up to 20% of the error. Depending on the atmospheric aerosol loading, this ratio may vary very widely.

Based on the IRTM and Viking Landers opacity data sets, it was shown ([3], [7]), that during the dust storm season (L_s=220° – 240°) visible-to-IR opacity ratio is very close to 2.5. We decided to accept this value for our calculations of albedo. We assume that the dust is the only scattering aerosol in the atmosphere during this time. Water ice may significantly increase extinction at the MOLA wavelength. Extensive water ice clouds formations were observed during the aphelion season in the equatorial regions. TES team calculates water ice opacity along with dust opacity. To estimate surface albedo we can select data where the water ice opacity is minimal, like during the dust storm season.

Results

We were only able to demonstrate this algorithm for a small region on the planet, because full dataset of TES opacities was not available at this time. We chose Syrtus Major as our test region. Returns from this region were mostly unsaturated. We have selected data from the dust storm season to use the 2.5 scaling factor for visible-to-IR opacity. No extraordinary dust activity was observed in the selected data. We compared MOLA derived albedo and the Plescot and Miner albedo dataset ([4]), compiled from the Viking IRTM bolometric channel data. The results are shown on Figure 2. MOLA albedo was calculated assuming the visible to IR opacity ratio of 2.5 and 30% returned signal enhancement due to the opposition effect. Albedo from [4] was corrected for wavelength and atmospheric effects using [1]. The general agreement is very good. The results of MOLA albedo calculations are consistent with the Viking IRTM derived albedo data set. Data taken during clear and dry periods of time exhibit large (1 to 3) variations in MOLA opacity to IR opacity ratio. The source of these variations is most possibly variability of the aerosol particle size distribution.

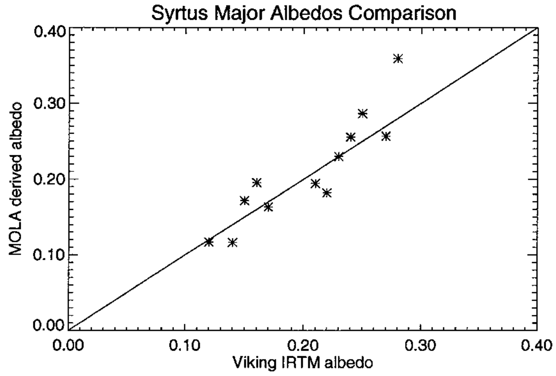

Figure 2: Comparison of MOLA albedo and Viking IRTM albedo. The solid line is the locus of equal albedos. Only data from the dust storm season (L_s=220° $-$ 240°) were used to construct this picture. Data come from the Syrtus Major region (20°-26°N and 290°-300°W). MOLA albedos were corrected for the opposition effect. The Viking IRTM data were corrected for the wavelength and atmospheric effects ([1]). Spectral properties of the surface materials and variability of the particle size distribution in the Martian atmosphere are the major sources of error.

Summary

Saturation of the reflectivity measurement did not allow complete mapping of the planet. During the dust storm season, when the dust atmospheric loading was at its maximum, MOLA collected unsaturated reflectivity data from about 80% of the planet. The bright Tharsis region still remains very poorly mapped in reflectivity.

We demonstrated algorithm for derivation of the normal albedo of the surface from the reflectivity measurement. We employed the $9\mu m$ dust opacity, derived from the MGS Thermal Emission Spectrometer observations ([6]) and presented some initial results. The values of albedo at the MOLA wavelength appear to be consistent with Plescot and Miner dataset ([4]), with the correction suggested by Clancy et al. ([1]). More data from the TES instrument will be available to us in near future, thanks to generosity of M. Smith, J. Pearl and B. Conrath from the TES team. Using the data from the mapping orbits, especially the data from the dust storm season, we will able to compile a map of the normal albedo at $1\mu m$.

Acknowledgments

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