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Mars Orbiter Laser Altimetry Pulse-Widths an Indicator of Surface Roughness at Gale Crater

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1. Introduction

One of the secondary science goals of the Mars Orbiter Laser Altimeter (MOLA) was to investigate surface roughness within the laser footprint using the backscatter pulse-widths of individual pulses [1]. As a pulse is fired, it diverges so that by the time it reaches the Martian surface the footprint diameter is approximately 170 m [1]. The pulse is then reflected back, and the photons are collected by the telescope. The time spread of the returning photons is measured and recorded by the instrument, and, after correcting for instrument and along-track slope effects, what remains is believed to indicate surface roughness within the footprint. At present, the baseline at which this method is thought to respond is 100 m. However, a corrected version of this dataset suggested that the actual response baseline is nearer 35 m, after the footprint diameter had been redefined to 70 m, bad data had been removed, and better slope corrections performed [2].

This work explores at which baseline these pulse-widths actually respond, by comparing pulse-width values to surface roughness estimates from digital terrain models (DTMs) produced from High Resolution Imaging Science Experiment (HiRISE) stereo-images [3]. The MOLA instrument has near-global coverage, albeit with 300 m along-track spacing and ≈4 km inter-track average spacing at the equator, so the effective calibration of pulse-width data would provide us with a valuable resource for identifying potential landing and roving sites, as well as looking at geology at fine scales relating to different surface processes.

2. Method

Data from the High Resolution Stereo Camera (HRSC), HIRISE and MOLA was loaded into a GIS (ESRI®ARCmap 10) and checked for positional errors. The MOLA gridded and track elevation data was used a base map, to check the correct georeferencing of the HRSC DTMs. HRSC image data was then compared against HRSC DTMs to check for errors, before the HiRISE data was loaded. HiRISE image data is then georeferenced to the HRSC image data, and then used to georeference the HiRISE DTM data. Different map projection systems are corrected for within the GIS.

Surface roughness maps are then produced at

baselines from 10 to 300 m using the RMS height, ξ, and the range, r. ξ is written as:

$$\xi = \left[\frac{1}{n-1}\sum_{i=1}^{n}(z(x_i) - \bar{z})^2\right]^{\frac{1}{2}}, \quad (1)$$

where n is the number of points sampled, $z(x_i)$ is the elevation at point x_i, and $\bar{z}$ is the mean of z for all the sample points which lay within the calculation diameter. The range is given as:

$$r = z_{max} - z_{min}\ , \quad (2)$$

where z_{max} and z_{min} are the maximum and minimum elevations within the search diameter respectively.

Surface roughness values are then extracted from each map at the MOLA pulse locations (Figure 1), and then plotted against pulse-widths. The response baseline for the MOLA pulse-widths is then found by finding the plot with the best r-squared value. Table 1 shows RMS height values extracted at a pulse location over Eberswalde Crater, shown in Figure 1.

Table 1. Example of RMS height values extracted from a MOLA pulse

Baseline	10 m	25 m	35 m	50 m	70 m	100 m	150 m	200 m	300 m
ξ	0.58	1.21	1.93	3.51	5.16	7.69	11.72	13.16	17.41

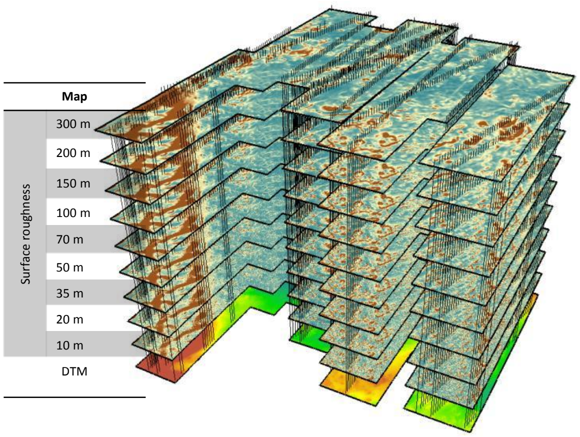

Figure 1. Representing how surface roughness information is extracted from each of the roughness maps at MOLA pulse locations.

3. Results

The analysis was performed using HiRISE DTMs from Gale crater (MSL Curiosity landing site). The best correlated results are shown for the original and corrected pulse-widths plotted against RMS height.

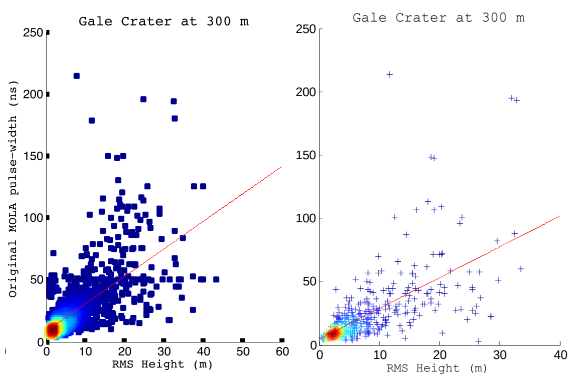

Figure 3. Left: results from Original pulse-widths and RMS height; top right: Corrected pulse-width and RMS height.

Using range as a measure of surface roughness did little to alter the poor correlations in the graphs above, with range performing marginally better using the corrected dataset, and RMS height performing better when using the original pulse-widths. Using the corrected version of the pulse-width dataset actually reduced the r-squared values, from 0.46 to 0.38, although this change is not significant due to the poor correlations witnessed here (Figure 3).

Gale Crater is the only site we studied, where poorer r-squared values were witnessed using the corrected dataset compared to the original dataset.

4. Conclusion

In conclusion, we can state that MOLA pulse-width data cannot be used as a reliable indicator of surface roughness at Gale Crater. This may be because there is a very narrow distribution of pulse-widths and surface roughness values extracted at MOLA pulse locations. This suggests that the pulse-width data is unable to determine small surface roughness values, and therefore may be better suited to determining between very rough and very smooth areas. To explore this further, we may investigate how MOLA pulse-widths compare to roughness in rougher regions, such as sites around Olympus Mons.

The reduced r-squared value, when using the corrected dataset, is not likely to be significant, as it is likely to be the result of the removal of a significant number of bad points that happen to lie near the line-of-best fit, such as the line of points that occur near 50 ns and stretch from 8 – 50 m RMS height.

Acknowledgements

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References

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