ON THE CALIBRATION OF MOLA PULSE-WIDTH SURFACE ROUGHNESS ESTIMATES USING HIGH-RESOLUTION DTMS.
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Introduction: Planetary surface roughness can be used for the identification of different terrain types; aerodynamic surface roughness estimates for better modelling of dust storm and dust devil initiation; radar backscatter return interpretation for sub-surface mapping at low frequencies and is critical in the selection of suitable landing sites for robotic lander or roving missions [1]. One of the secondary science goals of the Mars Orbiter Laser Altimeter (MOLA) was to study surface roughness at 100 m scales, which has a footprint of 168 m in diameter, using the backscatter pulse width of the laser pulse [2]. Once instrumental effects and surface slope corrections have been made to the backscatter pulse width, it should be possible to estimate the surface roughness within the footprint of the laser pulse. Slope corrections to the pulse width values in the final release (version L) of the MOLA Precision Experimental Data Record (PEDR) have been made using a minimum estimate for slope, calculated using elevation data at one pulse ahead and one behind in the along-track direction. This dataset has since been corrected for across track slopes using the MOLA gridded dataset and has had so called ‘bad points’ removed [3]. The footprint was subsequently revised to 75 m diameter, with a 35 m response length. We look here at comparing surface roughness values derived from the MOLA pulse-width data with surface roughness estimates derived at various scales from high-resolution digital terrain models (DTMs) to determine if these theoretically derived surface roughness lengths have any physically meaning.

Method: The final four contenders for the landing site for Mars Science Laboratory were used in this study, as they have extensive HiRISE (1m) and HRSC (50m) DTM coverage [4]. Pulse-width data from the MOLA PEDR (version L) and the data used in [3] were collected over each of these sites, and compared against surface roughness estimates at various scales from DTMs using the RMS height, ζ, shown as:

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

where n is the number of points, $z(x_i)$ is the elevation at point i, $\bar{z}$ is the mean elevation within the calculation window. The surface roughness was calculated at 10, 20, 35, 50, 70, 100, 150, 200 and 300 m diameters. This was repeated using HRSC DTMs, using the same MOLA data as previous. This assumed a circular footprint for each MOLA footprint and that the horizontal geolocation of the PEDR MOLA footprints was sufficiently accurate to only extract those DTM points which lay inside the footprints. Results were plotted against the MOLA pulse width values to determine at which scale the pulse-width data best responded.

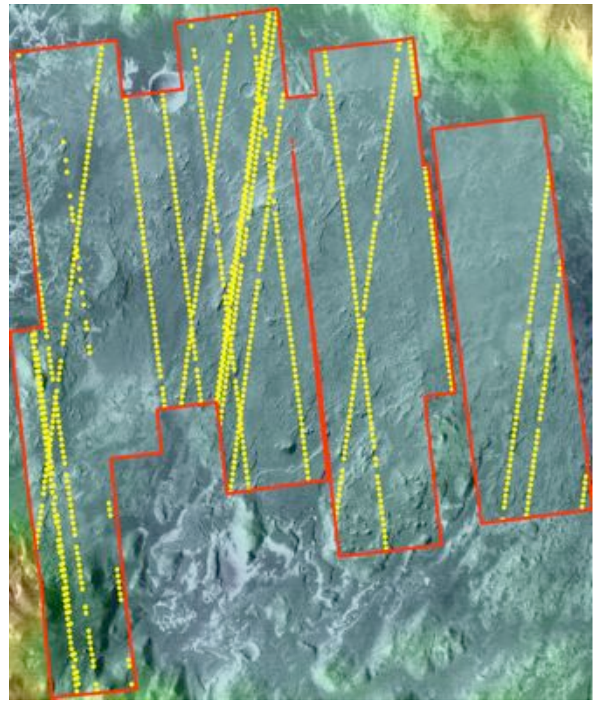
Figure 1. Eberswalde Crater project view. MOLA pulse locations from the corrected dataset are shown in yellow. HiRISE (red boxes) and HRSC DTMs and orthoimages are shown, rainbow colour LUT with red color is -400 m elevation and blue color is -1590 m.

Results: Initially, former landing sites were studied as part of this project. Results from the MOLA PEDR data were extremely poor, and showed no correlation with surface roughness measurements from DTMs. However, due to the lack of MOLA pulses in the corrected data used in [3], the study was reduced to the those sites mentioned above. Results using the corrected data in [3] were mixed, shown in Fig 2. Eberswalde and Holden Craters both show significantly improved correlations for a variety of surface roughness scales. The best correlations were found to be at surface roughness scales of about 150 m diameter. Results from Gale Crater showed poorer correlations, the best correlation being at 300 m, and Mawrth Vallis showed very poor correlations at all scales.

As the best correlations were found at scales larger than the grid resolution of HRSC DTMs, we looked at trying to establish whether MOLA pulse width data is better correlated with this dataset. Gale Crater showed a slight improvement in correlation, with a best-fit scale at 200 m; other results were poorer. Results from Eberswalde Crater showed a slight decline in correlation, but Holden Crater and Mawrth Vallis showed no correlation at any of the scales measured.

As pulse width is strongly affected by surface slope, we checked the MOLA pulse width values against surface slope measured from HRSC DTMs. We also plotted the MOLA data against elevation values. Surface slope at Eberswalde Crater and elevation at Gale Crater showed a weak correlation with MOLA pulse widths. Surface slope at Gale Crater showed similar correlations with MOLA pulse widths, as was found with surface roughness measurements. Other results showed no correlation.

Conclusion: It is clear that there need to be major slope corrections to the data, as well as the removal of many 'bad points' from the MOLA PEDR data before MOLA pulse width data can be used to predict surface roughness within a laser footprint. Even with these corrections, it is clear that this method is not able to accurately determine surface roughness at the MOLA pulse locations for our given current models. The variation in correlation values between study sites also suggests that this method cannot be used alone, as we do not know whether that region shows good correlation with surface roughness meaurements from DTMs, or, like Mawrth, there is no correlation. Another key observation is that the scales this method appears to respond best to are far larger than what is needed for the selection of a specific landing sites. It also calls into question previous global maps of surface roughness produced using these models as proposed in [5] and [6], as this work indicates the maps do not reflect actual physical phenomena.

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References: [1] Shepard, M K et al. (2001), JGR 106(E12) p32,777-32,795. [2] Smith, D E et al. (2001), JGR 106(E10) p23,689-23,722. [3] Neumann, G et al. (2003), GRL 30(11) p1561-1563. [4] Grant, J et al (2011), Planetary and Space Science 59 p114-1127. [5] Gardner, C S (1982), IEEE Transactions on Geoscience and Remote Sensing 30(5) p1061-1072. [6] Garvin, J B et al. (1999), GRL 26(3) p381-384.

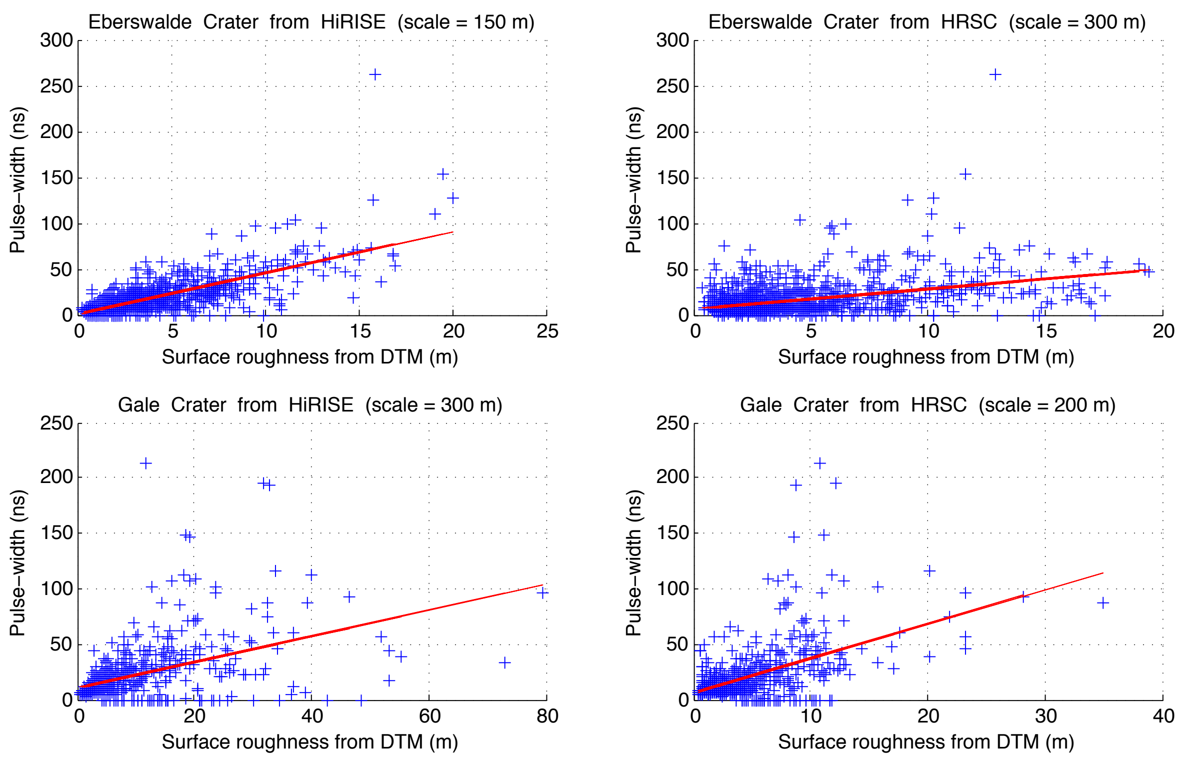

Figure 2. Plots of corrected MOLA PEDR pulse width data and surface roughness measurements from the DTMs for Eberswalde and Gale Craters only. Individual graph labels show at which scale the best correlations are found.