ON THE RELIABILITY OF MOLA DATA TO RESOLVE CRATER TOPOGRAPHY. S.J. Robbins[1] and B.M. Hynek[1,2], [1]LASP, UCB 600, University of Colorado, Boulder, CO 80309, [2]Geological Sciences Department, UCB 399, University of Colorado, Boulder, CO 80309. stuart.robbins@colorado.edu

Introduction: The *Mars Global Surveyor*'s Mars Orbiter Laser Altimeter (MOLA) instrument returned approx. 595 million elevation data points released as a Point Experiment Data Record (PEDR) from which the MOLA Experiment Gridded Data Record (MEGDR) was created and released [1]. MEGDR was used exclusively to determine the morphometric properties of 66,744 craters with diameters $D \geq 3$ km in [2]. While the question of the reliability of MEGDR with regards to PEDR was briefly addressed in [2], an open question was whether the original MOLA data itself could accurately resolve crater rims and other features to the extent that $D \sim 5$ km craters were reliably measured. In this new work, we present both a revised semi-automated topography code for determining crater morphometry and the results of that code when comparing MOLA-derived crater topography with that from much higher resolution digital terrain model (DTM) data that were created from the *Mars Express* High-Resolution Stereo Camera (HRSC).

The MOLA Instrument: MOLA operated by emitting an 8 ns laser pulse at 10 Hz towards the Martian surface and recording the light-time-return. Based on the average orbital speed, the along-track footprint spacing was ~300 m while each footprint was ~160 m in diameter. Inaccuracies in spacecraft orbit reconstruction resulted in ~100 m uncertainties in where each footprint was centered [1]. The across-track spacing varied significantly with latitude but was generally <2 km at the equator and much smaller towards the poles. Vertical accuracy was ~1 m. MEGDR at 1/128° per pixel scale (~463 m/px at the equator) were used in this work along with the ~595 million topographic points.

HRSC DTMs: HRSC is capable of up to 10 m/px imaging of the Martian surface, and it is the first planetary sensor system that has built-in stereo functionality. The vertical accuracy of the DTMs is estimated to be on the order of a few meters, while the accuracy relative to MOLA is ~10-30 meters [3]; horizontal offset was unimportant in this work. Due to an elliptical orbit and on-board lossy JPG compression, images returned and processed into DTMs are of variable pixel scale – 50 m/px, 75 m/px, and 100 m/px [3]. Only the 50 m/px data, for which 124 DTMs have been released as of August 2012, were used in this work. These are 1/1183° per pixel, nearly 10× the spatial resolution of MOLA MEGDR, and so they are assumed to be highly accurate for $D \sim 3$ km craters and useful as a test for the accuracy of MOLA.

Revised Topography Algorithm: The original topography code used in [2] was an entirely manual process and only operated with gridded topographic data: A researcher would draw a polyline tracing the highest points along the crater rim, a second polyline identifying points outside the crater, and a third identifying low-lying floor points. The average and standard deviation of MEGDR pixels at each vertex of each polyline were recorded as the rim height, pre-impact surface estimate, and floor depth.

Over the past year, a revised code has been developed that semi-automates the process and removes some variability between researchers. For rim height, the user creates a polyline that traces the rim. The code interpolates that line, searches each point radially from the crater center for the highest pixels, and then saves the mean and standard deviation of pixels $>\mu+\sigma$. A polyline representing an enclosed shape identifying the surrounding surface is drawn next, and every pixel within it is fit to a plane and the mean and standard deviation are saved. A polygon is then drawn to identify the crater floor, excluding superposed features, and the mean and standard deviation of pixels $<\mu+\sigma$ are saved. Once the code has performed these operations on the gridded data product, an option can be set to also do the same analysis with point data without duplicated effort on the part of the researcher. The surrounding surface and floor are analyzed the same way, while nearest neighbors are used for the rim.

It must be emphasized that this new code is a *different* topographic method than used in [2] and so the two are not easily comparable – on average, crater depths are ~15% deeper with this technique because it rejects values below $\mu+\sigma$ for the rim and above $\mu+\sigma$ in the crater floor However, this is a fairly versatile code with variables such as extent to which points are searched radially along the rim, whether or not the sigma-rejection is performed, and the minimum number of points to be included.

Results: The 124 highest-resolution HRSC DTMs cover ~3000 craters $D \geq 3$ km from the original Robbins database, and ~15,000 are $D \geq 1$ km. These are non-randomly distributed across the planet (Fig. **1**). Since MOLA data are analyzed in groups of 1/16th of the planet (each released MEGDR "image" block), the region with the most HRSC-covered craters (20.6% of the total) was analyzed first, 270-360°E by 0-44°S.

5101 craters $D \geq 3$ km were re-analyzed in MOLA, deriving topographic properties from both MEGDR and PEDR for 3643 of them (the remainder being too poorly resolved – see Fig. **2** illustrating the fraction of craters analyzable in each dataset). Overall, the two datasets agree well: When the ratio of the rim-floor depth of MEGDR is taken with respect to PEDR, the mean is 0.980±0.034, where 1.0 would be parity. Fig. **3** shows this ratio versus crater diameter, showing that PEDR-derived data are up to ~3% deeper on average centered at D = 10, but they are closer to parity at both larger and smaller diameters.

3186 craters are covered by the rectangular HRSC DTM footprints within this 1/16th of the planet, or very roughly 11% of the 27,958 craters done in the first "pass" of the planet of this region [2]. 686 of them are $D \geq 3$ km, while 3103 are $D \geq 1$ km, though 223 are in multiple DTMs. Of these, 314 were able to be analyzed in both MOLA and HRSC data. Independent of diameter, when the ratio of the rim-floor depth in MOLA PEDR is taken relative to HRSC DTMs, the mean is 0.927±0.068, indicating, overall, the majority of HRSC DTM-derived craters are ~8±7% deeper than MOLA-derived craters.

Fig. **4** shows these results as a function of crater diameter, PEDR being the comparison because it is assumed to be more accurate than MEGDR. A statistically significant best-fit line can be drawn through the data showing that, as one would expect, the data are most similar at larger crater diameters. A sigmoid function can also be fit, showing that the HRSC-derived data are ~10% deeper for diameters $D < 9$ km, and they are near parity for diameters $D > 10$ km.

Discussion: At this time, three conclusions can be drawn from this ongoing work:

- Regardless of accuracy issues, MOLA data are too poor resolution to measure craters D < 3-4 km, with coverage falling for $D \lesssim 7$ km. Similarly, the ability to analyze craters in HRSC falls below 50% for diameters $D \lesssim 1.25$ km.
- From the MEGDR vs. PEDR analysis, there is good agreement with little diameter-dependence upon the results. While this does not speak for the validity of the MOLA data at all diameters examined, it does illustrate that gridded data are approximately as reliable as point data for this type of analysis, in agreement with [2].
- If one assumes that the 10× higher spatial resolution HRSC DTMs are completely accurate at kilometer scales, then these data show that MOLA data, as a whole, are highly reliable when analyzing craters $D \geq 10$ km. They can still be used for smaller-diameter craters, but even when care is taken, crater topographic profiles may be subdued by up to ~10% on average.

We are continuing to re-analyze craters with MOLA data under the new topography code and will continue to use any newly released 50 m/px HRSC DTMs to further extend these datasets and provide them to the community. We also think it is important to emphasize that researchers should *always* define their terms when quoting derived topographic data: While the old code [2] and this new code are both deriving rim heights, surface estimates, and floor depths, the results differ by ~15% due to the different algorithms used.

References: [1] Smith *et al.* (2001) doi:10.1029/2000JE001364. [2] Robbins & Hynek (2012) doi:10.1029/2011JE003966. [3] Gwinner *et al.* (2010) doi:10.1016/j.epsl.2009.11.007.

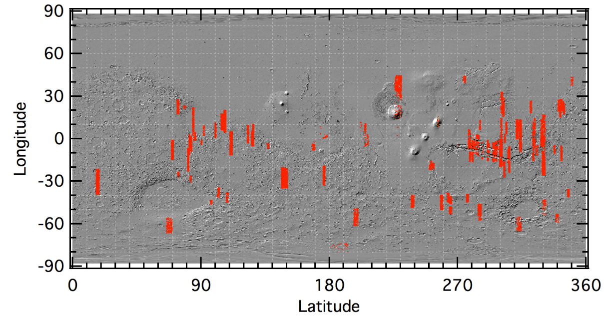

Figure 1: MOLA shaded-relief map of Mars where each red dot shows a crater within the rectangular footprint occupied by the 124 currently released 50 m/px HRSC DTM images.

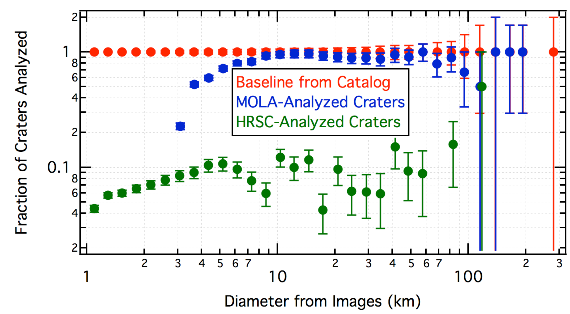

Figure 2: Size-frequency distributions of craters in the base catalog [1], analyzable in MOLA, and analyzable in HRSC in the region 270-360°E by 0-44°S. All were then divided by the base catalog to give the fraction of craters that could be analyzed.

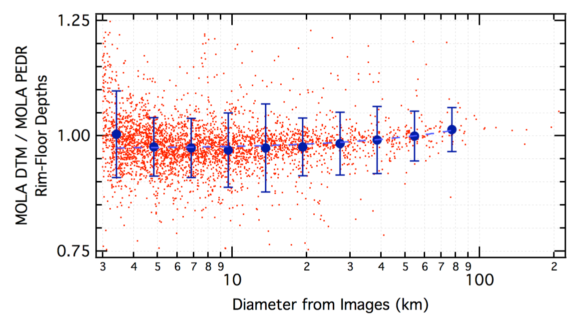

Figure 3: Crater rim-floor depths from MOLA MEGDR divided by PEDR data (red) that have been binned (blue) evenly in log(D) space.

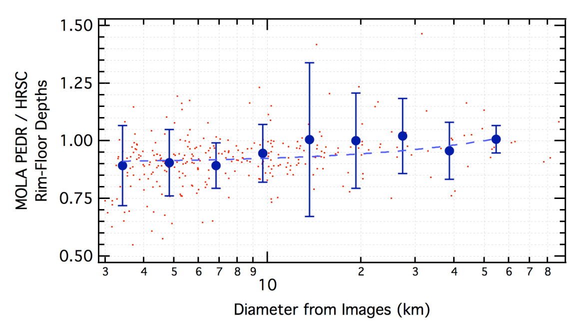

Figure 4: Crater rim-floor depths from MOLA PEDR divided by HRSC DTM data (red) that have been binned (blue) evenly in log(D) space. Dashed line is best-fit linear function.