CHARACTERIZING POSITIONAL OFFSETS IN MAP-PROJECTED MINI-RF MONOSTATIC DATA.
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Introduction: Radar is an important tool for remotely determining geophysical properties of planetary surfaces and subsurfaces. With coverage over much of the lunar surface, the Lunar Reconnaissance Orbiter (LRO) Mini-RF monostatic dataset is useful for lunar science and exploration. Existing Mini-RF map-projected monostatic radar data available from the Planetary Data System (PDS) are affected by significant cross-track and along-track offsets due to topographic parallax and a timing error respectively [1]. In order to correct for these offsets and improve the positional accuracy of the dataset, the origins of these inaccuracies must be characterized before a solution can be implemented in a reprocessing effort.

The existing collection of Mini-RF map-projected (Level 2) monostatic swaths [2] appear to manifest these offsets as a translational shift in both north-south and east-west directions. This diagonal offset can be broken down into along-track and cross-track components, two different offsets with presumed different causes. It is thought that cross-track offsets may be reduced with improved topographic correction, utilizing digital elevation models (DEMs) with improved resolution and accuracy in comparison with the models available when the Level 2 products were initially created. The along-track error is much less understood. It likely originates from a timing error between calculated and actual start times for a given observation [1]. However, the offsets are not consistent across the Mini-RF monostatic dataset. Here we investigate the nature of observed along-track offsets and tests the efficacy of utilizing improved DEMs to correct for cross-track error.

Methodology: For this work we used a shaded relief map made in ArcGIS Pro and derived from the SLDEM2015 256 pixel per degree (ppd) global DEM [3] as a basis for observing offsets in Mini-RF monostatic swaths [2]. Monostatic radar images were selected on two criteria: location between the 60°N and 60°S (the latitudinal range of the SLDEM2015), and by orbit number in order to provide a relatively even distribution of data points across the collection of available observations. Otherwise, swaths were selected randomly and contain both S and X-band wavelength observations.

Ninety monostatic swaths [2] were converted into cubes using USGS Integrated Software for Imagers and Spectrometers (ISIS) [4], and subsequently imported into ArcGIS Pro and overlain on the shaded relief map. Adjusting the transparency of individual swaths allows for offsets to be seen clearly between distinctive small craters identifiable in both images. Approximate distances of along-track offsets were measured in ArcGIS Pro in three separate locations per swath, and the mean average calculated as a reasonable estimate of along-track offset. Swaths too noisy to clearly identify common features and measure offsets were considered unsuitable for these purposes and rejected from the sample set. For a smaller randomly selected subset of samples, new Level 2 versions were reprocessed from available Level 1 data with the current ISIS default Lunar Orbiter Laser Altimeter (LOLA) DEM (128 ppd) [5] as the shapemodel for map projection and overlain on top of the same SLDEM2015 [3] shaded relief map. These were then compared to corresponding Level 2 products available from the PDS relative to the shaded relief map to evaluate the efficacy of using an updated DEM for topographic correction.

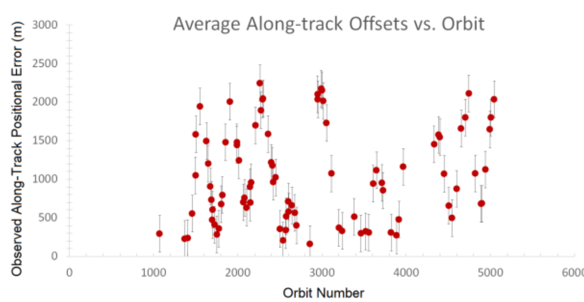

Figure 1. Scatter plot showing measured average offset versus LRO orbit number. Error bars are representative of a possible two-pixel error in measurement in relation to the SLDEM2015 [3] shaded relief map.

Results: A sample set of polar images was previously used to characterize along-track offsets. That examination of timing offset relative to LRO orbit number identified a sawtooth pattern in along-track error as orbit number increases [1]. The current work measured along-track offsets in a sample dataset of equatorial swaths (**Figure 1**) and found that while the same pattern generally holds true, it appears less tightly constrained to the same sawtooth pattern, with a significant amount of potential variation. Note that these results contain a reasonable amount of error based upon the resolution of the shaded relief map used for reference. All efforts were made to measure along-track error to within one or two pixels relative to the shaded relief map, which equates to a potential error of ~±237 m for any given measured offset. A future examination would benefit from a more expansive set of data points and a more rigorous quantitative analysis to enhance visual qualitative examination.

Summary: These results indicate that the along-track offset resulting from a potential timing error may be less uniformly distributed than previously anticipated. This could mean that devising a "one-size-fits-all" approach to correcting along-track error may prove difficult.

Applying higher resolution DEMs to topographically correct individual swaths appear to significantly reduce cross track error in most cases (**Figure 2**). Preliminary results suggest that this is both a simple and viable method for correcting the cross-track component on monostatic offsets. Further investigation should include a more expansive dataset and test additional DEMs, particularly the higher resolution SLDEM2015 [3]. Future work will endeavor to further understand the nature of the along-track error and implement a solution and correct for cross-track error, ultimately resulting in an effort to reprocess the Level 2 monostatic products with more refined positional accuracy.

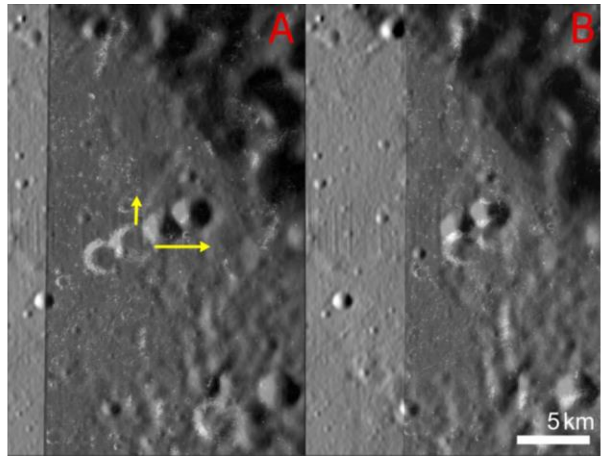

Figure 2. (**A**) Mini-RF Level 2 radar image (lsz_02277_2cd_eku_24s175_v1) [2] at 55% transparency, overlaid on a shaded relief map derived from the SLDEM2015 [3]. Yellow arrows illustrate the magnitude of cross-track and along-track errors. (**B**) Application of a LOLA DEM to reprocess the same Level 2 product. Note that the cross-track offsets are greatly reduced.

References: [1] Kirk R. L. et al. (2016) *Int. Arch. Photogram. Rem. Sens. Spatial Info. Sci. XLI-B4*, 425-429. [2] LRO Mini-RF Calibrated Level 2 Data (2008) *PDS*, doi: 10.17189/1520649. [3] Barker M. K. et al. (2016) *Icarus*, *273*, 346-355. [4] Becker K. J. et al. (2013) *LPSC.* abstract #2829. [5] Smith D. E. et al. (2010) *GRL*, *37(18)*.