
SLOPE CHARACTERISTICS OF NEW SAR-StereO DERIVED TOPOGRAPHY OF VENUS. B. J. Thomson1, K. L. Mitchell2, N. P. Lang3, and D. Nunes4,1Department of Earth and Planetary Sciences, University of Tennessee, Knoxville, TN (bthom@utk.edu), 2NASA Jet Propulsion Lab/Caltech, Pasadena, CA, 3Mercyhurst University, Erie, PA.

Introduction: Improvements in processing capability have facilitated the extraction of new data products from existing planetary data sets. One example of this on Venus is the production of topography from Magellan stereo SAR (Synthetic Aperture Radar) data [1, 2]. Here, we contrast this new data product with the preexisting radar altimetry data and assess the potential of these new topographic data to shed light on outstanding science questions, including revisiting the scattering functions used to process the Magellan SAR data.

Data sources: Magellan data characteristics: The Magellan mission was a radar mapping mission that used a 12.6 cm wavelength (2.385 GHz) radar system. Full resolution SAR data from Magellan have a best pixel scale of 75 m. Magellan radar altimetry pulses were interspersed with SAR measurements and were collected using a separate, nadir-pointed horn antenna. These radar altimetry data have a spatial resolution of about 10 km, and were resampled into a gridded product (GTDR: global topography data record) with a resolution of about 5 km [3].

Photogrammetry: Like stereo photogrammetry, radar photogrammetry requires two views of a surface acquired at different look angles. Variations in the relative position of features between the different observations or parallax can be used to determine relative elevations. Although stereo products can be generated from radar data with opposite look directions [e.g., 4, 5], in practice it is easier to use radar observations from the same look direction with different angles of incidence. East-looking Cycle 1 and Cycle 3 SAR data from Magellan, separated by angles of incidence of about 20°, were used to generate topography using automated stereo-matching algorithms by [1, 2]. The resulting products have a DTM (digital terrain model) post spacing of about 600 m, which represents a block of 8x8 SAR pixels. Given that the gridded radar altimetry has a spatial resolution of 4.64 km [3], the SAR stereo topography represents an improvement by a factor of 7.7 in resolution. The limiting factor with topography generated from Cycle 1–3 stereo is the restricted extent of Cycle 3 data, which includes only 21.3% of the surface.

Methodology: To compare and contrast these different topographic data, we selected a swath of data covering 144 to 156°E lon, −45.3 to 43.2°N lat (swath #7 of [1]). We first determined point-to-point slopes for each dataset along a N-S direction. Given that both sets of topographic products are raster grids, we could have computed slopes using a best-fit plane to a 3x3 matrix of grid cells, but we wanted to examine the shortest baseline possible and also facilitate comparison to roughness studies conducted using laser altimeter data of Mars [e.g., 6, 7] and the Moon [e.g., 8, 9]. We used these bidirectional slopes to compute mean slopes (θ̄) in a 30 km sliding window (a window large enough to have a statistically significant number of points), and then found the RMS (root mean square or θrms) slope as defined in eq. 1. Data gaps were treated as NaNs (Not a Number values) and were excluded from the calculations.

\[ θ_{rms} = \sqrt{\frac{1}{N} \sum_{i=1}^{N} \left( \tan^{-1} \left( \frac{2i-2}{x_i-x_{i+1}} \right) - \theta \right)^2} \] (eq. 1)

Results: A side-by-side comparison of RMS slopes derived from the GTDR and SAR stereo data is given in Fig. 1. Aside from visual differences due to the completeness of the data coverage (99% of the GTDR pixels contain data, while only 45% of the SAR stereo pixels are filled), there is more fine structure evident in the higher resolution data as expected. A comparison of histograms of bidirectional slope values (Fig. 2) indicates that steeper slopes are more abundant in the smaller baseline of the SAR stereo data. This is not unexpected as surface roughness is typically scale-dependent [10]. But these results differ from slopes measured on a 300 km baseline with Pioneer Venus radar data [11], which found a global deficiency in regionally flat surfaces (i.e., those with slopes <0.1°) relative to the Earth. This difference might be attributable to the small area under consideration here.

Implications: Understanding the distribution of slopes on a rough (i.e., natural geologic) surface is important for interpreting its radar scattering properties. Pixel values in Magellan SAR data were normalized to an empirically-derived formula [12, 13], given in eq. 2.

\[ σ_0(θ) = \frac{K_1 \cos θ}{(\sin θ + K_2 \cos θ)^3} \] (eq. 2)
Here, $\sigma_0$ is the average radar backscatter, $\theta$ is the angle of incidence, and $K_1$ and $K_2$ are empirically-determined constants equal to 0.0188 and 0.111, respectively. The Magellan SAR processor erroneously implemented the values of $K_1 = 0.0118$ and $\theta = \theta + 0.5^\circ$ [13].

Small-scale RMS slopes on Venus (tens of cm to tens of meters) have been inferred using the Hagfors [14] model of lunar radar scattering. This model assumes a gently undulating surface with a Gaussian distribution of surface heights and an exponential autocorrelation function. Our eventual goal is to use stereo topography to test and refine the assumptions used to derive model dielectric constant and roughness, which requires an estimate of the slope distribution within the scene and/or altimetry footprint. This would be an improvement on past analyses that employed the topography directly from the altimetry data.


**Acknowledgements:** The portion of this research by Mitchell and Nunes was carried out at the California Institute of Technology Jet Propulsion Laboratory under a contract with NASA, and was supported via a grant from the NASA Planetary Data Archiving Restoration and Tools program (14-PDART14_2-0136).

**Figure 1.** RMS slope values from radar altimetry (left) compared with SAR stereo-derived topography from [1] (right). Warmer colors indicate higher RMS slope values, especially over Diana Chasma in the lower third of the image. Numeric labels given alongside each image refer to the number of rows and columns in each image.

**Figure 2.** Normalized distributions of the bidirectional, point-to-point slopes in the radar altimetry (GTRD: global topography data record) given in green with the SAR stereo-derived topography given in red.