Surface Properties of Maxwell Montes Using New Arecibo Dual-polarization Radar Data

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Background and Motivation

Maxwell Montes, the highest and steepest mountain range on Venus, has been of great interest to the Venus science community due to the presence of complex tectonic structures as well as material properties. Previous studies have shown that Maxwell Montes, like many of Venus's highlands, has distinctly elevated values of radar reflectivity and thus low values of radar emissivity [1] [2]. However, there are certain characteristics of Maxwell Montes which sets it apart from other highlands. For example, past observations from Magellan radar, emissivity and altimetry data suggests that the surface undergoes a step-like shift in the emissivity values as a function of the altitude [3] [4]. Also, the radar properties and elevation exhibits a "snow-line", across which radar backscatter coefficients increase sharply (and emissivities drop sharply) with increasing elevation [3] [5].

In this work, we use circular polarisation ratio (CPR, μ_C) as a proxy for radar brightness to verify its relation with planetary radius (and emissivity) in Maxwell Montes as well as for some other radar-bright and radar-dark areas of Venusian surface. Later on, we use the trendlines between mean values of echoes in opposite sense circular polarisation and same sense circular polarisation (σ_{OC}-σ_{SC}) in order to understand whether the variations in Maxwell radar echoes arise from changes in the surface reflectivity (dielectric permittivity), or are more strongly linked to changes in the surface morphology (e.g., wavelength-scale rock population, volume scattering from mantling debris).

Data and Methodology

We have used:

1. **Arecibo Observatory S-band "calibrated" multi-look radar data**: Due to the power calibration differences between 2015 and 2017 data [6], we used the 2015 data exclusively for analysis of Maxwell features and the 2017 data for inter-comparison of Maxwell with other features
2. Elevation (and planetary radius) from the Magellan Global Topography data Records (GTDR)
3. Emissivity from the Magellan Global Emissivity data Records (GEDR)

We have divided the Maxwell Montes region into multiple areas for regional comparisons. The different regions are referred in next sections and shown in figure 1.

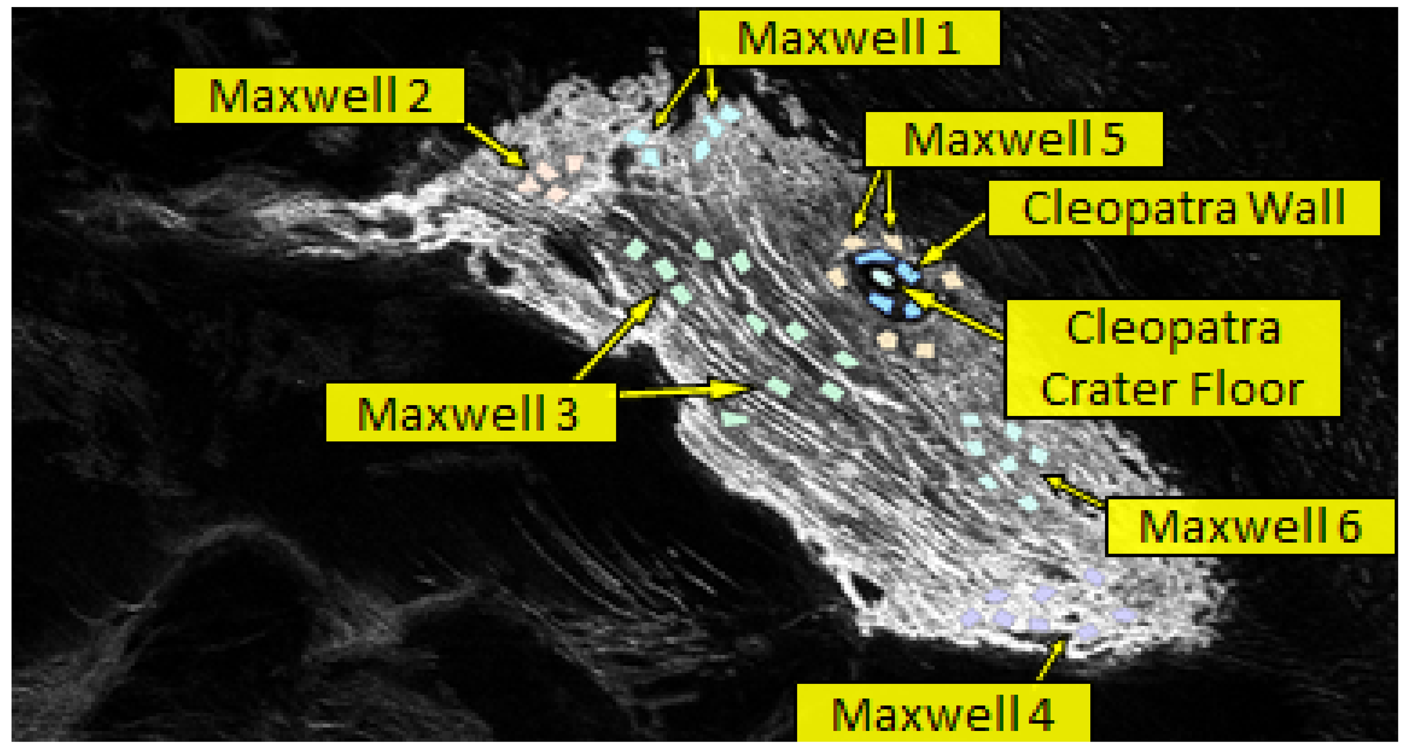

Figure 1. 2015 Arecibo S-band radar data of Maxwell Montes Region. Polygons show different regions which are used in figure 2, 3, 4

We compared the radar brightness across Maxwell Montes with other radar-bright features, e.g.,:

- Floors of the craters Audrey, Aurelia, Seymour, Faustina, Browning, Mukhina
- Seymour impact melt flow
- Lava flows associated with Sif and Gula Mons

and radar-dark features, e.g., fine-grained parabolas associated with the above listed craters.

Results and Discussion

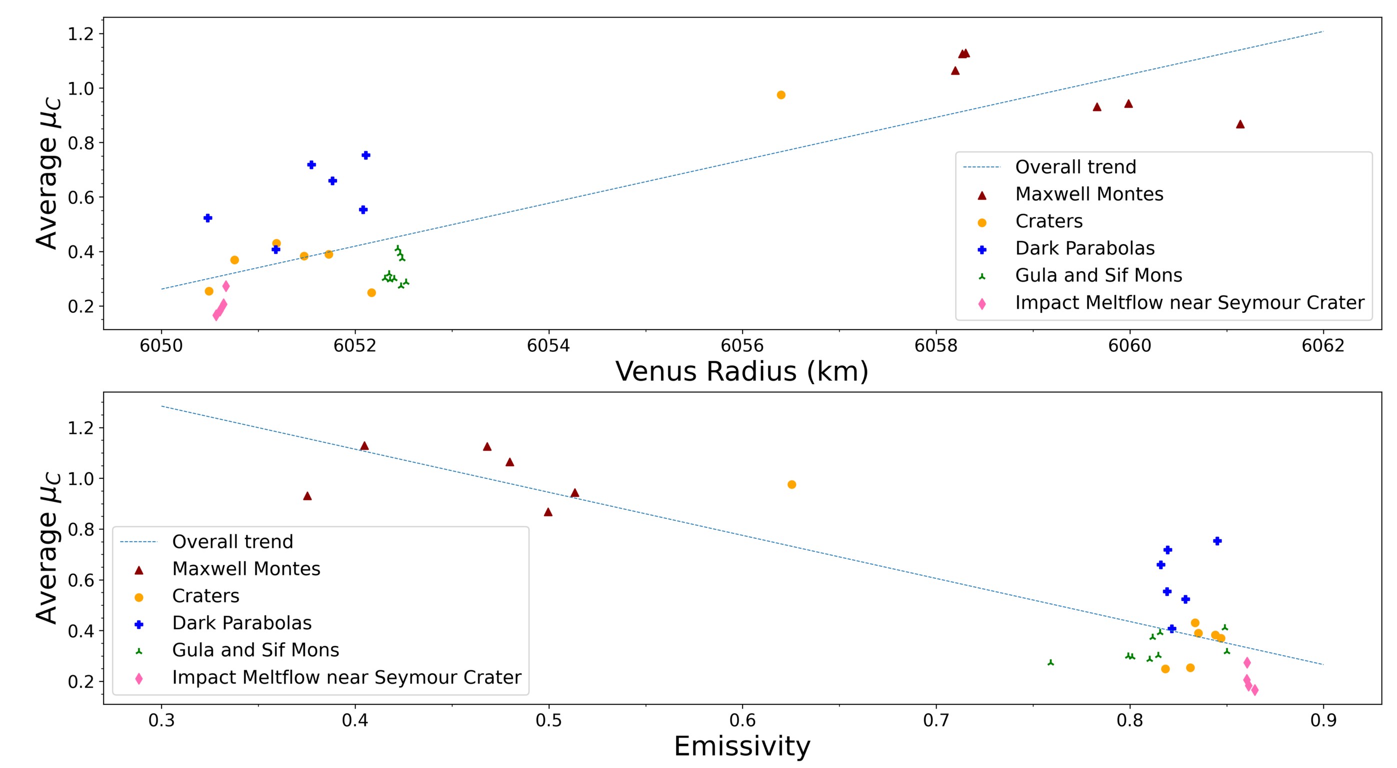

Figure 2. Arecibo S-band Circular Polarization Ratio (μ_C) trends with Venus radius (top) and emissivity (below) for the features analyzed in this study.

Figure 2 uses μ_C as a proxy for radar brightness. As seen, Maxwell Montes (red triangles in figure 2 shows a clear contrast with respect to both emissivity and planetary radius compared to other geologic features, consistent with previous studies. However, μ_C alone isn't enough to explain the regional variations or high values of backscatter coefficients in Maxwell Montes. Rather, the $\sigma_{OC} - \sigma_{SC}$ trends have been suggested as a better diagnostic tool for that purpose [7] [8].

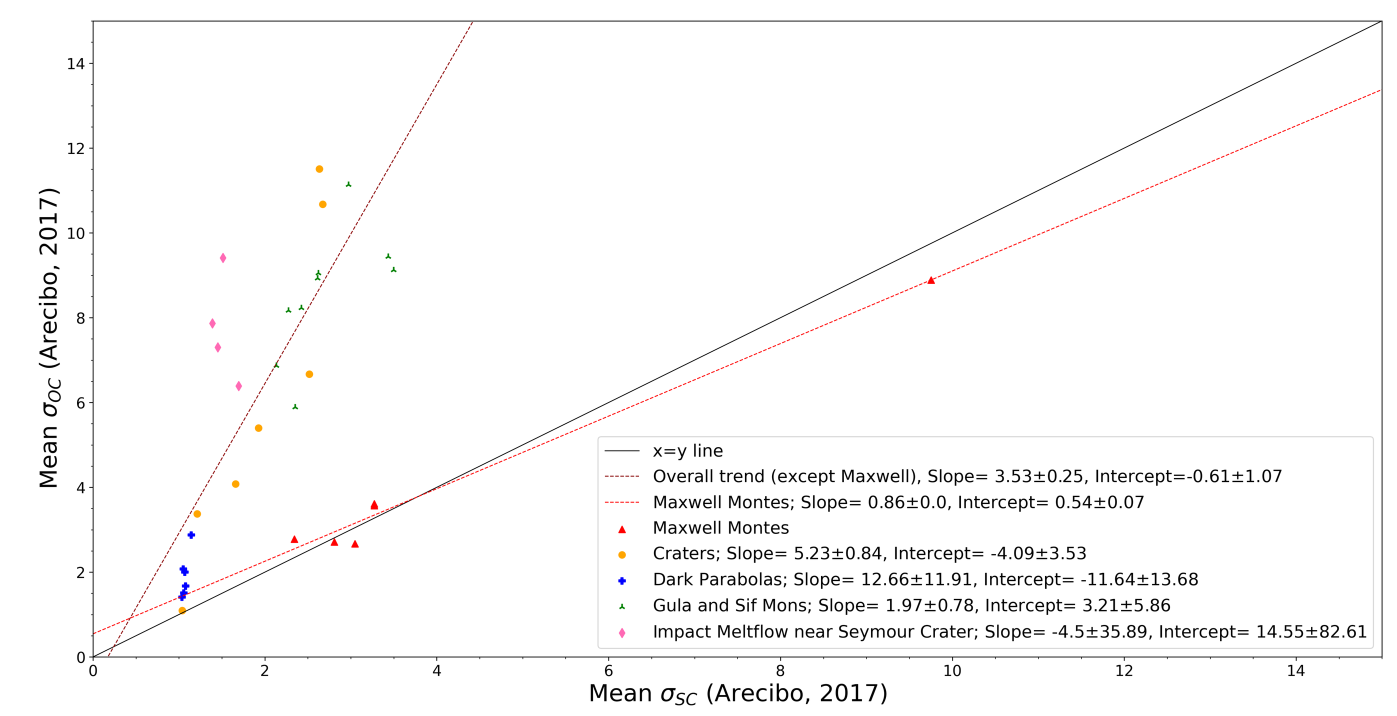

Figure 3. The mean of σ_{OC} plotted against that of σ_{SC} for all the regions analyzed in this work.

As seen from figure 3, there is a noticeable difference in slope and intercept of the linear least squares fit of σ_{OC} and σ_{SC} for all regions excluding Maxwell (dark-red dotted line) and only Maxwell region (red dashed line). Now, as per [7], the slopes and intercepts derived by a linear least squares fit (shown here with 1-sigma uncertainty) constrain the abundance of wavelength-scale particles and effective dielectric permittivity respectively. Accordingly, we suggest a sharp contrast in the near-surface size-density distribution of wavelength-scale scatterers, particle shapes, and material (via permittivity) between Maxwell Montes and other landforms analyzed in this work.

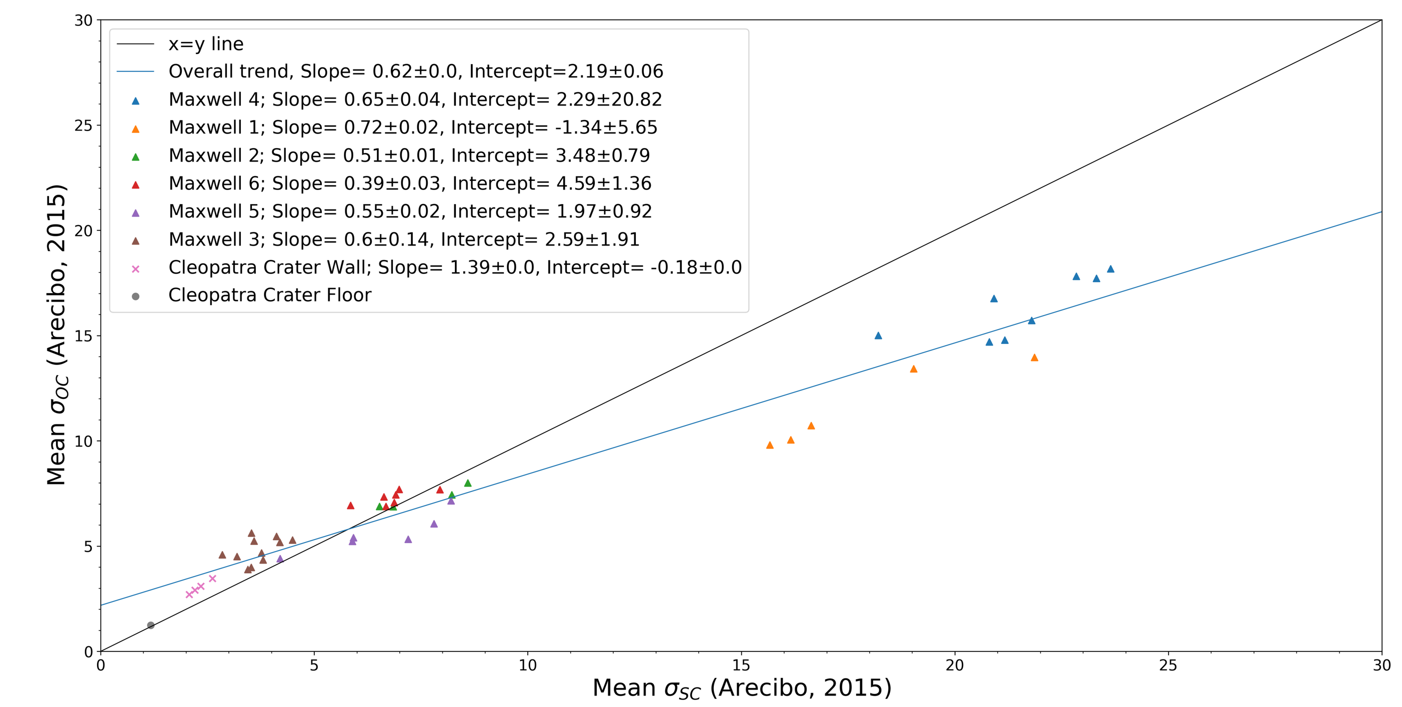

Figure 4. The mean of σ_{OC} plotted against that of σ_{SC} for regions selected from Maxwell Montes.

Moreover from figure 4, the σ_{OC}-σ_{SC} relations for regions within the Maxwell Montes lead us to the following inferences:

- The radar-bright regions (Maxwell 1, 4) outside of the lower-SC return region [4] have relatively larger trend line slopes and smaller intercepts (with Maxwell 4 having a large variance) implying a greater surface rock population and lower effective electric permittivity, likely due to a greater porosity.
- Lower SC-return regions proximal to the Cleopatra crater (Maxwell 5) and toward its west (Maxwell 3) have similar trend line slopes with little difference in the intercepts implying a rock population with similar size, shape distributions and dielectric properties.
- Regions toward south of Cleopatra crater (Maxwell 6) has a higher trend line intercept suggesting a higher effective dielectric permittivity.

References

[1] Peter G. Ford and Gordon H. Pettengill. "Venus: Global Surface Radio Emissivity". In: *Science* 220.4604 (1983), pp. 1379–1381.

[2] Gordon H. Pettengill et al. "Venus surface radiothermal emission as observed by Magellan". In: *Journal of Geophysical Research* 97.E8 (1992), p. 13091.

[3] Bruce A. Campbell. "Surface formation rates and impact crater densities on Venus". In: *Journal of Geophysical Research: Planets* 104.E9 (1999), pp. 21951–21955.

[4] Bruce A. Campbell and Jennifer L. Whitten. "Crater Ejecta Across Maxwell Montes, Venus, and Possible Effects on Future Rock Type Measurements". In: *Geophysical Research Letters* 49.9 (May 2022).

[5] Allan Treiman et al. "Venus' radar-bright highlands: Different signatures and materials on Ovda Regio and on Maxwell Montes". In: *Icarus* 280 (Dec. 2016), pp. 172–182.

[6] Bruce A. Campbell and Donald B. Campbell. "Arecibo Radar Maps of Venus from 1988 to 2020". In: *The Planetary Science Journal* 3.3 (Mar. 2022), p. 55.

[7] Anne K. Virkki and Sriram S. Bhiravarasu. "Modeling Radar Albedos of Laboratory-Characterized Particles: Application to the Lunar Surface". In: *Journal of Geophysical Research: Planets* 124.11 (Nov. 2019), pp. 3025–3040.

[8] Edgard G. Rivera-Valentín et al. "Arecibo S-band Radar Characterization of Local-scale Heterogeneities within Mercury's North Polar Deposits". In: *The Planetary Science Journal* 3.3 (Mar. 2022), p. 62.