High Radar Reflectivity on Venus' Highlands: Different Signatures on Ovda Regio and Maxwell Montes.
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Venus' highlands appear brighter than its lowlands in reflected radar (e.g., Magellan Synthetic Aperture Radar = SAR [1]), and this variation is inferred to relate to the decrease of surface temperature with elevation [2,3]. However, the cause(s) of the brightness (also diminished radar emissivity) remain unknown and controversial; current hypotheses include chemical weathering of rock, and 'frost' precipitation from the atmosphere. The radar-reflective substances have not been identified. Here, we revisit earlier studies of Venus' radar properties, and confirm them at higher spatial resolutions. Further, Ovda Regio and Maxwell Montes show qualitatively different patterns of changing radar properties with elevation, which implies different causes for the radar brightness.

We confirm and refine the conclusions of earlier work on Ovda Regio (a near-equatorial highlands region) and emphasize significant differences between it and Maxwell Montes (the highest elevations on Venus, at high northern latitude). These differences suggest that the two highlands regions were subject to different processes (geological, chemical, or atmospheric), or are made of different rock types.

Introduction: Prior studies of the radar properties of Venus' highlands relied on Magellan radar altimetry and measurements of radar emissivity [2,3], both of which have large footprints (8x10km and 18x23km respectively on Ovda, 8x10km and 41x55km on Maxwell). These studies showed that the radar emissivity of Venus' surface changes dramatically with elevation, which then inititated a caustic debate about the substance(s) responsible for the varying radar properties [4,5].

Method: We revisited these issues at higher spatial resolution using stereogrammetric elevations [6] in place of Magellan altimetry, and SAR reflection intensity in place of radar emissivity. The stereogrammetry is tied to the radar altimetry, but provides 600m footprints, compared to 8x10km of radar altimetry. Artifacts in the radar altimetry are propogated into the stereogrammetry, and we excluded those areas (e.g., small radar-dark areas can appear to be at unrealistically low elevations [7]).

SAR backscatter intensities (backscatter coefficients) were taken from FMIDR mosaics, and have much higher spatial resolution than do radar emissivity data (75-150 m resolution vs. 10-50 km). SAR backscatter is less definitive than emissivity, as it varies with surface roughness and orientation, in addition

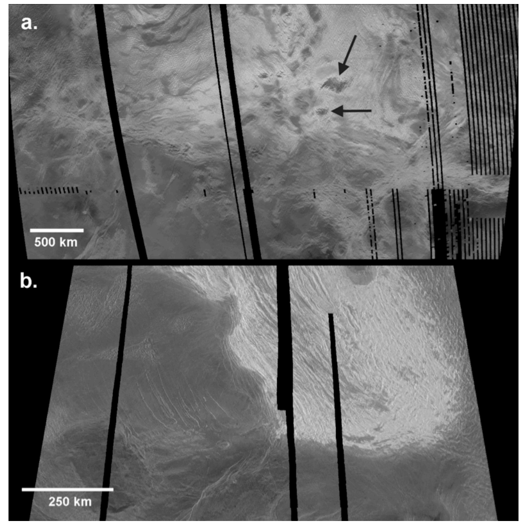

Figure 1. Magellan SAR images, from FMIDRs, sinusoidal projections [9]. **a.** Part of Ovda Regio (ctr. 90°,-11.25°), note gradual increase in brightness from plains toward higher elevations (S to N), and sharp transition to darkest areas (arrows) at summits. **b.** Part of Maxwell Montes (ctr. 1.4°, 62.75°), note sharp increase in brightness from plains towards higher elevations (S to N), and gradual darkening toward its summits.

to material properties. Thus, our results can be compared to those based on emissivity [2,3,8], but only qualitatively.

From Magellan FMIDRs, we identified polygons of ~4 km extent that were visually judged to have relatively constant radar backscatter. For each polygon, we calculated an average elevation [6], and an average SAR pixel value (DN), which was converted to a radar backscatter coefficient [10]. We collected these data for ~2000 polygons in the Ovda Regio highlands (two nearby areas, ~150-200 km extents), and another ~2000 polygons in southwestern Maxwell Montes (along three radar swaths or noodles, each ~20 km x 200 km).

Ovda Regio: Ovda Regio shows a steady, gradual trend of SAR DN increasing with elevation, consistent with the trend of decreasing emissivity [1,2,3]. At the highest elevations, however, the SAR DN drops precipitously (Figs. 1a, 2a); this change also appears as an increase in emissivity [1,2], which we confirm at greater spatial resolution. At elevations above ~4750m, the backscatter coefficient drops precipitously to values characteristic of the lowland plains, which confirms the observations of [2,8], and their hypothesis that the variations in radar properties in Ovda Regio

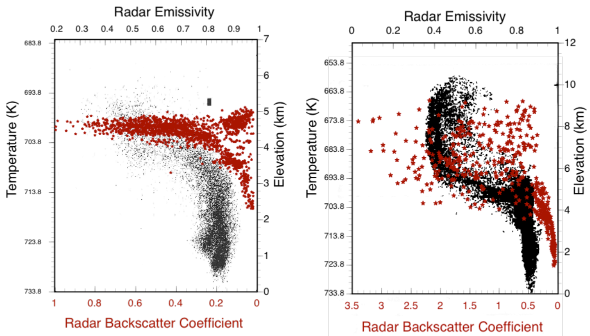

Figure 2. SAR reflection coefficient and emissivity vs. elevation and temperature [15]. Our results in red; emissivity data in black. Radar Backscatter Coefficient is approximately the inverse of emissivity. **a.** Ovda Regio. Emissivity data from [2], square is emissivity with elevation by stereo DEM. **b.** Maxwell Montes. Emissivity data from [3].

are consistent with the presence of a ferroelectric substance [11] in the rock or regolith.

Maxwell Montes: The foothills of Maxwell Montes show a gradual increase in radar backscatter coefficient up to ~4500-5500m elevation. Above that, the radar backscatter coefficient jumps dramatically, coincident with a considerable drop in radar emissivity [1,3] — the so-called ‘snow line’. Different nearby radar swaths show different ‘snow line’ elevations, which could represent slight misregistrations among the swaths, or real variations in ‘snow line’ elevation.

Above ~5000m, radar backscatter coefficients are widely dispersed, possibly representing strong variations in slope orientation, toward and away from the SAR beam. The areas of study in southwestern Maxwell are characterized by radar bright and radar darker areas. Overall, radar backscatter appears to decline with increasing elevation (Figs. 1b, 2b); at higher elevations (~7000-9000m), the backscatter coefficent is slightly greater than the plains surrounding Maxwell. This decline in radar backscatter is not mirrored in emissivity, which shows a relatively constant value above ~7000m, Fig. 2b [3]. The cause of the decline in backscatter coefficient is not known, but it could be ascribed to changes in: material properties or substances, surface roughness and/or average slope orientation, or regolith thickness (e.g. [12,13]).

Comparison and Discussion: From Figures 1 and 2, it is clear that Ovda and Maxwell have distinctly different radar signatures. Lowlands surrounding both have low radar backscatter coefficients, which increase with increasing elevation. On Ovda, the increase in backscatter is gradual and continuous to a maximum value at ~4750m; on Maxwell, there is a discontinuous jump to high backscatter at ~5500m [3,14]. At their highest elevations, both Ovda and Maxwell show a decrease in radar backscatter to lower values; however, the decreases have different elevations and characters. On Ovda, radar backscatter drops precipitously above ~4750m to values typical of lowland plains. On Maxwell, radar backscatter declines gradually and irregularly from ~7000m up to the highest elevations studied.

For Ovda Regio, our new data confirm the inference of [2,8], that its radar properties are consistent with the presence of a ferroelectric substance [10]. That material, as yet unknown, must have a phase transition at the critical elevation (~4750m) and temperature (~700K) – ferroelectric at higher elevation (lower T), and paraelectric at lower elevation (higher T).

For Maxwell Montes, our new data confirm the inferences of [3,14] of a ‘snow line.’ Maxwell’s jump in radar backscatter at ~5000m could represent a chemical reaction between atmosphere and surface that proceeds at lower T (high elevation) [3], or precipitation from the atmosphere at these cooler temperatures [14].

Conclusions: Ovda Regio and Maxwell Montes both show increases in radar backscatter (and decreases in radar emissivity) with increasing elevation, but the characters of those increases are so different (Figs. 1,2) that they cannot have the same single cause. Either Venus’ atmosphere behaves differently over Ovda than over Maxwell, or the rocks of Ovda and Maxwell are distinctly different. Both options here have significant implications for our understanding of Venus.

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