RADAR BACKSCATTER AND EMISSION MODELS OF POSSIBLE PYROCLASTIC DEPOSITS ON VENUS.

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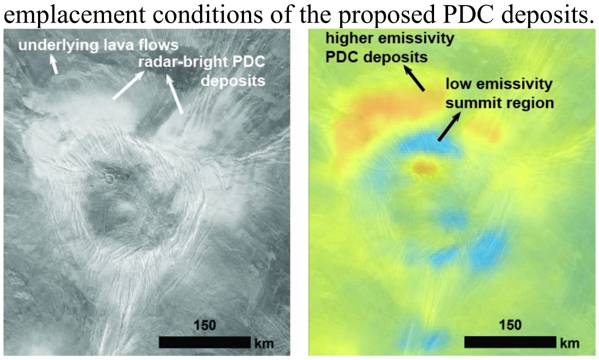
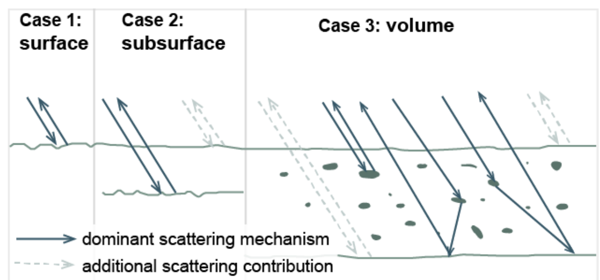
Introduction: Summits of large shields and coronae in Eistla Regio and Dione Regio have deposits with diffuse margins, large spatial extents, and bright appearance in synthetic aperture radar (SAR) data acquired at wavelength λ =12.6 cm by the Magellan mission and the Arecibo Observatory (Figure 1). The lack of internal flow features and well-defined margins characteristic of lava flows, combined with proximity of the deposits to volcanic summits have resulted in a hypothesized pyroclastic origin for these deposits [1-5]. It has been proposed that pyroclastic density (PDCs) fed by a collapsing column associated with recent, volatile-rich eruptions emplaced the radar-bright deposits. Pyroclastic deposits are indicative of volatile-rich magma sources. Studying the origin of these deposits is therefore useful for understanding volatile inventory and eruptive history. Prior studies of the proposed PDC deposits have focused on geomorphology, geologic and stratigraphic mapping, emplacement mechanics, and empirical backscatter and polarimetry studies [1-6]. We expand on these previous works by theoretical modeling of the Magellan backscatter and emissivity data to place constraints on the physical / dielectric properties, and emplacement conditions of the proposed PDC deposits.



Data and methods: Using Magellan datasets, we measured the radar backscatter coefficient and emissivity at the sites of the proposed PDC deposits, which include Irnini and Anala Mons in Central Eistla Regio, Didilia and Pavlova Corona in Eastern Eistla Regio, and Innini and Hathor Mons in Dione Regio. The measured HH co-polarized radar backscatter (σ_{hh}) values range between -9 and -14 dB; the measured H-polarized emissivity (e_h) varies between 0.80 and 0.87, compared to an average plains emissivity of ~0.85 [7].

We use theoretical backscatter and emission models to determine total σ_{hh} and e_h as a function of incidence angle for three different one- and two-layered deposit scenarios. Since radar wave penetration into a likely low-density pyroclastic unit is not negligible, we consider both surface and subsurface backscattering and emission. The dominant scattering mechanisms considered are surface scattering at the surface-atmosphere boundary (case 1), subsurface scattering at the buried boundary between two dissimilar layers (case 2), and volume scattering by distributed inhomogeneities inside a low-loss media (case 3). The improved integral equation method (I^{2}EM) is used to compute backscatter and emission from the surface (all three cases) and from subsurface dielectric horizons (case 2) [8]. In case 3, all volumetric inclusions are treated as oblate spheroids that follow an exponential size distribution. Volume scattering is computed using first order vector radiative transfer (VRT) approach [9]. Emission from volume inclusions is computed using zeroth order VRT [8].



Results and discussions: The models show that the observed backscatter and emission can be reproduced by all three dominant scattering and emission models – surface, subsurface and volume (Figure 3 shows modeled backscatter). Therefore, distinguishing between the three plausible deposit scenarios is not possible with currently available Magellan data. However, comparing the modeled results from each scenario to the Magellan observations allows us to narrow down the range of values for properties such as deposit density and thickness independently for each scenario.

Case1. For the surface scattering case, the Magellan backscatter data are fit well by a surface with intermediate to high roughness and relatively higher dielectric constant of $\varepsilon_1{}'$~7 (dark brown dashed curve in Figure 3a). This corresponds to a relatively high density of ρ ~2800 kg m^{-3}, based on the empirical relation between dielectric constant and density [10].

Case2. If we assume dominant scattering and emission from a continuous dielectric horizon in the subsurface, then the Magellan backscatter data are fit well by scattering from a thin (~10-15 cm). low dielectric ($\varepsilon_1' \sim 2$; ρ ~1000 kg m^{-3}) deposit on top of a very high dielectric, rough substrate (light brown dashed curve in Figure 3a). The modeled high permittivity for the substrate is comparable to the ferroelectric model proposed for anomalously low radio emissivity locations at high altitudes [11], which also found adjacent to the diffuse deposits (Figure 1).

Case3. For cases where volume scattering is the dominant contribution to the observed backscatter and emission, the data are consistent with scattering and emission from 0.5 λ to 0.1 λ sized scatterers that occupy 5-10% of the total deposit volume. At such low volumetric concentrations, scattering from different types of inclusions (vesicles, clasts) exhibit only small (<2-3) dB differences (Figure 3c).

Based on the modeled deposit properties, we interpret the proposed PDC deposits to have one of the following characteristics and origin.

1. A dense, welded deposit (ρ~2800 kg m^{-3}) with high λ-scale roughness. High degree of welding implies emplacement from high temperature PDCs. High surface roughness is likely caused by post-emplacement processes in this case.
2. A thin (λ-scale thickness), low-density (ρ~1000 kg m^{-3}), low-loss (tanδ=0.005) mantling deposit, on top of a chemically altered high reflectivity unit with high roughness. The lack of surface alteration and associated low emissivity of the deposits relative to the surroundings is indicative of a young emplacement age, without sufficient time since emplacement to have undergone alteration.
3. A thick, low-density (ρ~1000 kg m^{-3}), low-loss (tanδ=0.005) deposit with ~5-10 vol% of scatterers of size 0.5 λ to 0.1 λ. Scatterers could be vesicles or lithics; distinguishing between scatterer types at such low volume concentrations is not possible. If most of the scattering is from voids, then the deposit is unlikely to be densely welded.

Distinguishing between these three scenarios and identifying the exact nature of the deposit is not possible with the current Magellan datasets available. The upcoming VERITAS and EnVision missions will acquire higher resolution SAR imagery at wavelengths different from Magellan, orthogonal cross-polarized backscatter measurements, and sounding radar observations, all of which will be valuable for further characterization of the proposed PDC deposits.

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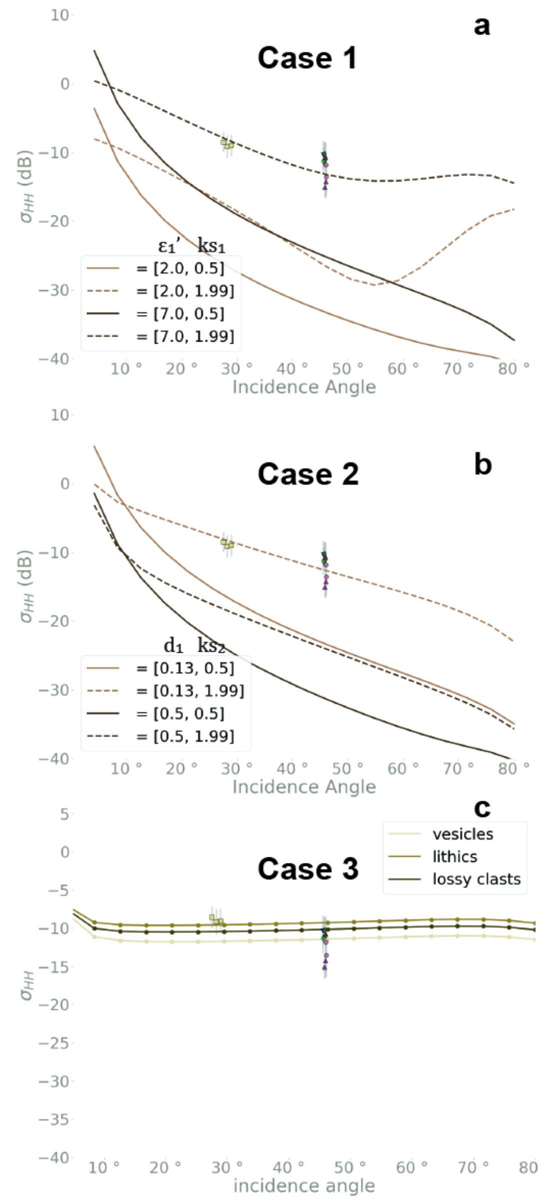

Figure 3: Modeled backscatter as a function of incidence angle for the three deposit scenarios

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