Terrestrial Analogue studies from ISRO's Venus mission perspective: Polarimetric radar properties of Hawaiian Lava Flows

Sriram S. Bhiravarasu[1], P. D'Incecco[2], J. Filiberto[3], D. A. Gorinov[4], S. Bhattacharya[1], T. Chakraborty[1], D. Putrevu[1], and G. Di Achille[2]

[1]Space Applications Centre, Indian Space Research Organization, Ahmedabad 380015, India; [2]National Institute for Astrophysics (INAF) - Astronomical Observatory of Abruzzo, Teramo, Italy; [3]Astromaterials Research and Exploration Science (ARES) Division, NASA Johnson Space Center, Houston, TX, 77058, USA; [4]Space Research Institute of the Russian Academy of Sciences, Moscow, Russia

Detection of present and past volcanism on Venus is one of the major goals of the proposed ISRO's Venus orbiter mission. The S-band, high-resolution (40 m/pixel) fully Polarimetric Synthetic Aperture Radar (PolSAR) instrument on this mission [1] may have the capabilities to detect volcanism within the mission lifetime using repeated PolSAR imagery, and possibly SAR Interferometry (InSAR, experimental mode). The global mapping efforts of Venus by Magellan mission has enabled comprehensive mapping of lava flows and indicated that Venus has an extensive history of volcanism, the ages of which are largely unknown (e.g. [2]). While Magellan radar emissivity data (e.g. [3, 4]) and Near Infrared emissivity data from VIRTIS [5] suggested the occurrence of recent episodes of volcanic activity (e.g. Maat Mons and Ganis Chasma), as well as the presence of stratigraphically young lava flows (e.g. Idunn Mons), measuring changes in radar backscatter amplitude alone to identify lava flows has many challenges. Although very large changes in the shape of the terrain can be observed in radar backscatter amplitude changes (e.g. [6]), smaller, or relatively flat lava flows are difficult to detect. Previous terrestrial studies suggest that PolSAR and InSAR techniques are very effective for mapping lava flows (e.g. [7-9]), and can be used when changes cannot be distinguished in radar backscatter images.

We use the unvegetated lava flows on Hawai'i island as a terrestrial analogue to study Venus lava flows for the following reasons: (a) It is extensively studied at several wavelengths commonly used in remote sensing studies (including PolSAR and InSAR methods); and (b) it is a volcanically active area with new lava flows frequently covering older emplaced flows. To investigate the surface roughness, texture, and fine-grained mantling associated with Mauna Loa and Kilauea lava flows, we utilize C- and L-band PolSAR datasets obtained from RISAT-1A (EOS-4) and ALOS PALSAR missions respectively.

In particular, we will use the quad-polarized backscatter and polarimetric parameters to characterize the texture of the terrestrial lava flows to understand whether the Venus crust is continuously disrupted during flow emplacement. While some previous studies (e.g. [10, 11]) suggested that surface roughness of most of the Venus flows is comparable to that of terrestrial pāhoehoe flows, other studies indicated that fractal dimensions of some large lava flows on Venus imply high eruption rates which favour the formation of a'a flows (e.g. [12]). We will also analyse the terrestrial flows for the presence/absence of pyroclastic mantling as radar-bright diffuse deposits near the summit regions of some coronae on Venus have been proposed to be young pyroclastics, and possible evidence of a renewed epoch of mantle volcanism that taps into deeper volatiles [13]. A recent study using EOS-4 RISAT-1 data of a part of fresh Mauna Loa lava flows (2022 eruption) emphasizes the ability of fully polarimetric SAR data to understand the diversity of physical properties (e.g. texture and morphology) associated with them (Sreejith et al. 2024); and we will apply similar methods to the PolSAR data obtained from ISRO's Venus mission for our proposed objectives.

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