LAVA FLOW SCATTERING ANALYSIS: SATELLITE RADAR AND DLR F-SAR – 2023 ICELAND ANALOG FIELD CAMPAIGN. M. Mastrogiuseppe[1], G. Di Achille[2], A. Murra[1], L. Gambacorta[1], B. Campbell[3], S. Hensley[4], M.C. Raguso[5], M.D. Dyar[6], G. B. M. Pedersen[7], J.L. Whitten[3], S. E. Smrekar[4] and the VERITAS Science and Engineering Team. [1]Sapienza, University of Rome, Italy, marco.mastrogiuseppe@uniroma1.it, [2]National Institute for Astrophysics (INAF), Teramo, Italy, [3]Smithsonian Inst., D.C., U.S.A, [4]Jet Propulsion Laboratory, [5]California Institute of Technology, Pasadena, CA, U.S.A, [6]Mt. Holyoke Coll., MA, U.S.A, [7]University of Iceland, Reykjavík, Iceland.

Introduction: The upcoming VERITAS mission, selected as part of NASA's Discovery program, is equipped with the X-band Venus Interferometric Synthetic Aperture Radar (VISAR) instrument. The mission will give a unique opportunity to the scientific community to understand Venus's geological activity [1]. In order to enhance the analysis of VISAR (X-band) SAR data, test data processing algorithms, and draw comparison with S-band SAR data from alternative missions (Magellan and EnVision), the VERITAS Science Team designed and conducted a two-week field analog campaign in August 2023 in Iceland [2], in partnership with the German Aerospace Center (DLR). This campaign incorporated both airborne radar mapping [3] and on-site surface characterization, focused on obtaining ground truth data for NIR emissivity [4] and essential parameters that can affect radar backscatter measurements on Venus [5].

In this study, we aim to enhance our understanding of radar scattering in scenarios from lava flows to help the VERITAS science team prepare for Venus. Our approach integrates air- and spaceborne multi-frequency SAR data to examine properties of radar backscattering in relation to the local incidence angle. Electromagnetic scattering models are used to estimate the surface roughness and dielectric properties of the selected volcanic flows. This will enable us to refine models using VERITAS and other radar data to measure roughness, reflectivity and surface changes on Venus.

Iceland as a Venus Analog: Iceland sits atop a hot-spot at the intersection of a mantle plume and the mid-Atlantic ridge. The center of the island is a unique volcanic landscape, presenting a wide variety of volcanic and tectonic features that are geologically fresh and with almost no vegetation. Venus is a volcanic planet with plentiful geological evidence for active plumes, many resembling the Iceland surface. These geological similarities make Iceland an excellent place to study "Venus on Earth". During the 2023 Iceland campaign, the Team focused efforts in different terrains (Fig.1-a): *(i)* the Askja volcanic deposit and the Holuhraun lava field (yellow box) in the Highlands, and *(ii)* the Fagradalsfjall volcanic center (green box) in the Reykjanes peninsula (Fig.1). The dry and rocky landscapes of both resemble Venus' surface [2].

Airborne SAR Campaign: The goal for the airborne mission was to produce regional-scale coverage using DLR's F-SAR full-polarimetric, multi-band airborne synthetic aperture radar system with interferometric capabilities [6]. The radar system, mounted on board the Dornier DO 228-212 and operating at a 20,000 feet altitude, acquired 30 primary flightlines over the two sites. The radar was capable of imaging simultaneously at wavelengths analogous to VERITAS (X-band), Magellan and EnVision (S-band) radar instruments. Flight lines were optimized to maximize cross-track coverage and to partially overlap successive swaths, thus sampling the same key surface features with both Magellan- and VERITAS-like incidence angles. Fig. 1-b shows radar reflectivity in the three bands (L-,S-, X-band) as acquired by DLR's F-SAR sensor in VV polarization over the area of Askja.

This test site contains fresh lava from the 2014/2015 Holuhraun eruption as well as older lava fields and

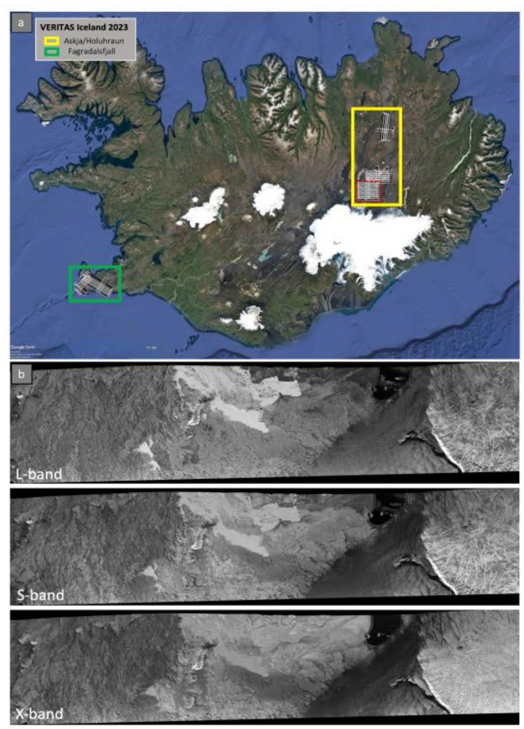

Fig. 1 – *(a)DLR's F-SAR flightlines (white lines) over the Reykjanes peninsula (green box) and Holuhraun/Askja site (yellow box) acquired during the VERITAS Iceland 2023 field campaign. (b) Multi-band airborne SAR VV images acquired over the Askja site (red dashed box).*

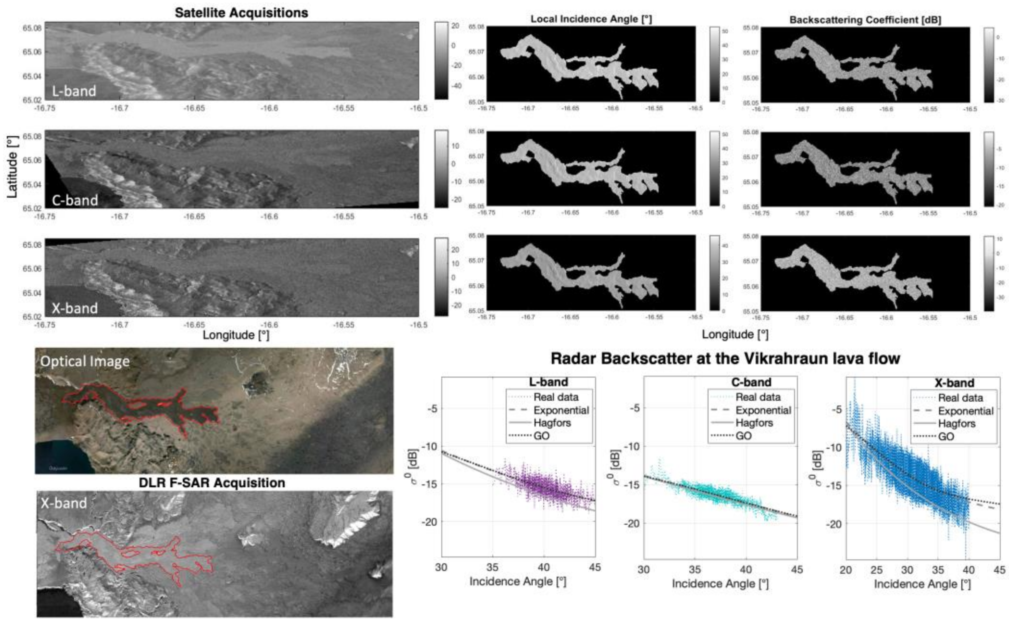

Fig. 2 – *The Askja site: Satellite SAR images acquired by ALOS-Palsar (L-), Sentinel-1A (C-) and COSMO-SkyMed (X-band), optical image from GoogleEarth and DLR F-SAR image. Local incident angle θ and radar backscatter σ^0 masks for the Vikrahraun flow are derived from the satellite images and then utilized to fit EM models. Each color corresponds to a different SAR sensor.*

aeolian sediments which are considered an ideal analog for Venus.

Satellite SAR Data Selection: Over the flightlines acquired by the DLR's F-SAR sensor at different bands, we have selected all available SAR images acquired by civilian spaceborne sensors. Fig. 2 illustrates one of the flows under study, the 1961 basaltic lava flow Vikrahraun emplaced at Askja volcano. The area was imaged by different satellite sensors: (i) ALOS-Palsar (L-band, λ = 23.62 cm), (ii) Sentinel-1A (C-band, λ = 5.55 cm) and (iii) COSMO-SkyMed (X-band, λ = 3.1 cm) and with incidence angles ranging between 37° and 40°. A selection of images suitable for the study will be extended to different months and years to investigate any seasonal behavior of the backscattering.

Preliminary Results: Using a combination of geological maps, digital elevation models (DEMs), and optical images (Fig. 2), different lava flows have been identified in each satellite SAR image. Radar backscatter and local incidence angles masks have been then produced for each flow. By fitting EM models (e.g., Fig. 2), we aim to constrain dielectric and surface properties (e.g., rms slope and scattering albedo) specific to individual lava flows observed during the VERITAS Iceland campaign. Furthermore, surface parameters will be explored using multifrequency EM formulations as derived in [7]. This approach will validate geophysical parameter estimation and algorithms, and improve error quantification. In addition, radar-derived parameters will be compared to those obtained from in-situ DEM analysis [8,9], This comparative analysis will maximize scientific returns of VERITAS by providing a framework for measuring surface roughness and dielectric propeties, as well as guidelines for the inference of surface changes over time.

Conclusions: The VERITAS/DLR field campaign offered a unique opportunity to collect remote sensing data to enhance the science return from the upcoming VERITAS mission. Processing and analysys of all the airborne data is still ongoing, with preliminary results presented at this conference [3].

Our research will progress through the comparison of radar products over various lava flows, utilizing both spaceborne and airborne platforms. Once integrated with roughness and dielectric in-situ measuraments, the iceland SAR data will help to constrain surface effects on radar backscatter and provide a guide for the interpretation of data from VERITAS.

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