TOPOGRAPHIC DATA ANALYSIS FOR THE VERITAS 2023 ICELAND FIELD CAMPAIGN. G. Cascioli[1,2], B. Carr[3], E. Mazarico[2], D. Nunes[4], C.W. Hamilton[3], J. C. Andrews-Hanna[3], O. C. Knox[3], M. C. Raguso[4], J. Whitten[5], D. Buczkowski[6], S. Smrekar[4]. [1]University of Maryland Baltimore County, Baltimore, MD. [2]NASA Goddard Space Flight Center, Greenbelt, MD [3]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ [4]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA [5]Smithsonian Institution, Washington, DC [6]Applied Physics Laboratory, Johns Hopkins University, Laurel, MD

Introduction: VERITAS is a NASA Discovery-class mission set to launch in 2031. VERITAS' state-of-the-art instrumentation includes an interferometric SAR, an emissivity mapper, and a gravity science investigation [1-4]. The mission will provide foundational datasets to understand the evolution and past and present geological and geophysical processes on Venus. In August of 2023, VERITAS science team members performed a two-week field campaign in Iceland to gather data to characterize and calibrate VERITAS instruments [5-10]. We report here on the volume and quality of the surface topography dataset, discuss the data reduction strategy, and provide a first look at the final dataset, associated analyses, and derived products that will be made publicly available to the scientific community.

Data Description: The purpose of this dataset is to compile a catalog of geometric surface properties (elevation, slope, roughness) of lava flows with different morphologies. This will help to understand the radar-surface interaction and better interpret the global Venus SAR dataset that will be collected by VERITAS. VERITAS will include the Venus Interferometric Synthetic Aperture Radar (VISAR) X-band (7.9 GHz; 3 cm wavelength) radar instrument operating in single pass radar interferometric configuration. It is therefore important to characterize the surface topography of analog volcanic terrains on the scale of ~3 cm to better interpret the radar backscatter properties of Venus and explore how to distinguish between different volcanic materials and facies. Surface topography of 41 distinct sites was measured using three portable terrestrial laser scanners (TLS). Each site was identified as a potential Venus volcanic surface analog and measured with the TLS in a 5×5 m square patch configuration (e.g., Fig. 1). We also conducted Unoccupied Aircraft System (UAS) mapping surveys covering most of the TLS sites at a comparable resolution. All patches were also imaged by an airborne multiband (L-, S-, and X-bands) SAR flown and operated by a DLR team (see [10] for more details).

To better understand surface roughness effects on radar backscatter, sub-radar-pixel digital elevation models (DEMs) are needed. For each patch, 8–10 individual laser altimetric scans were collected with a millimetric resolution, resulting in ~40–60 million measurement points per patch. The location of each TLS location was measured with differential GPS, allowing for cm-level positioning via PPP postprocessing.

The UAS surveys provided high-resolution (20 MP) sets of images, numbering from 300–1000 images per patch, with geotagging accuracy of <5 cm [11]. Data acquisition included both nadir and oblique perspectives from altitudes of 2–5 m above ground level, resulting in ground sampling distances of ~1 mm. Collected imagery was postprocessed using the structure-from-motion (SfM) photogrammetry technique to generate point clouds (~100 million points per patch), DEMs, and orthomosaics [11]. DEM achieved resolutions of < 1 cm are a factor of several finer than the shortest radar wavelength utilized (3.1 cm, X-band), which supports analysis of radar surface scattering. Spatial reference was provided during the SfM processing by aligning the point clouds to basemaps. This approach allowed for detailed and extensive mapping of the lava flow features, complementing the TLS measurements and contributing to a more comprehensive dataset for understanding surface topography and radar-surface interactions.

Data reduction and analysis: Although we previously described our data-reduction strategy [12], here we report the first results of our analysis of the collected data, which is intended to support interpretation of the radar observations. We seek to

Figure 1 – VERITAS PI Sue Smrekar and a team member *(*Jeff Andrews-Hanna*)* set up the TLS for data collection. Pink rocks delineate the 5x5 m patch geometry.

understand the terrain diversity and classify geologic units as a function of their topographic statistical-spectral properties. Moreover, in support of a future combined analysis of both Magellan and VERITAS radar data, we are studying how different wavelengths of observation map into the statistical properties of the terrains (e.g., Fig. 2). We will discuss our approach for classifying terrains based on both analytic and machine learning-based methods.

We are interested in the variability of surface properties (e.g., slope, roughness) at radar-relevant wavelengths within a geologic unit and between different units. With the ultimate scope of better understanding the radar response to different terrains.

The TLS patches were preliminarily analyzed using a *k-means* unsupervised classification algorithm applied to either the 2D Fourier power spectrum or the roughness spectrum. Our preferred approach applies the algorithm to the log of the power spectrum that has been logarithmically sampled to provide a more even sampling of the low- and high-frequency components. While classification based on the Fourier power spectra and roughness spectra yielded consistent groupings of the TLS patches, these groupings only loosely corresponded with the geological classifications of the units (e.g., rubbly pahoehoe, spiny pahoehoe, ropey pahoehoe, or tephra/sediment). These results confirm previous analyses finding that it is difficult to uniquely discriminate between different volcanic surface types from topographic properties alone [13].

Conclusion: The VERITAS 2023 Iceland field campaign successfully acquired topographic data that will yield high resolution georeferenced DEMs. Data were collected at several morphologically distinct sites in conjunction with airborne SAR images. These datasets will allow precise characterization of the radar-surface interaction at a sub-pixel scale. This information is essential for testing theoretical predictions of how the Venus environment will change the surface morphology and textures of Venus lava flows [14]. The raw and derived datasets will be made available to the wider scientific community (The UAS data is already available at [11]).

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References: [1] Smrekar S. et al. (2022) *IEEE Aerospace Conf.*, 10.1109/AERO53065.2022.9843269. [2] Hensley S., et al. (2020) *IEEE Radar Conf.*, 10.1109/RadarConf2043947.2020.9266323. [3] Helbert J. et al., (2022) SPIE, 10.1117/12.2634263. [4] Mazarico E. *et al*. (2021) *AGU*, P35H-2218. [5] Nunes et al., (2025) LPSC. [6] Raguso et al., (2025) LPSC. [7] Adeli et al., (2025) LPSC. [8] Garland et al., (2025) LPSC. [9] Alemanno et al., (2025) LPSC. [10] Hensley et al., (2025) LPSC. [11] Carr and Hamilton (2024) https://doi.org/10.25422/azu.data.26035837.v2. [12] Cascioli et al., (2024) LPSC. [13] Tolometti, G. D. et al. (2022) JGR, 127, 10.1029/2021JB023419. [14] Head J. & Wilson L. (1986) JGR. 91, 9407.

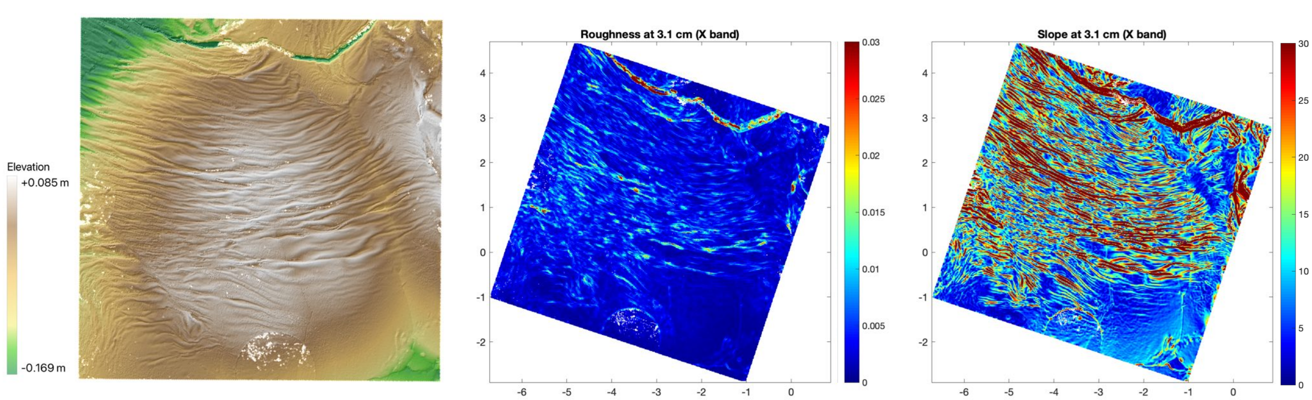

Figure 2 – (left) 1cm DEM of a selected 6x6 m TLS terrain patch. (right) Roughness (left) and slope (right) computed at X-band wavelength (3.1 cm) on the 6×6 m patch. The semicircle-like artifacts are due to the observation geometry and are cut from the final products (measuring 5x5 m).