NEAR-INFRARED DATA ACQUISITION FOR THE VERITAS 2023 ICELAND FIELD CAMPAIGN.

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Introduction: The composition of lava fields on Venus and their alteration state are poorly constrained. The Venus Emissivity Mapper (VEM) [1, 2] on board NASA's Venus Emissivity, Radio Science, InSAR, Topography and Spectroscopy (VERITAS) mission [3] and its twin VenSpec-M on ESA's EnVision mission will observe the surface of Venus in the NIR range through five atmospheric windows covered by six spectral bands. These will enable studying the spectral characteristics of the Venusian surface, as well as lava types and possible alteration processes. To prepare for these missions and deepen our understanding of the emissivity spectral characterization of various volcanic rocks, we developed a field camera system analogous to VEM, named "VEMulator", and have undertaken in-situ measurements in the spectral range of the VEM instrument during field work at Venus analogue sites. We will relate these data to emissivity spectra of field samples collected in the Venus chamber at the Planetary Spectroscopy Laboratory (PSL) of DLR-Berlin [1].

The VERITAS expedition in Iceland, in early August 2023 [4, 5] addressed these objectives. This expedition included DLR airborne synthetic aperture radar (SAR) data, collected in X-band, similar to VERITAS, and S-band, similar to Magellan and EnVision. The ground team collected surface topography and roughness using LiDAR scanners [6, 7] and permittivity [8] as ground truthing for the airborne SAR data. We acquired NIR data using the VEMulator 2.0 (Fig. 1), which uses similar NIR spectral range to VEM surface channels (0.86-1.2 µm).

Iceland: The vegetation-free, geologically recent basaltic lava fields of Iceland make this area a prime Venus analog. In the pre-field campaign study phase, we identified Askja/Holuhraun in the highlands and Fagradalsfjall on the Reykjanes Peninsula as two regions of interest that offer a wide variety of surface textures, sand cover, and diverse fumarolic deposits, as well as macro- and micro- fractures (for more details on the ROIs see [5]). Fagadalsfjall is of particular interest

Fig.1-VEMulator2.0 targeting fumarolic deposit and alteration products due to escaping hot gases from a fracture - the 2022 lava field of Fagradalsfjall. Calibration targets (black rectangle (8cm in length) and gray circle) are shown with yellow arrows.

because of its very fresh lava flows in 2021, 2022, and 2023, the still-cooling lava in the subsurface, and the fumarolic alteration products on the surface.

In-situ NIR data acquisition: The VEMulator2.0 is an in-house built camera system equipped with an InGaAs detector – similar to the VEM flight model – and a filter wheel with six bandpass filters: 860, 910, 990, 1030, 1100, 1200 nm. An earlier and simpler version of this set-up had been successfully used in a field campaign in Vulcano, southern Italy [9]. In Iceland, data were collected in daytime (reflected sunlight) and at nighttime as emittance of the very hot (~100-480°C) lava flow at the active fissure at Litli-Hrutur.

Daytime data. The main goal here is to understand the NIR spectral response of different basaltic surfaces. Seven images (one each of six filters and no filter) were collected at each location. The sites were selected based on their surface texture and mineralogy. The goal was to image varying surface textures as well as contacts between different materials, such as sand cover over the 2014-2015 Holuhraun lava flow field, fumaroles and their deposits associated with Holuhhraun and Fagradalsfjall lava, tephra mantled lava flows near

Askja lava field (including the 1961 flow and older lava units), very fresh surfaces of Fagradalsfjall's 2021-2023 fields, and near surface alteration, due to escaping hot gases (including water vapor), exposed via fractures in Fagradalsfjall.

The imaged sites were scanned by the LiDAR team to obtain a high-resolution (millimeter-scale) DEM of the area of interest. These data will constrain surface geometry. GPS coordinates of the VEMulator location and the imaged targets have been collected, providing cm-scale precision on the camera-target distance. Two calibration targets were used in each imaged scene: one black surface as blackbody, and a gray disc (shown with yellow arrows in Fig. 1). Both calibration targets were spectrally analyzed in the PSL laboratory before and after the field campaign, thus have known spectra that will help improving our data calibration processes.

Nighttime data. The main goal here was to collect in-situ emittance of a fresh lava flow in the NIR spectral range of VEM. We imaged the hot lava surface (approximately 100-480°C) of the active vent of Litli-Hrútur where an eruption terminated two days prior to our arrival (Fig. 2a) to obtain in-situ emittance of the basaltic rock at Venus temperature, in nighttime. We used a FLIR thermal camera to find the hot spots (Fig. 2b), working with colleagues at the Univ. of Iceland. This allowed direct observation of surface temperature and identification of several cracks where hot gases were escaping from the cooling lava. One raw, uncalibrated, VEMulator image at 910 nm is shown in Fig. 2c. The bright spots in the VEMulator image directly match the hot spots in the Fig. 2b. All these collected data will provide detailed spectral information and a deeper understanding of the surface composition of the studied lava flows.

Sample collection. We collected samples from every imaged scenery by VEMulator. A total of ~60 kg of samples was transported to DLR in Berlin for post-processing and analyses using reflectance and emittance methods available there. All the samples are carefully labeled and stored in the sample collection laboratory at DLR-Berlin.

Laboratory measurements: Bi-directional and hemispherical reflectance spectra from 0.7-2.63 µm were collected using the Bruker Vertex 80V spectrometer at the PSL in DLR-Berlin. The data will be used to relate the results of the laboratory reflectance measurements to the daytime field data to better understand the NIR spectral response of surface material using the six spectral bands. We will collect emissivity measurements using the Venus chamber at PSL, to correlate with the in-situ nighttime data using different types of Icelandic basalt. This will expand our datasets of emissivity spectra of Venus-analog materials as part of the VEM calibration plan [10].

Summary: In this campaign, we collected in-situ NIR data and 60 kg of samples of Venus analog materials. We are currently at the post-processing phase of the data and sample analyses. Correlation with the surface roughness and permittivity is also planned for the near future. By comparing the field and laboratory datasets, we can assess the capabilities of the VEM instrument in distinguishing lava types and compositions. Correlation with other field datasets will help finding close synergies with other instruments in preparation for the Venus missions. This work lays a foundation for detailed interpretation of Venus mineralogy and is vital preparation for the scientific goals of the NASA VERITAS and ESA EnVision.

Acknowledgments: SA, SPG, NM, AD received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 871149. GC, EM was supported by NASA Planetary Science Division Research Program through the GSFC GIFT ISFM.

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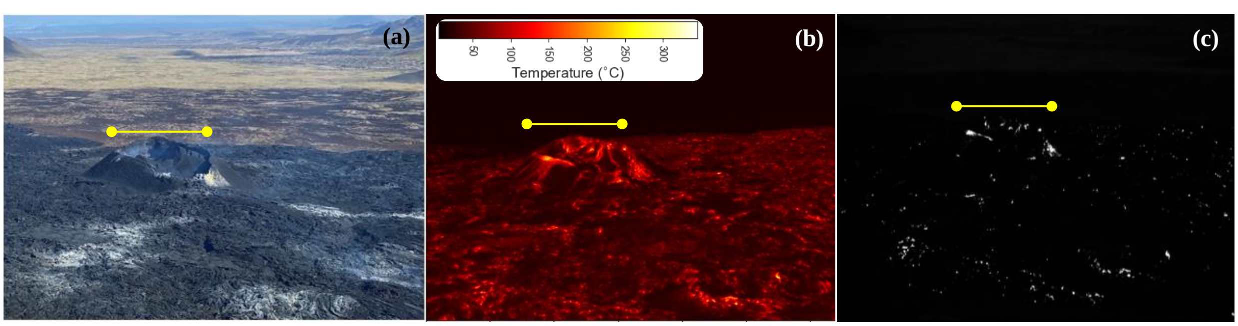

Fig. 2: a) *The crater of the 2023 eruption in Litli-Hrutur, Fagradalsfjall. The crater is ~90m in diameter, annotated with the yellow solid line in all three panels. b) Thermal image of the crater, revealing hotspots, here >300°C. c) Raw VEMulator2.0 image in 910nm, capturing the emitted light from hot spots of the crater shown in (a) and (b).*