FROM BERLIN TO VENUS WITH VERITAS AND ENVISION – VNIR EMISSIVITY SPECTRA OF VENUS ANALOGUE ROCKS AND THE VEM/VENSPEC-M VERIFICATION PLAN. G. Alemanno[1], J. Helbert[1], A. Maturilli[1], M. D. Dyar[2,3], S. Adeli[1], S. Smrekar[4], [1]Institute for Planetary Research, DLR, Rutherfordstrasse 2, 12489 Berlin, Germany (giulia.alemanno@dlr.de), [2]Dept. of Astronomy, Mount Holyoke College, South Hadley, MA 01075, [3]Planetary Science Institute, Tucson, AZ, 85719, [4] Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., Pasadena CA, 91109 (USA)

Introduction: The Venus Emissivity Mapper (VEM) on the VERITAS mission and the VenSpec-M on the ESA EnVision mission are similar multi-spectral imaging systems designed specifically for mapping the surface of Venus using the near infrared atmospheric windows around 1 µm. They will provide the first global map of rock types on the surface of Venus as well as constant monitoring for volcanic activity at global (VERITAS) and regional/local (EnVision) scales.

VEM/VenSpec-M will observe the surface of Venus in 14 bands: six bands are dedicated to mineralogy, two will be used to measure near-surface water vapor abundance, three will detect cloud contrast variations and three background bands will allow straylight correction.

To correctly interpret VEM/VenSpec-M data and map the Venus surface composition, several types of data are needed:

- emissivity laboratory data from samples at Venus surface temperatures
- hemispherical reflectance data of Venus analogs
- a proper VEM/VenSpec-M data verification plan that includes engineering instrument calibration and a careful data validation plan.

Berlin PSL – "The Venus spectroscopy power house'': At the Planetary Spectroscopy Laboratory (PSL) of the German Aerospace Center (DLR in Berlin, Germany), a high-temperature emissivity setup allows routine measurements of VNIR emissivity spectra of Venus analogues at relevant Venus surface temperatures (400°C, 440°C, and 480°C) in a vacuum (0.7 mbar) environment [1, 2].

The Venus emissivity chamber, attached to a Bruker Vertex 80V FTIR spectrometer, measures emissivity of solid (in 5-cm disks) and granular samples (filling a 5-cm volume). Samples are heated in custom-made sample cups using a very powerful induction system. To avoid glowing of steel in the VNIR, hot ceramic cups with a steel disk (the heater) enclosed are used. The hot ceramic is opaque in the VNIR and the emitted radiance does not affect the measurements. Several temperature sensors are located in the emissivity chamber and allow monitoring of the sample temperature as well as the chamber temperatures.

Hemispherical reflectance measurements (at T ambient) are performed for comparison to emissivity measurements on all fresh and processed samples [3].

The PSL emissivity setup plays a key role in the calibration campaign for the flight instruments for VERITAS and Envision.

The VEM/VenSpec-M verification plan:

1. Creation of spectral library. To date, PSL has measured the emissivity of more than 100 rock samples under Venus surface conditions. Based on those measurements, we are confident that the six bands measured by VEM/VenSpec-M will have the capability to distinguish basalt from granite (**Figure 1**) [4] given the predicted performance [5]. The difference in absolute emissivity between rocks of mafic and granitic compositions (~30%) is significantly larger than the emissivity uncertainty of the instrument (4%) [5]. Data shown in **Figure 1** include grain size variations on Venus as well as natural variability in the samples.

It is likely that distinction of intermediate compositions will be possible based on their iron contents. In support of that effort, the spectroscopy verification plan will create several spectral increasingly complex libraries:

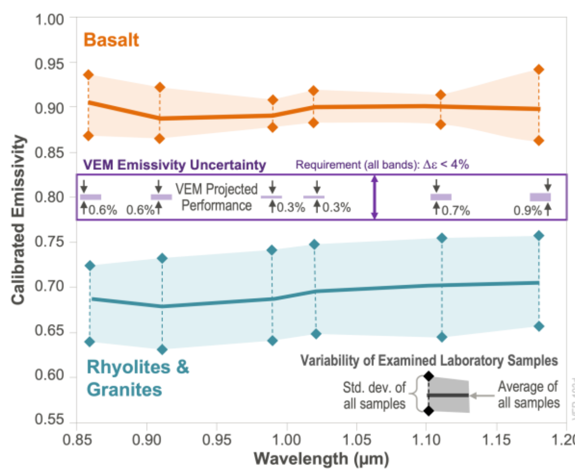

Figure 1. Calibrated emissivity of mafic and granitic rock types compared with predicted performance of VEM/VenSpec-M.

- The **minimal** database needed to serve the requirement to distinguish basalt vs. granite and to address weathering/coating requires at least 250 samples.
- The **basic** database (approx. 500-1000 samples) is needed to span intermediate compositions and

characterize mineral phases, mixtures of rock types (quarters), and minerals (particulates).

- An **extended** database will contain hypothesis-driven samples (e.g., metallic snow) in keeping with ongoing research questions.
- Finally, we expect to add spectra from samples contributed by the Venus **community**.

Samples included in the calibration database are selected based on the total alkali vs. silica TAS diagram for volcanic rocks and on availability of varying rock textures and grain sizes.

Extension of the calibration database will rely on the natural samples from terrestrial analogue sites to be measured in the laboratory. Essential to this endeavor are field campaigns in Venus analogue sites [6, 7, 8] and a variety of close collaboration with research institutes around the world.

2. Calibration using flight models and Q model. The Venus chamber at PSL is equipped with an NIR transparent window that allows the flight instruments to be mounted for measurements of calibration samples at appropriate surface temperatures. This capability has been invaluable during development phase and it allows:

- Measurement of a selected set of analog samples with instrument Flight and Qualification Models (FM and QM).
- Stimulation of the VEM/VenSpec-M sensor with a “realistic” scene.
- Relating lab measurements to actual VEM/VenSpec-M instrument measurements to support data analysis at Venus.
- Verification of performance models to check the absolute calibration, filter performance, and SNR per band.

Figure 2. The VEM/VenSpec-M prototype on top of the Venus emissivity chamber at PSL during measurements to verify instrument performance.

3. Engineering instrument calibration. On-ground and in-flight calibration are foreseen for the orbital instruments. On-ground instrument calibration will include pre-flight geometric, spectral, and radiometric calibrations based on MERTIS calibration campaign and pipeline. As far as possible, this calibration will be performed under flight-like conditions, as was accomplished for MERTIS. The in-flight instrument calibration will be based on radiometric calibration and dark calibration through deep space observations. Absolute calibration will be performed as part of the routine science operation by mapping the Venera, VEGA and DAVINCI landing sites.

4. Machine learning models. Igneous rocks are typically classified on the basis of chemical information about Na, K, and Si (e.g., the total alkali vs. silica TAS diagram for volcanic rocks). Because those elements are featureless in the 1 µm region, orbital identifications of Venus rock types instead depend upon transition metals (dominantly Fe) that do have spectral features in that region. Therefore, we will train machine learning models to predict FeO using the growing suites of laboratory calibration data collected with the Venus emissivity setup at PSL [9].

As part of spectrometer data validation plan, machine learning models will be used to:

- test ways to predict basalt vs granite from relative data using slopes, Δ from average, band pairs relative to average, and band ratios,
- explore ways to predict FeO from relative or absolute spectroscopy data,
- Study the effects of coatings and experimentally weathered samples,
- explore ways to create a rock classification map from relative data, and
- explore regression methods to predict FeO from relative and absolute spectral data.

Conclusions: The basic plan outlined here not only provides fundamental data needed for VEM and VenSpec-M, but can also be adapted to create data products suitable for calibration of the VenDi (Venus Descent Imager) instrument on the DAVINCI mission. Such use of an integrated calibration plan will benefit all three missions and produce coordinated results that can be directly compared.

References: [1] Helbert et al. (2023), Abstract #1679, LPSC2023. [2] Maturilli at al. (2023) this meeting. [3] Maturilli, A. et al. (2021) AGU Fall Meeting, P45E-2480. [4] Helbert J et al. (2021) Sci. Adv. 7, DOI: 10.1126/sciadv.aba9428. [5] Dyar, M. D. et al. (2020). GRL, 47, https://doi.org/10.1029/2020GL090497. [6] Adeli et al. (2023), this meeting. [7] Adeli et al., (2023) this meeting. [8] Baqué, M. et al., (2022) EPSC Abstracts Vol. 16, EPSC2022-1151. [9] Dyar, M.D. et al. (2021) Icarus, 358C, 114139.