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Retrieval and study of near-infrared surface emissivity maps of Themis Regio on Venus with VIRTIS-M (Venus Express)

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Abstract

Surface emissivity maps of Themis Regio on Venus have been derived from nightside radiance spectra acquired by VIRTIS-M-R aboard Venus Express to explore the region's geology. The emissivity retrieval bases on a new approach combining a full radiative transfer model to simulate the spectra and a multi-spectrum retrieval algorithm to retrieve parameters that are common to a set of spectra. Assuming geologic activity to be negligible during the observations, the emissivity maps at 1.02 µm, 1.10 µm, and 1.18 µm were retrieved as parameter vector that is common to many spectral image cubes covering Themis Regio. This approach provides the so far most precise semi-quantitative emissivity data at Themis Regio in the near IR range. Resulting emissivity maps display clear spatial variations relative to a referance value. We discuss the relevance of these variations to geologic structures and surficial properties.

1. Introduction

Little is known about Venus' surface composition because the dense atmosphere prevents direct observations of the surface at visible and IR wavelengths. The visible and infrared thermal imaging spectrometer (VIRTIS) aboard ESA's Venus Express mission provided new three-dimensional data of the Venusian atmosphere and information on global surface properties [1-4]. This includes systematic studies of the nightside thermal emissions of Venus in the near infrared spectral transparency windows between 1.0 and 1.2 µm. A first application of the new retrieval method described in section 2 was performed with the VIRTIS-M-IR measurements at Themis Regio on Venus. VIRTIS-M-IR data were reasonably binned to match the achievable spatial resolution of about 100 km [5], and retrieved emissivity maps were referenced to Magellan topography and a geologic map [6]. These data can be used to determine information about additional surface properties.

2. Method

Venus surface emissivity retrieval bases on a detailed radiative transfer forward model [7-10], a multi-spectrum retrieval technique (MSR) [9-11], and a detailed error analysis [10]. The forward model simulates the radiance spectra. It considers absorption, emission, and multiple scattering by gaseous and particle constituents of the atmosphere. MSR can retrieve parameters that are common to a set of spectra. Moreover, it regularizes the retrieval by incorporation of available *a priori* mean values and standard deviations of parameters to be retrieved and physically reasonable spatial-temporal *a priori* correlations. The retrieval pipeline results in emissivity maps relative to a reference value. Main findings for Themis Regio are discussed in section 3.

3. Results

The relative emissivity map of Themis Regio at 1.02 µm is derived from a 64-repeition data set and shown in Figure 1. Themis Regio is a highland region classified as a corona-dominated hotspot rise [12] and related to long duration, non-simultaneous, small-scale upwellings. Gravity data and topographic swell suggest the region is likely underlain by an active plume with ongoing surface deformation due to growth of the rise [13]. The target area includes geologic structures like the Shiwanokia Corona with steep sided domes, Shulamite Coronae, Abeona and Mertseger Mons, impact craters like Kenny, Aksentyeva, and Sabin with a dark parabola, graben, and wrinkle ridges.

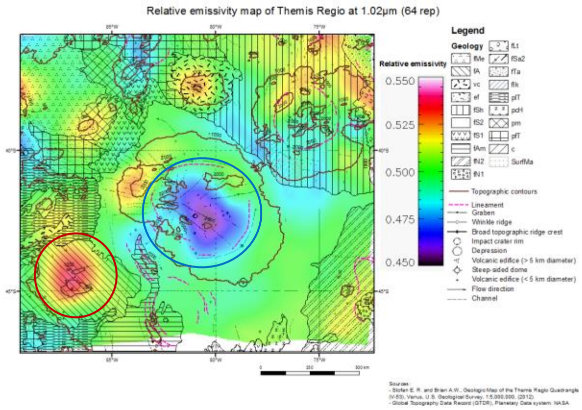

Figure 1: 1.02µm emissivity map [6] overlaid onto the geologic map. Right: Legend, geology, and color bar for the retrieved emissivity. Red circle: Abeona Mons; blue circle: Shiwanokia Corona.

The map displays relevant variations that indicate the heterogeneity of Venus' surface emissivity. Red (increased values relative to the reference emissivity) and blue (decreased values relative to the reference emissivity) colored areas show reliable and relevant differncies compared to their surroundings (yellow, green, cyan). In general, these emissivity "anomalies" can be caused by local changes in composition, age, and/or textural differncies of the surface (smooth fresh vs. rough old and weathered areas). Shiwanokia Corona has areas of low emissivity (blue circle in Figure 1). The complexity in this region might suggest long histories and an apparently older coronae [14]. In contrast, an increase of emissivity might be related to a higher iron content of mafic minerals or smooth and relatively fresh material. One example is the radar-dark Abeona Mons (Figure 1, red circle). Its high emissivity signature might rather correlate with stratigraphically relatively young units interpreted to be of volcanic origin, consistent with findings in [15]. Further results of emissivity retrieval are presented and discussed.

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