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Detection of Venus surface anomalies in the Northern hemisphere by VIRTIS/VEX and discussion of retrieved results

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Abstract

Venus nightside emission measurements by the Visible and Infrared Thermal Imaging Spectrometer (VIRTIS) aboard Venus Express (VEX) [1], [2] are used to extract information about surface features in the Northern hemisphere of the planet. A radiative transfer calculation technique is applied to simulate Venus nightside radiation as a function of surface, atmospheric and instrumental parameters. A radiance ratio based quick-look extraction of topographic information is compared to Magellan radar data. Some discrepancies are identified. These anomalies are examined in detail using a new multi-spectral retrieval algorithm. The anomalies are discussed in terms of possible surface emissivity variations. Radiance spectrum retrievals along several complete Northern hemisphere orbits indicate an emissivity decrease in the highlands in accordance with increased Magellan radar reflectivities.

Radiative transfer model

Surface information can be extracted from the spectral windows located between 1.00 and 1.35 µm (Fig. 1). The windows at 1.74 and 2.3 µm provide information about atmospheric temperature and composition below the main cloud deck. The radiative transfer simulations for a quantitative evaluation of atmospheric and surface parameters include absorption, emission, and multiple scattering by atmospheric gaseous and particulate constituents as well as deep atmosphere continuum absorption features [3]. Look-up tables of quasi-monochromatic absorption cross-sections of gaseous constituents are calculated on the basis of a line-by-line procedure that makes use of appropriate spectral line databases. It is well known that gaseous absorption features under the extreme temperature and pressure conditions in the deep atmosphere of Venus are strongly modified by a so called continuum, which is due to far line wing and pressure-induced absorptions. Some of these continuum coefficients are not well known so far. The deep atmospheric continuum can be assumed to be common to all measured spectra. A simultaneous retrieval of many spectra that were recorded for a high variety of atmospheric and surface conditions is used, therefore, to estimate the wavelength-dependent continuum absorption coefficient.

Mie scattering theory is applied to derive the microphysical parameters of the H_2SO_4 clouds. Multiple scattering in the dense cloudy atmosphere is considered using a discrete ordinate procedure. The synthetic radiances that are calculated at high spectral resolution are convolved with the VIRTIS spectral response function. Fig. 1 shows that measurements and calculations are in excellent agreement.

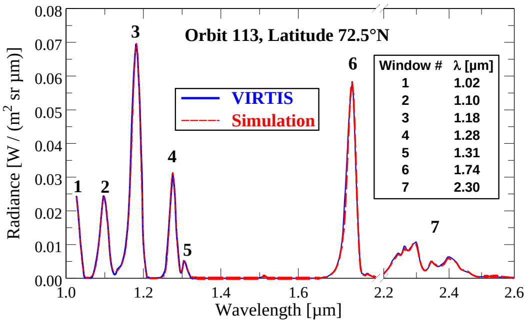

Figure 1: Comparison of VIRTIS measurement and radiative transfer simulation (orbit 113 at 72.5°N).

Results

It was shown by Arnold et al. [3] that the surface windows at 1.02, 1.10 and 1.18 µm exhibit a clear

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dependence of transmitted radiation on the cloud opacity and on topographical features and, thus, on surface thermal emission. Due to the conservative scattering behaviour of the clouds (little spectral dependence of upwelling radiation is added by them), radiance ratios of the bands below 1.31 µm with respect to the most topography sensitive surface window at 1.02 µm can be used as a quick-look tool to extract the surface elevation. In general, the Magellan and the ratio-based VIRTIS topographies are well correlated but discrepancies are detected in localized areas (Fig. 2).

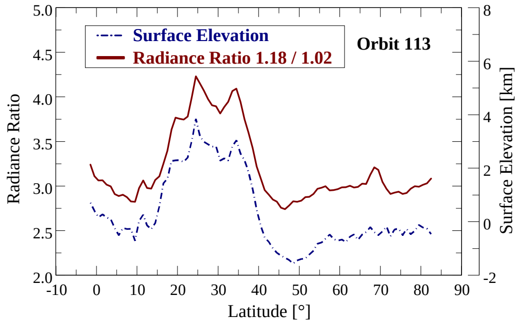

Figure 2: Averaged window radiance ratio in comparison to Magellan surface elevation for orbit 113. Notice the anomaly near 70°N.

These comparisons might hint at local variations of deep atmosphere temperature profiles and composition, or point to an anomaly in the composition or structure of surface materials. Some of the predicted anomaly candidates clearly originate from measurement or calibration errors (deformed spectra), while other show a significant possible surface emissivity anomaly (e.g. Fig. 3 near 70°N).

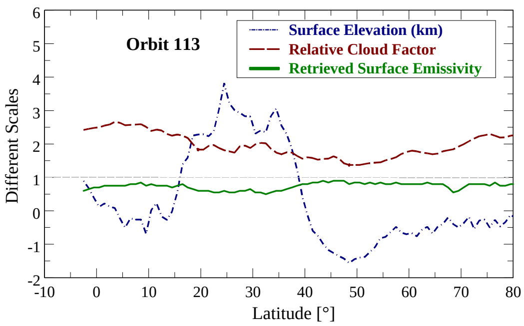

Figure 3: Magellan elevation and retrieved relative cloud opacity and surface emissivity for orbit 113. Notice the emissivity feature near 70°N.

A preliminary analysis of the measurements along several complete Northern hemisphere orbits reveals a systematic trend towards lower surface emissivities for higher surface elevations (Figs. 3 and 4). This is in accordance with increased Magellan radar wavelength reflectivities for higher elevation areas.

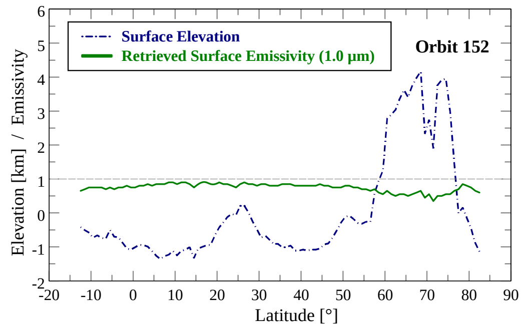

Figure 4: Preliminary surface emissivity retrievals suggest lower values for higher elevation areas.

Conclusions

The VIRTIS/VEX data form a valuable basis for systematic surface and deep atmosphere studies. The measurements show a high variability due to variations in the cloud optical depth and surface elevation. Cloud independent radiance ratios allow the detection of surface anomalies. Preliminary retrievals of VIRTIS spectra reveal emissivity anomalies for some of the ratio-predicted candidates for surface anomalies. They also indicate a systematic trend towards lower emissivity for highlands, which corresponds to an increased Magellan radar reflectivity for these areas. Future improvements of the radiative transfer code and refinements of retrieval algorithms will enable a proper separation of atmospheric and surface radiation contributions and the separation of surface temperature and emissivity effects.

References

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[2] Piccioni, G. et al. (2007) *Nature*, *450*, 637-640.
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