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PII: S0032-0633(15)00015-X
DOI: http://dx.doi.org/10.1016/j.pss.2015.01.014
Reference: PSS3903

To appear in: *Planetary and Space Science*

Received date: 12 February 2014
Revised date: 13 August 2014
Accepted date: 20 January 2015

Cite this article as: David Kappel, Rainer Haus, Gabriele Arnold, Error analysis for retrieval of Venus' IR surface emissivity from VIRTIS/VEX measurements, *Planetary and Space Science,* http://dx.doi.org/10.1016/j.pss.2015.01.014

Error analysis for retrieval of Venus' IR surface emissivity from VIRTIS/VEX measurements

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Abstract

Venus' surface emissivity data in the infrared can serve to explore the planet's geology. The only global data with high spectral, spatial, and temporal resolution and coverage at present is supplied by nightside emission measurements acquired by the Visible and InfraRed Thermal Imaging Spectrometer VIRTIS-M-IR (1.0–5.1 µm) aboard ESA's Venus Express. A radiative transfer simulation and a retrieval algorithm can be used to determine surface emissivity in the nightside spectral transparency windows located at 1.02, 1.10, and 1.18 µm. To obtain satisfactory fits to measured spectra, the retrieval pipeline also determines auxiliary parameters describing cloud properties from a certain spectral range. But spectral information content is limited, and emissivity is difficult to retrieve due to strong interferences from other parameters.

Based on a selection of representative synthetic VIRTIS-M-IR spectra in the range 1.0–2.3 µm, this paper investigates emissivity retrieval errors that can be caused by interferences of atmospheric and surface parameters, by measurement noise, and by *a priori* data, and which retrieval pipeline leads to minimal errors.

Retrieval of emissivity from a single spectrum is shown to fail due to extremely large errors, although the fits to the reference spectra are very good. Neglecting geologic activity, it is suggested to apply a multi-spectrum retrieval technique to retrieve emissivity relative to an initial value as a parameter that is common to several measured spectra that cover the same surface bin. Retrieved emissivity maps of targets with limited extension (a few thousand km) are then additively renormalized to remove spatially large scale deviations from the true emissivity map that are due to spatially slowly varying interfering parameters. Corresponding multi-spectrum retrieval errors are estimated by a statistical scaling of the single-spectrum retrieval errors and are listed for 25 measurement repetitions. For the best of the studied retrieval pipelines, temporally varying interfering atmospheric parameters (cloud parameters, minor gas abundances) contribute errors in the order of 3%–10% of the true emissivity, depending on the surface window, the reference spectrum, and assuming statistical independence of the parameters. Temporally constant interfering parameters that spatially vary on a scale of 100 km (surface elevation, interfering emissivities) add 9%–16%. Measurement noise with a standard deviation of 10^{-4} W/(m^2 sr µm) leads to additional 1%–4%. Reasonable modifications of *a priori* mean values have negligible impacts. Retrieved maps are most reliable at 1.02 µm. There is an overall tendency for better results for cases with small cloud opacity, high surface elevation, high emissivity, and small observation angle, but this depends on the emissivity window, retrieval pipeline, and measurement repetition number. Calibration, preprocessing, and simulation errors can lead to additional errors. Based on the presented results, a subsequent paper will discuss emissivity data retrieval for a selected surface target.

Keywords: Venus, Surface emissivity, Retrieval error, VIRTIS

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