RETRIEVAL OF SURFACE PROPERTIES IN THE NIR NIGHTSIDE WINDOWS OF VENUS

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Abstract

Based on a radiative transfer simulation model as well as new multi-window retrieval techniques, deep atmosphere and surface parameters can be retrieved from VIRTIS-M-IR data in the NIR nightside spectral transparency windows of Venus. A detailed error analysis for surface emissivity retrieval demonstrates the necessity for a new multi-spectrum retrieval technique.

Local emissivity anomalies and differences in highland and lowland regions of Venus have been identified. One example (Idunn Mons) is discussed in the present paper.

Introduction

Retrieval of Venus' surface emissivity is a key challenge to study surface composition, weathering processes, and as a consequence crucial aspects of planetary evolution, geology, and climate of Venus. The Visible and Infrared Thermal Imaging Spectrometer (VIRTIS) aboard ESA's spaceprobe Venus Express records spectrally, spatially, and temporally resolved data of the atmosphere and surface in the NIR nightside spectral transparency windows of Venus [1, 2]. The infrared mapping channel VIRTIS-M-IR yields a spectrum of 432 bands covering the range between 1.0 μm and 5.2 μm at 256 spatial pixels for each exposure. Hundreds of successive exposures at a time yield spectrally resolved two-dimensional images of targets on Venus, providing an excellent data base for surface emissivity retrieval [3, 4].

Methodical approaches

In order to extract surface parameters from the measurements, a Radiative Transfer Simulation Model (RTM) including special features of Venus' deep atmosphere like continuum absorption was developed and applied to the data [5]. The RTM simulates observed radiances in dependence on atmospheric and surface parameters on a line-by-line basis. It incorporates absorption, emission, and multiple scattering by gaseous and particulate constituents.

The Multi-Window Retrieval Technique (MWT) makes simultaneous use of information from different atmospheric windows of an individual spectrum. It iteratively optimizes several atmospheric and surface parameters until the simulated spectrum well fits the measurement for all utilized spectral windows. The determined parameters are interpreted as the state of atmosphere and surface that led to the observed spectrum. However, this is mathematically an ill-posed problem, since different state vectors can parameterize the same spectrum equally well. The usual approach to improve the situation is the regularization of the retrieval by incorporating *a priori* mean values and standard deviations of the parameters to be retrieved. This way, the probability to determine unlikely values for the parameters is decreased.

Due to a certain continuity of atmospheric composition, contiguous measurements are not likely to originate from completely un-related single-spectrum state vectors. These spatial and temporal correlations between the state vectors are always present, but usually neglected in retrieval algorithms. The new Multi-Spectrum Retrieval Technique (MST) [3] allows for additional incorporation of physically reasonable spatial-temporal *a priori* information on atmospheric parameters. Since the context of adjacent measurements is taken into account now, the reliability of retrieved single-spectrum state vectors is improved, and the probability to determine unlikely spatial-temporal distributions for the state vectors is decreased. Also, MST allows for the determination of parameters common to a selection of several spectra. Neglecting geologic activity, surface emissivity for a pixel on Venus' surface can be retrieved as parameter that is common to several measurements repeatedly covering that pixel. This considerably enhances the reliability of retrieved emissivity.

Results

The RTM-MWT results show an excellent agreement of simulated and measured spectra in most cases as it is illustrated in Figure 1.

A detailed retrieval error analysis using RTM-MWT reveals that surface emissivity is particularly difficult to determine from VIRTIS-M-IR spectra [6]. For instance, an uncertainty in the abundance of cloud mode 1 particles of 50% can lead to an error of 20% in retrieved emissivity, depending on the utilized spectral ranges for retrieval. Similarly, 1 km uncertainty in bottoms / tops of the cloud mode altitude profiles can lead to 5% emissivity error, 6% uncertainty in H_2SO_4 concentration to 9%, 100 m in surface elevation to 8%, and 1 K in deep atmospheric temperature profile at 0 km to 13% emissivity error (Figure 2). Therefore, MST is utilized for a more reliable retrieval of a surface emissivity map.

One example for MST outputs is visualized in Figure 3. It shows scatterplots of retrieved 1.02 µm surface emissivity in the region of Idunn Mons as a function of surface elevation when emissivity is considered as common parameter or not. The scatter of the results is much higher in the latter case, i.e. the treatment of emissivity as common parameter significantly improves the retrieval reliability. 1570 spectra were used in total, corresponding to 99 surface bins with at least 15 repetitions for each bin.

The shield volcano Idunn Mons represents an isolated emissivity anomaly on Venus' surface. The 1.02 µm emissivity differs between Idunn hills and surrounding lowlands. This can be the result of recent volcanic activity [7] or may result from different material, and/or variable weathering conditions.

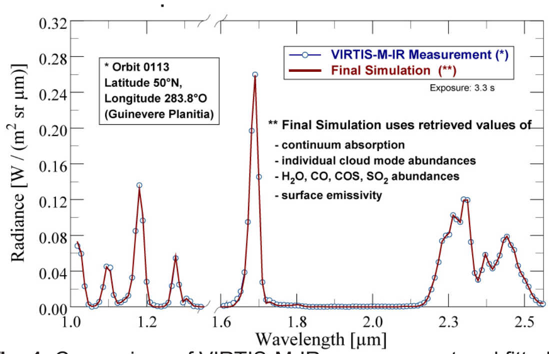

fig. 1. Comparison of VIRTIS-M-IR measurement and fitted simulation.

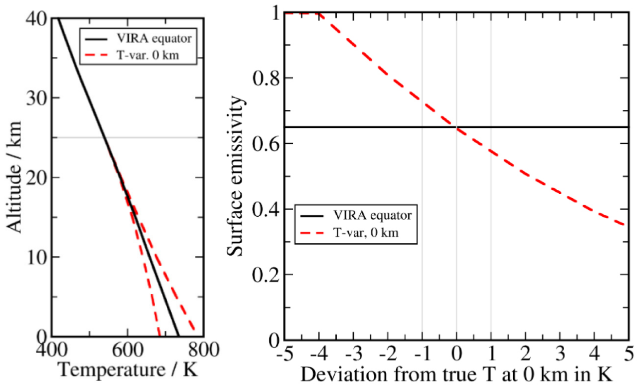

fig. 2. Example for retrieved surface emissivity as a function of deep atmospheric temperature profile. *Left:* Exaggerated perturbations around equatorial VIRA temperature profile. *Right:* Retrieved 1.10 µm emissivity for unperturbed and perturbed temperature profiles. Equatorial VIRA is the true temperature profile, 0.65 is the true emissivity of the analyzed synthetic spectrum.

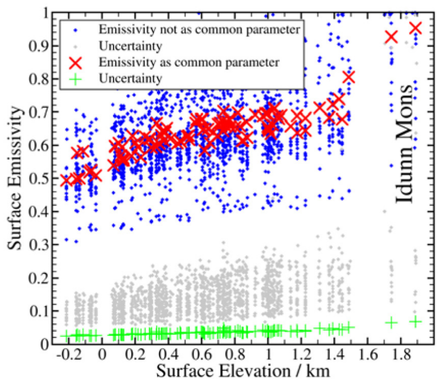

fig. 3. Scatterplots of retrieved 1.02 µm emissivity as a function of surface elevation near Idunn Mons.

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