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Surface emissivity retrieval from VIRTIS/VEX data in the Quetzalpetlatl quadrangle on Venus based on the new MSR multi-spectrum retrieval technique

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Abstract:

Surface emissivity is difficult and error-prone to retrieve from VIRTIS measurements of Venus' nightside. A detailed radiative transfer forward model simulation is used to generate synthetic spectra for given atmospheric and surface parameters. The new MSR multi-spectrum retrieval technique is applied to retrieve atmospheric and surface parameters that allow the synthetic spectra to fit the measurements. The incorporation of expected spatial-temporal correlations between parameters describing a selection of contiguous measurements leads to much more reliable parameters, as does the retrieval of surface emissivity of a surface bin as a parameter that is common to measurements that repeatedly cover that bin, thereby neglecting geologic activity.

The method is applied to Quetzalpetlatl quadrangle including the Lada Terra rise and the Quetzalpetlatl corona. This area combines corona-dominated rises, rifted volcanic rises, and large coronae structures [1]. Retrieved emissivity at 1.02 µm is related to regional geologic units.

Introduction:

Venus' surface properties are not well known except from a few *in situ* measurements and from RADAR mapping. Surface emissivity in the infrared (IR) is more specific to surface materials and textures than RADAR data. The only global data source at high spatial, spectral, and temporal resolution are the IR nightside emissions acquired by the IR Mapping channel of the Visible and InfraRed Thermal Imaging Spectrometer (VIRTIS-M-IR) aboard ESA's spaceprobe Venus Express (VEX) [2, 3]. At each exposure, the range 1.0 - 5.2 µm is sampled by 432 spectral bands for 256 spatial pixels, and many successive exposures yield a carefully calibrated [4] spectrally resolved two-dimensional image of a target on Venus. Such a target can repeatedly be covered by several images recorded over the duration of the mission, providing an excellent data base for surface emissivity retrieval [5].

The hot surface (735 K at 0 km according to VIRA) emits surface temperature, composition, and texture dependent radiation that is, along with deep atmospheric emissions, multiply scattered and partly absorbed by the overlying atmospheric and cloud layers. On Venus' dayside, sunlight is scattered by the clouds and strongly outweighs the relevant surface emissions as well as sunlight reflected at the surface. On the nightside, the dense CO_2 atmosphere and the thick H_2SO_4 clouds completely black out several spectral ranges and leave only a few narrow spectral transparency windows that probe down to the surface and deep atmosphere.

For given atmospheric and surface parameters, these mechanisms are simulated by a detailed radiative transfer forward model [6]. A single-spectrum retrieval algorithm compares a simulated with a measured spectrum and modifies the parameters until the simulation well fits the measurement. The resulting parameters then adequately describe the measured spectrum and are interpreted as the underlying state of atmosphere and surface that led to the measured spectrum. Due to the limited spectral information content, different state vectors may describe the same spectrum equally well, and incorporation of expected mean values and standard deviations for all parameters serves to regularize the retrieval. While this already decreases the probability to determine unlikely parameter values, the surface emissivity retrieval error is still too large to obtain reasonably reliable surface data.

The MSR technique:

The drive to compensate thermodynamic disequilibria yields a certain continuity of atmospheric parameters. Thus, contiguous measurements are likely to originate from spatially-temporally correlated single-spectrum state vectors. Such *a priori* correlations are usually neglected in retrieval algorithms. The new Multi-Spectrum Retrieval technique MSR [7] takes them into account and thus decreases the probability to determine unlikely spatial-temporal state vector distributions as well as noise effects. Parameters with more different correlation lengths or times can be better disentangled. The extreme case is the disentanglement of parameters with finite from those with infinite correlation length or time. The latter can be treated as common to a suitable selection of measurements. MSR's reduction of the effectively available size of the state vector space decreases the uncertainty of retrieved parameters and thus improves their reliability.

MSR enables the retrieval of surface emissivity in the first place. When geologic activity is neglected, surface emissivity of a surface bin is common to all measurements that cover this bin. The surface emissivity map of a target on Venus can be retrieved as parameter vector that is common to a suitable selection of spectrally resolved two-dimensional images that repeatedly cover that target.

Results:

MSR is applied to a geologically interesting region in the Quetzalpetlatl quadrangle (V-61, [8]). The study area is bounded by 335°-360° longitude and 65°-50° southern latitude. It is situated in the region most frequently measured by VIRTIS-M-IR, allowing to take a high number of repetitions into account. The surface target is divided into 250 equal-area bins of roughly 100 km x 100 km. Each bin is covered by 16 measurements, yielding 4000 spectra. With no least-square residual exceeding 5% of its measured spectrum's least-squares norm, the quality of the fits is uniformly excellent (Fig. 1).

A single-spectrum retrieval error analysis was performed to identify the main interfering parameters aside from CO_2 opacity uncertainties: surface elevation, deep atmosphere lapse rate, H_2O mixing ratio, and H_2SO_4 concentration of cloud droplets.

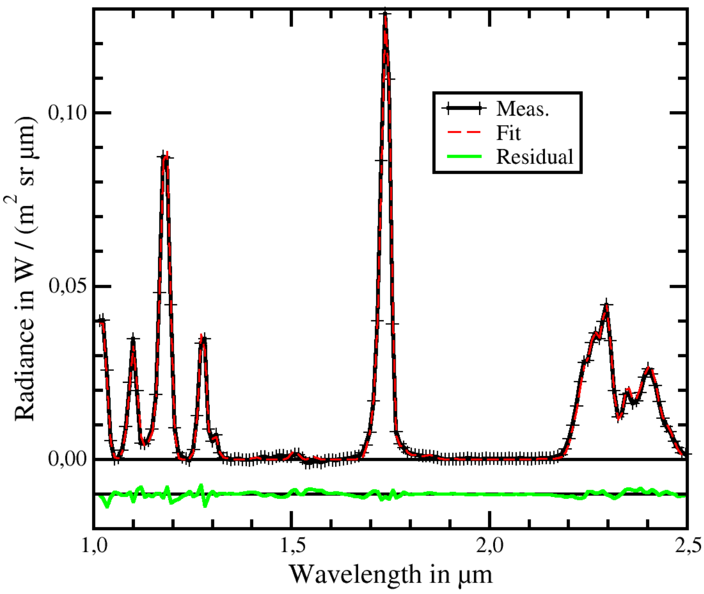

Fig. 1. Comparison of VIRTIS-M-IR measurement and fitted simulation.

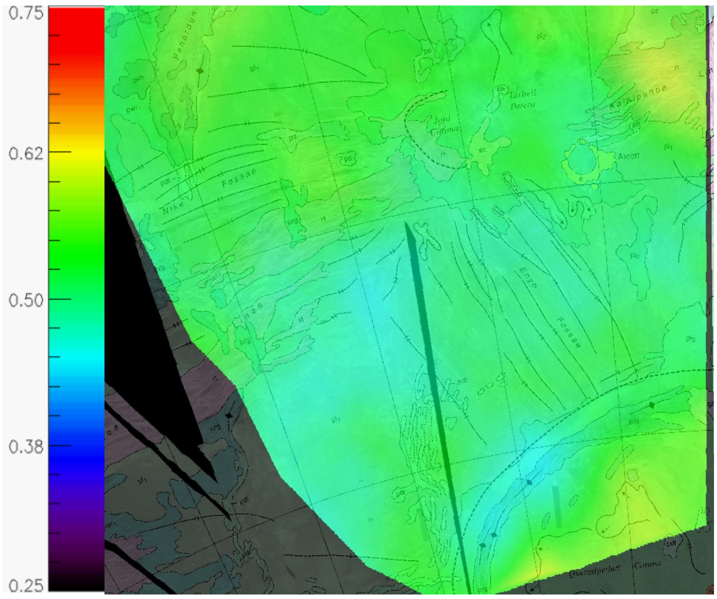

Fig. 2. Retrieved 1.02 µm emissivity at Quetzalpetlatl corona rim (overlaid to geologic map).

Fig. 2 shows one example of the retrieved 1.02 µm emissivity near the Quetzalpetatl corona. Variations of the emissivity are not primarily correlated to topography and therefore not to surface temperature. They are rather linked to the surface geology. Like parts of the corona rim (ridge), lower units of the lobate plains Enyo Fossae can be related to lower emissivity. Higher emissivity values in the south of the corona rim are correlated to the youngest lava flows (lobate plains, upper unit).

References:

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