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Retrieval of temperature profiles and cloud parameters in the nightside mesosphere of Venus based on VIRTIS-M-IR and VENERA-15-PMV radiation measurements

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Abstract

Latitudinal variations of mesospheric temperature profiles, cloud top altitudes, and cloud optical depths were investigated using both VIRTIS-M-IR and VENERA-15-PMV nadir-looking nightside radiation measurements over the northern hemisphere of Venus. Prominent and well-known temperature structures like 'cold collar' and 'hot dipole' were re-examined and decreasing cloud top altitudes towards the pole were identified. First results on spectral changes of cloud optical depth were obtained that are required to produce optimum fits of measured brightness spectra. The variations may indicate spatial and temporal changes of cloud composition.

1. Introduction

One of the main scientific goals of ESA's ongoing Venus Express mission is the global investigation of surface features of Venus by analysis of measurements performed by the Visible and Infrared Thermal Imaging Spectrometer (VIRTIS). Surface emissivity can be retrieved from VIRTIS-M-IR nightside emission signatures at 1.02, 1.10, and 1.18 µm, respectively. The results, however, strongly depend on assumed CO_2 continuum absorption coefficients k_c. Likeliest k_c values were determined from multi-spectrum analyses in the 1.0-2.5 µm spectral range and found to be sensitive to changes of atmospheric temperature profile and cloud parameters [4]. Thus, the retrieved surface emissivity explicitly and implicitly depends on the cloud model used in the retrieval procedures.

Altitude resolved information on cloud parameters like top and bottom altitudes, modal composition, and modal abundances can be obtained from locally and spectrally resolved radiation measurements in the infrared bands of CO_2 located at 4.3 and 15 µm, respectively. Observed radiances in the center and wing regions of these bands are not only very sensitive to the thermal structure of the middle atmosphere at altitudes between 60 and 90 km (the mesosphere), but also to variations of cloud features, and any cloud parameter retrieval requires a simultaneous temperature retrieval to be performed, and vice versa.

Time-averaged retrieved temperature profiles in the middle atmosphere at similar locations should agree within a few K between different data sources. Deviations may indicate that cloud composition and altitude distribution models are not optimal. A change of aerosol composition would modify the spectral features of optical parameters. This may result in different retrieved temperature profiles and cloud opacities and could eventually lead to different surface emissivity results.

2. Temperature retrieval

The first step of work has focused on a comparative temperature retrieval using both new data from VIRTIS-M-IR (covering the CO_2 4.3 µm absorption band) [6] and older data from the Russian Fourier spectrometer (PMV) experiments performed in the 1980s on VENERA-15 (covering the CO_2 15 µm band) [9]. More than 1000 individual VIRTIS spectra and about 770 PMV spectra for different latitudes between 0° and 85° North were investigated and compared with the VIRA model [5] as well as with results from radio occultation sounding by the Venus Radio Science Experiment (VeRa) [8].

Atmospheric temperatures above 70 km altitude typically increase towards the poles. Strong thermal inversions, however, may occur at altitudes between 60 and 70 km and latitudes above 55°N producing such striking atmospheric features like the cold collar and the hot dipole [7]. VIRTIS and PMV temperature profiles at different latitudes are consistent with VIRA and VeRa data and largely agree with results obtained for the southern hemisphere [1], [2]. Average temperature differences to VIRA never exceed 10 K and are typically below 7 K. The similarities between northern and southern hemisphere temperature fields indicate global N-S axial symmetry of atmospheric temperature structure.

3. Cloud parameter retrieval

Atmospheric temperatures between 55 and 75 km are sensitive to the location of the cloud top (CT). CT altitude in terms of unity cloud optical depth at 1 μm was determined from spectrum fits in the near wings of the 4.3 (VIRTIS) and 15 μm (PMV) CO_2 bands, respectively. Lower CT altitudes may require the use of higher total cloud column factors to arrive at suitable total cloud opacity. The cloud bottom altitude at 48 km was not varied in this study.

Both VIRTIS-M-IR and PMV nightside data indicate that the cloud top for latitudes below 55°N is located nearly constant at 72-74 km, but drops down to 67 km in polar regions. Individual spectra show cloud top altitudes as low as 65 km. This general trend well agrees with results obtained from VIRTIS-M-IR dayside observations at 1.6 μm on the southern hemisphere [3].

The distant wings of the corresponding CO_2 bands were used to derive spectral changes of cloud optical depth that are required to produce optimum fits of measured brightness spectra once the atmospheric temperature profile was determined. The retrieval of cloud parameters for different cloud modes seems to be possible from PMV measurements that sound the atmosphere to a somewhat lower level (~55 km) compared with VIRTIS.

4. Conclusions

Mesospheric temperature profiles and varying cloud top altitudes were determined that are in good agreement with previous work. First preliminary results with respect to spectral changes of cloud parameters with location and time have to be interpreted with much care, however, since it is likely that some of the suggested spectral changes are due to errors in the CO_2 opacity (sub-Lorentz line shapes, line mixing, line database errors) and resulting temperature retrieval errors. The retrieved cloud optical depth spectral changes strongly vary with latitude, but there is no systematic trend. This may indicate spatial and temporal variations of chemical cloud composition.

More work is underway that eventually could lead to improvements of Venus‘ surface emissivity retrieval.

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