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Investigation of Venus' atmospheric thermal structure and cloud features over the northern nightside hemisphere applying self-consistent retrieval procedures

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Abstract

A new multi-window retrieval procedure (MWR) simultaneously determines air temperatures and cloud parameters in the nightside atmosphere of Venus in a self-consistent way. Comparative analyses of data independently recorded by the VIRTIS-M-IR and PMV instrument over the northern hemisphere of Venus are used to determine constraints on physical state parameter variations. Averaged retrieved temperature fields and cloud parameters are in good quantitative accordance with previous results.

1. Introduction

NIR spectroscopic measurements (1.0-5.1 µm) were performed by the Visible and InfraRed Thermal Imaging Spectrometer (VIRTIS-M-IR) aboard ESA's Venus Express space probe, while the Profile Measuring Instrument for Venus (PMV, Fourier spectrometer FS-1/4) on the earlier Soviet Venera-15 satellite covered the spectral range 6-36 µm. A detailed comparative investigation of Venus' thermal structure and cloud composition based on these two experiments has not been done before. The data sets are complementary in the sense that any initial cloud model and retrieved actual parameters must allow to generate reasonable fits in both spectral ranges. Due to PMV data coverage, present investigations are restricted to the northern hemisphere of Venus. The NIR range shortward of 5 µm strongly responds to insolation changes, and deep atmosphere signatures are not detectable at daylight. Thus, only nightside data from both experiments was used.

2. Algorithm validation

The multi-window retrieval procedure (MWR) has been described in detail by Haus et al. [1]. Temperature profiles are determined from the 4.3 and 15 µm CO_2 bands. An analytically parameterized initial model of four-modal cloud altitude distributions is used. Cloud properties are retrieved from the wings of these bands in terms of single mode factors and upper cloud altitude boundaries that modify the cloud top altitude. In case of VIRTIS, large particle (mode 3) factors are determined at 2.3 µm, where deep atmosphere continuum absorption [4] has to be considered. In order to investigate the performance of the retrieval procedure, sets of synthetic spectra at different latitudes and for different 'true' atmospheric temperature profiles and cloud parameters were generated considering Gaussian noise corresponding to the approximate noise equivalent radiance at 4.3 µm in case of VIRTIS data. MWR is then applied to recover the model parameters whereupon the synthetic spectra are based. Different initial guess temperature profiles and cloud parameters are used for this purpose. The differences of noisy 'true' and fitted brightness temperatures do not exceed a few tenths K outside the 4.3 µm band center and absolute differences of true and retrieved temperatures are usually below 1.5 K between 60 and 84 km. This corresponds just to the sounding range of VIRTIS measurements. Differences between true and retrieved cloud parameters (e.g. single mode abundance factors, cloud top altitude) are usually below 2%, but reach sometimes 10% at polar latitudes. Analog investigations in the PMV range yield a maximum temperature difference of 2.5 K at 58 km near the pole. PMV data are sensitive to temperature changes at altitudes of 55-90 km.

3. Retrievals from real spectra

The new MWR technique for self-consistent temperature profile and cloud parameter retrieval provides very good spectrum fits of real measurements. This is illustrated in Figure 1 where PMV brightness temperature spectra from orbit 29 at

29, 62, and 79°N are compared with MWR fits. The two ranges between 450 and 520 cm^{-1} and at about 1150 cm^{-1} are influenced by SO_2 feature variations, which are not considered in the present operational analyses. Retrieved temperature profiles are shown in the inset. Retrieved cloud mode 2 factors and cloud top altitudes are 0.95, 0.36, 0.19 and 84.6, 70.0, 64.8 km, respectively.

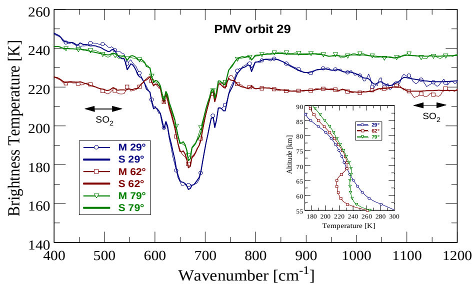

Figure 1. Comparison of PMV measurements (M) and simulation results (S) at 29, 62, and 79°N and retrieved temperature profiles (inset).

3. Temperature results

The main features of retrieved averaged temperature profiles in the northern hemisphere of Venus correspond well to previous results from Pioneer Venus Infrared Radiometer and Venera-15-PMV data [7, 9] and also well agree with analyses of VIRTIS-M-IR data from the southern hemisphere [2] and VeRa data [8]. The similarities between northern and southern hemisphere temperature fields indicate global N-S axial symmetry of atmospheric temperature structure. Temperatures in equatorial latitudes southward of 30°N are nearly constant at all altitudes up to 80 km. They decrease quite continuously polewards below 58 km. The pole is colder by about 40 K at 55 km altitude and colder by 20 K at 50 km. At altitudes above about 70 km, the temperature increases with increasing latitude. Polar regions are warmer than equatorial regions by about 10-15 K at high altitudes up to 95 km. At latitudes between about 55 and 75°N, there is a strong temperature inversion layer centered between 62 and 66 km altitude (‘cold collar’). A warmer region northward of 70°N at about 60 km is related to the ‘hot dipole’, a rotating and highly variable structure over the pole [6].

4. Cloud parameter results

A significant decrease of cloud top altitudes is observed from about 70 km at low and mid latitudes down to about 61.5 km at polar latitudes. Averaged cloud particle size and opacity are found to increase from a local minimum at 50°N towards the equator and the North Pole. The planetary average of cloud opacity derived from VIRTIS data is 34.7 at 1 µm. The results are in good quantitative correspondence with previous observations [3, 5, 9].

References

[1] Haus et al.: Self-consistent retrieval of temperature profiles and cloud structure in the northern hemisphere of Venus using VIRTIS/VEX and PMV/VENERA-15 radiation measurements, submitted to Planet. Space Sci.

[2] Grassi, D. et al.: Thermal structure of Venusian nighttime mesosphere as observed by VIRTIS-Venus Express, J. Geophys. Res. 115(E09007), 11pp., 2010.

[3] Ignatiev, N.I. et al.: Altimetry of the Venus cloud tops from the Venus Express observations, J. Geophys. Res. 114(E00B43), 10 pp, 2009.

[4] Kappel, D. et al., Refinements in the data analysis of VIRTIS-M-IR Venus nightside spectra, Adv. Space Res. 50, 228-255, 2012.

[5] Lee, Y.J. et al., Vertical structure of the Venus cloud top from the VeRa and VIRTIS observations onboard Venus Express, Icarus 217, 599-609, 2012.

[6] Piccioni, G. et al.: South-polar features on Venus similar to those near the north pole, Nature 450, 637-640, 2007.

[7] Taylor, F.W. et al., Temperature, cloud structure, and dynamics of Venus middle atmosphere by infrared remote-sensing from Pioneer Orbiter, Science 205, 65–67, 1979.

[8] Tellmann, S. et al.: Structure of the Venus neutral atmosphere as observed by the Radio Science experiment VeRa on Venus Express, J. Geophys. Res. 114(E00B36), 354-372, 2009.

[9] Zasova, L.V. et al., Exploration of Venus with the Venera-15 IR Fourier Spectrometer and the Venus Express Planetary Fourier Spectrometer, Cosmic Res. 44, 349-363, 2006.