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Atmospheric thermal structure and cloud features of Venus as retrieved from VIRTIS/VEX measurements

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Abstract

Updated results on mesospheric nightside thermal structure and cloud features of Venus are presented that were retrieved from VIRTIS-M-IR measurements during eight Venus solar days between April 2006 and October 2008 using new methodical approaches. Maps for the southern hemisphere cover parameter variations with altitude, latitude, local time, and mission time. The mesospheric temperature field strongly depends on latitude and local time. Zonal averages of retrieved temperature profiles and cloud parameters in both hemispheres show global N-S axial symmetry. Cloud top altitude at 1 µm decreases from 71 km at the equator to 61 km over both poles. Average cloud particle size is minimal at mid latitudes.

1. Data and algorithms

The Visible and InfraRed Thermal Imaging Spectrometer (VIRTIS) on Venus Express [1, 2] provided an enormous amount of new data and a four-dimensional picture of the planet Venus (2D imaging + spectral dimension + temporal variations) on global scales. VIRTIS data from the moderate resolution infrared mapping channel M-IR cover the NIR spectrum between 1.0 and 5.1 µm. The spectral dimension permits a sounding of atmospheric properties at different altitude levels.

Refinements in the data analyses [3] and new methodical approaches for self-consistent temperature profile and cloud parameter retrievals were applied where the latter carefully separate the influence of these parameters on measured spectra [4, 5]. This allows for explicit cloud parameter studies. A data selection strategy was developed that is especially useful for statistical exploration of massive data sets. Combined radiative transfer and multi-window retrieval techniques simultaneously process information from different spectral ranges of an individual spectrum. Mesospheric temperature altitude profiles (58-85 km) are determined from 4.3 µm CO_2 absorption band signatures. Specific parts of the 4.3 µm band wings as well as of the deep atmosphere transparency window at 2.3 µm are utilized to derive cloud parameters (single mode abundance factors, cloud top altitude, total opacity). A wavelength-dependent CO_2 opacity correction is considered in the transparency windows [3, 4, 6].

2. Temperature results

Zonal averages of temperature features in both hemispheres are very similar and give evidence of global N-S axial symmetry of atmospheric temperature structure (Fig.1). Results for both hemispheres well correspond to earlier results reported in the literature [7-10]. A strong cold inversion layer, which is located at latitudes between 50 and 75° and altitudes between 58 and 70 km, divides the atmosphere vertically. For fixed altitudes below this 'cold collar', temperature decreases with increasing latitude poleward of 30°, while it increases above 70 km poleward of 40-50°. Warmer and vertically nearly isothermal regions poleward of 75° extend from 58 to 66 km and are associated with a strongly time-dependent bright polar vortex. Collar and vortex regions exhibit the strongest zonal average temperature variability with standard deviations up to 8.5 K at 75°S and 63 km altitude compared with about 1.0 K at low and mid latitudes above 75 km.

The mesospheric temperature field strongly depends on local time. At altitudes above about 75 km, the atmosphere is warmer in the second half of night, while the dawn side at lower altitudes is colder than the dusk side by about 8 K. Local minimum temperature of 220 K occurs at 03:00 h local time at 65 km and 60°S. Temperature standard deviation at polar latitudes is particularly large near midnight.

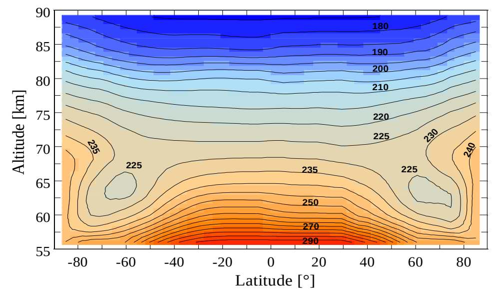

Fig.1. Zonal average of mean temperature field as a function of latitude and altitude in both hemispheres. Temperatures are given in K.

Mesospheric temperature variability with solar longitude seems to be forced by solar thermal tides with a dominating diurnal component. There are no explicit temperature trends with mission time. The averaged mesospheric thermal structure was essentially stable between 2006 and 2008. The overall influence of cloud parameter changes on retrieved mesospheric zonal average temperature structure is moderate and does not exceed 2-3 K at altitudes between 60 and 75 km.

3. Cloud parameter results

Global N-S axial symmetry is also observed in cloud structures. Zonal averages of cloud top altitude at 1 µm slowly decrease from 71 km at the equator to 70 km at 45-50° and rapidly drop poleward of 50°. They reache 61 km over both poles (Fig.2). This result is in good qualitative agreement with earlier findings [8, 11, 12].

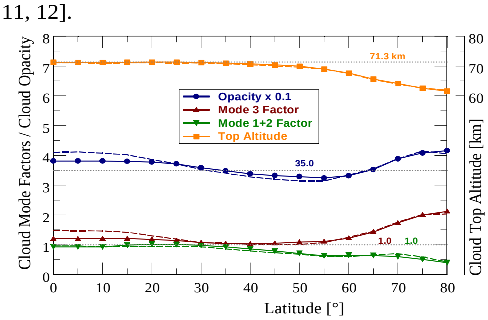

Fig.2. Zonal averages of cloud mode factors, cloud opacity, and cloud top altitude as functions of latitude in both hemispheres (solid lines with symbols: South; broken lines: North; dotted lines: initial model).

Average particle size in the vertical cloud column increases from mid latitudes toward the poles (in agreement with [12, 13]) and also toward the equator resulting in minimum and maximum zonal average cloud opacities of about 32 and 42 (Fig. 2) and a planetary average of 36.5 at 1 µm. Zonal averages of cloud features are similar at different solar days, but variations with local time are very complex and inseparably associated with the atmospheric super-rotation.

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