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Water vapor abundance above Venusian clouds on the dayside from SPICAV VIS-IR nadir measurements

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Introduction

Several in-situ experiments and ground-based observations allowed to measure water vapor abundance in the Venus atmosphere. The Pioneer Venus Orbiter Infrared Radiometer and Venera 15 Fourier Transform Spectrometer observations of thermal emission from Venus middle atmosphere resulted in global maps of water vapor abundance above the clouds using fundamental 45-µm rotational water band. The cloud-top H_2O abundance observed by the PV OIR instrument vary from 10±5 ppm at night to 90±15 ppm in the equatorial region shortly after the sub-solar point [1, 2]. The water vapor abundance measured by Venera 15 FS was within 5-15 ppm at altitudes of 58-62 km [3]. The mesospheric measurements of H_2O mixing ratio above 70 km resulted in values mostly below 3 ppm [4-8].

The Venus-Express mission works on the orbit around Venus since April 2006. Two experiments, VIRTIS and SPICAV/SOIR, allow mapping of H_2O abundance from the surface to the mesosphere [8-11]. Here we present results of SPICAV IR measurements of the H_2O abundance above the cloud-top on the day-side in the near-IR spectral range.

Instrument description

SPICAV VIS-IR channel is an AOTF single pixel spectrometer for the spectral range of 0.65-1.7 µm with a spectral resolution of 5-8 cm^{-1} [12]. Resulting resolving power at 1.4 µm is ~ 1400. It measures sequentially the spectrum of reflected solar radiation from Venus on the dayside and the emitted Venus radiation in spectral “windows” on the night side. The spatial resolution from Venus Express orbit is 10-15 km. Compared to similar SPICAM-IR instrument on Mars Express the spectral range SPICAV on Venus Express is extended down to 0.65 µm with enhanced sensitivity in the entire range, and especially at 0.65-1.1 µm to measure the radiance from the atmosphere below clouds and the surface of Venus on the night side. The field of view of the instrument for nadir observations is 2°, corresponding to 10 km from the pericenter of the Venus-Express orbit.

An important goal of the SPICAV IR is to measure the H_2O content above and below clouds. On the day-side the spectrometer is capable to measure H_2O in several bands: 0.94, 1.14 and the strongest 1.38 µm. Since April 2006 numerous observations on the day-side have been performed from pericenter and apocenter of the orbit. The presentation will be concentrated on nadir observations performed in the period from April 2006 to October 2008 (orbits 23-900).

Method

We used HITRAN 2004 database as a source spectral lines parameters [13]. To account for broadening of H_2O lines in the CO_2 atmosphere we multiplied the air-broadened half-widths from the HITRAN 2004 by 1.7, following Gamache *et al.* (1995) and Brown *et al.* (2007) [14-15].

The atmospheric profile has been taken from VIRA model [16]. The cloud model assumes H_2SO_4 (75%) mode 2 particles.

Radiative transfer is computed using Spherical Harmonics Discrete Ordinate Method (SHDOM) [17]. Monochromatic spectra have been converted with the SPICAV IR instrumental function.

The main problem of the H_2O retrieval above clouds is an accurate determination of the cloud

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top altitude. The depth of CO_2 band can be used to determine the cloud level because it depends on the optical path in the scattering and absorbing atmosphere as it was shown by Ignatiev et al. [18].

Modeling of the cloud top (τ=1) at 1.43 μm

The cloud vertical distribution can be modeled by the cloud top (the unit column optical depth) and the scaled height H.

The efficiency of this method for the cloud top mapping on the dayside was recently splendidly demonstrated by Ignatiev et al. [18] based on VIRTIS M data.

Retrieval of H_2O mixing ratio above the cloud top

Using the altitude of the cloud top and the scale height of 3-4 km the inverse problem for H_2O retrieval can be solved.

The uniform distribution of H_2O in the atmosphere up to 100 km has been assumed. The observations of H_2O vertical profile from SOIR have shown more or less stable constant mixing ratio from 0.5 to 2 ppm above 75 km.

Results

Assuming H=3 km, obtained cloud top varies from 66 to 73 km (fig. 1). The low latitude region shows weak variations of the cloud top within 1-2 km for selected orbits with the average value of 72 km. In the high northern latitudes (78N max) the cloud top decreases to 67 km. Since the SHDOM works in the plane-parallel geometry, we have excluded solar zenith angles higher than 80˚.

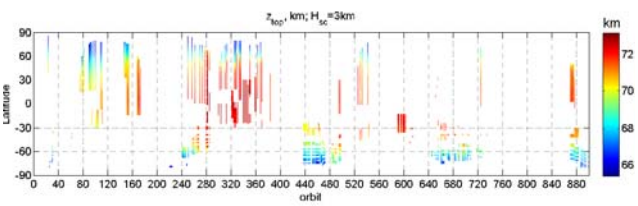

Figure 1. Clouds top distribution for SPICAV IR nadir orbits.

Obtained H_2O content varies inside 3-6 ppm and shows weak variations from orbit to orbit and with the latitude (fig.2). In this report the local time and latitude distribution will be presented and main uncertainties will be discussed. Future work assumes a comparison with simultaneous observations of VIRTIS-H spectrometer at 2.56 μm band for validation of obtained results.

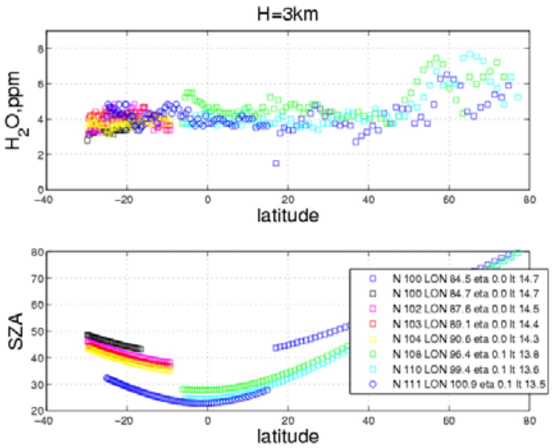

Figure 2. H_2O abundance above the clouds for different orbits

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