EPSC Abstracts
Vol. 7 EPSC2012-674-1 2012
European Planetary Science Congress 2012

Water vapor and the cloud top variations in the Venus' mesosphere from SPICAV observations

A. Fedorova(1,2), J.L.Bertaux(3), E.Marqc (3), O. Korablev(1,2), A.Zykova (2,1), F. Montmessin (3)
(1) IKI (Space Research Institute), Moscow, Russia (fedorova@iki.rssi.ru / Fax: +7-495-333-21-02),
(2) Moscow Institute of Physics and Technology (MIPT), 9 Institutsky dr., 141700 Dolgoprudny, Moscow Region, Russia
(3) LATMOS, 11 Bd d'Alembert, F-78280 Guyancourt, France

Abstract

SPICAV VIS is a spectrometer based on AOTF (acousto-optical tunable filter) and working in the spectral range of 0.65-1.7 μm. It provides the measurements of H_2O abundance above the clouds based on 1.38 μm band and the cloud top altitude based on the CO_2 bands in the range of 1.4-1.6 μm. The new calibrations of the instrument in 2010-2012 allow updating of results reported earlier. The cloud top altitude has been routinely retrieved for the dataset from 2006 to 2012 (VEX orbits 23-2000) taking into account multiple-scattering in the cloudy atmosphere. The possible long-term and year-to-year variations will be studied. The H_2O content from 1.38 μm near-IR band varies inside 1-3 ppm and shows a prominent sensitivity to vertical gradient of the H_2O distribution below 65 km that make an interpretation of data non-trivial.

1. Introduction

Water vapor is one of important gases in the Venus' atmosphere. H_2O play a significant role in the chemistry of the lower and middle atmosphere of Venus due to it involves in the sulfur oxidation cycle that produces H_2SO_4, and in active photochemistry above the clouds. The recent observations of water confirm that H_2O distributes mostly uniform in the mesosphere with mixing ratio of 1-2 ppm [1]. Inside the clouds the water amount increases to a value of 30 ppm at 40 km. The microwave observations show a high variability of H_2O starting from 0 to 4 ppm [2]. The VIRTIS-H/VEX observations in turn show mostly uniform distribution of water about 3-5 ppm near 70 km with a large scatter from 1 to 15 ppm above the Pole [3]. The cloud-top H_2O abundance a 60-65 km has been observed by Pioneer Venus Orbiter Infrared Radiometer and Venera 15 Fourier Transform Spectrometer [4, 5]. The PV OIR instrument was found a substantial variation of H_2O abundance in the equatorial cloud-top region shortly after the sub- solar point at altitude of 62 km. The question about variability of water vapor above and inside the clouds is still opened.

2. Instrument description

The SPICAV ("Spectroscopy for Investigation of Characteristics of the Atmosphere of Venus") is a part of SPICAV/SOIR experiment onboard of the Venus-Express spacecraft. SPICAV IR spectrometer is a single pixel spectrometer for the spectral range of 0.65-1.7 μm, based on AOTF technology consisting of 2 spectral channels (LW and SW) [6]. The spectral resolution is 5.2 cm^{-1} for LW. Resulting resolving power is ~ 1400 at 1.4 μm. Field of view of the instrument for nadir observations is 2° corresponding to 10 km from the pericenter of the Venus-Express orbit. The spectra measures in two orthogonal polarizations by two bi-color detectors. SPICAV IR can be operated in the nadir/limb and solar occultation modes. Here we will consider the data treatment and results from day-side observations of SPICAV IR in nadir to obtain the water vapour distribution in the mesosphere.

3. Observations

We consider here a dataset from the middle of 2006 to the end of 2011 (VEX orbits 23-2000). The dataset covers a wide range of latitudes and local times.
The measuring of water and the cloud top based on the spectral range of 1.3-1.6 μm including the 1.38 μm band of H_2O and 1.43 μm band of CO_2 (fig.1). The previous analysis of SPICAV spectra reported in 2008-2010 has been substantially revised due to the recalibration of the instrument and especially of the instrumental function that has been obtained during the flight.

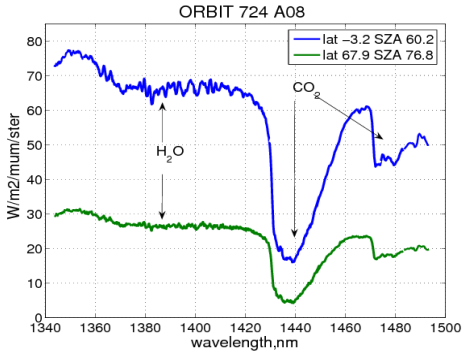

Figure1: Example of observations at orbit 724 near pericenter. CO_2 and H_2O bands are presented.

4. Atmospheric modeling

The direct modeling of near IR spectra performed using a one-dimensional version of the Spherical Harmonics Discrete Ordinate Method (SHDOMPP) [7]. As a spectroscopic source the HITRAN 2008 database has been used [8]. The temperature-pressure profiles have been taken from VIRA [9] and are latitude dependent (interpolated between the set of latitude from 30 to 85°). The clouds' model is based on Venera 11-14 measurements and haze measurements by SPICAV/SOIR solar occulations [10] with a scale height of 4 km. The two aerosol modes (1 and 2) composed of H_2SO_4 (80%) particles have been adopted.

5. The cloud top distribution

The depth of CO_2 1.43 μm band was used to determine the cloud level as it was shown by [11] because it depends on the optical path in the scattering and absorbing atmosphere.
The cloud vertical distribution can be modeled by the cloud top (the unit column optical depth) and the scaled height H. Several assumptions have been made to model the CO_2 band. The scale height H of upper clouds on Venus varies from 2 to 4 km. We choose a fixed value of 4 km that is close to SPICAV/SOIR upper haze measurements at high northern altitudes. Moreover, previous observations have shown the scale haze of the cloud top can varied from 2 to 5 km from the equator to the Pole that has not been taken into account in the current research (fig.2).

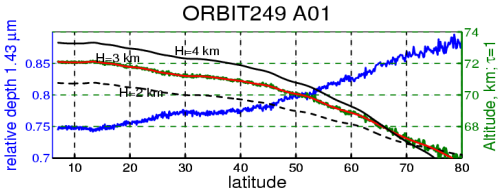

Figure 2. Sensitivity of the cloud top variation to the aerosol scale height.

Assuming H=4 km, obtained cloud top varies from 65 to 75 km. The low latitudes show weak variations of the cloud top during a single orbit (within 1 km) and a wider variation for the whole dataset between 70 and 75 km. In the high northern latitudes the cloud top decreases to 65-68 km. To avoid the error from the multiple scattering in the spherical atmosphere we have excluded solar zenith angles higher than 80° (figure 3, 4). The long duration of VEX measurements allow to search the year to year variability.

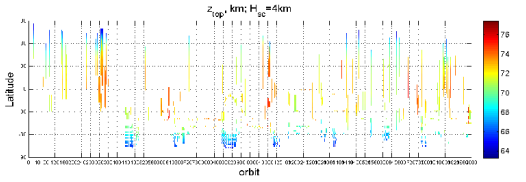

Figure 3: Variations of the cloud top with time (orbit number) and latitude for orbits from 23 to 2000

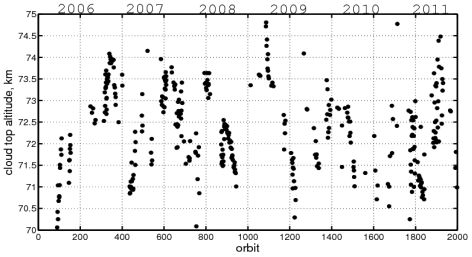

Figure 4: Variations of the cloud top with orbit. The values were averaged within the latitude range of 40°S-40°N, local time 8:00-16:00 hours and emission angle below 30°.

6. H_2O

Using the altitude of the cloud top the inverse problem for H_2O retrieval can be solved. The H_2O fitting procedure is practically identical to SPICAM IR procedure described in [12] except of the multiple-scattering in the cloudy atmosphere has been included. The main difference with our early work is non-uniform vertical distribution of H_2O inside the clouds. Based on the aerosol model and the cloud top retrieved from CO_2 band and assuming the uniform distribution of H_2O in the atmosphere up to 110 km we can obtain a mixing ratio of water exceeds 10 ppm that was not supported by other observations. 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 [1]. On the other hand the bright aerosol in near-IR allows the light to penetrate to lower altitudes <60-65 km where the water mixing ratio increases [4, 5]. The vertical distribution of water vapor within the clouds is a huge source of uncertainties in our results. It could explain the variations of water that was not observed from 2.56 μm band [3].
The current results of H_2O contents based on new calibrations and non-uniform distribution of waver inside the clouds show values of mixing ratio varies from 1 to 3 ppm for aerosol scale height of H=4 km. The sensitivity to cloud and haze model and water vertical distribution is studied.

Acknowledge

We thank CNES and CNRS for financing SPICAV in France and Roscosmos in Russia. The Russian team acknowledges RFBR grants 10-02-93116. Korablev O., Fedorova, A. and N. Zykova acknowledge also support from the Russian Government grant to the Moscow Institute of Physics and Technology for the ISPAVR laboratory.

References

[1] Fedorova, A., O. Korablev, A.C. Vandaele et al. (2008), HDO and H2O vertical distributions and isotopic ratio in the Venus mesosphere by SOIR spectrometer on board Venus Express, J. Geophys. Res. 113, E12, CiteID E00B22, doi:10.1029/2008JE003146, 2008.

[2] Sandor, B.J. and R.T. Clancy (2005), Water vapor variations in the Venus mesosphere from microwave spectra, Icarus, 177, Issue 1, 129-143.

[3] Cottini, V., Ignatiev, N., Piccioni, G. et al., Water vapor near the cloud tops of Venus from Venus Express/VIRTIS dayside data, Icarus, Volume 217, Issue 2, p. 561-569, 2012

[4] Koukouli, M.E., P.G.J. Irwin, and R.W. Taylor 2005. Water vapor abundance in Venus' middle atmosphere from Pioneer Venus OIR and Venera 15 FTS measurements, Icarus 173, 84-99.

[5] Ignatiev, N.I., Moroz, V.I., Zasova, L. V., Khatuntsev, I.V. 1999 Water vapour in the middle atmosphere of Venus:An improved treatment of the Venera 15 IR spectra, Planetary and Space Science 47 (8-9), 1061-1075.

[6] Korablev, O., Fedorova, A., Bertaux, J.-L. et al., SPICAV IR acousto-optic spectrometer experiment on Venus Express, Planetary and Space Science 65, 38–57, 2012.

[7] Evans, K. F. 2007. SHDOMPPDA: A Radiative Transfer Model for Cloudy Sky Data Assimilation. Journal of the Atmospheric Science 64, 3854-3864.

[8] Rothman et al. 2009. The HITRAN 2008 Molecular Spectroscopic Database, Journal of Quan. Spectroscopy & Radiative Transfer, 110, 533-572.

[9] Keating, G.M., J.-L. Bertaux, S.W. Bougher, T.E. et al. (1985), VIRA (Venus International Reference Atmosphere) Models of Venus Neutral Upper Atmosphere : Structure and Composition, eds : A.J. Kliore, V.I. Moroz, and G.M. Keating, Advan. Space Research, 5, No11, 117-171.

[10] Wilquet V., A. Fedorova, F. Montmessin, et al. (2009), Preliminary characterization of the upper haze by SPICAV/SOIR solar occultation in UV to mid-IR onboard Venus Express, J. Geophys. Res., 114, E00B42, doi:10.1029/2008JE003186.

[11] Ignatiev, N. I., Titov, D. V., Piccioni, G. et al. 2009. Altimetry of the Venus cloud tops from the Venus Express observations Journal of Geophysical Research 114 (E5), CiteID E00B43.

[12] Fedorova, A., Korablev, O., Bertaux, J.-L., Rodin, A., Kiselev, A., Perrier, S. 2006. Mars water vapor abundance from SPICAM IR spectrometer: seasonal and geographic distributions. J. Geophys. Res. 111, E09S08, doi:10.1029/2006JE002695.