EPSC Abstracts
Vol. 7 EPSC2012-694-1 2012
European Planetary Science Congress 2012

New measurements of Venus' dayside winds with CFHT/ESPaDOnS

P. Machado (1,2), T. Widemann (2), D. Luz (1), J.Peralta (1) and L.Rossi (2)

(1) CAAUL-Centro de Astronomia e Astrofísica da Universidade de Lisboa, Observatório Astronómico de Lisboa, Tapada da Ajuda, 1349-018 Lisboa, Portugal.(2) LESIA-Laboratoire d'Etudes Spatiales et d'Instrumentation en Astrophysique, Observatoire de Paris,CNRS, UPMC, Université Paris-Diderot, 5 place Jules Janssen, 92195 Meudon, France.

Abstract

A renewed interest in measuring Venus' winds at cloud top level from the ground has emerged in the course of the Venus Express mission. In orbit since 2006, Venus Express characterizes the atmospheric circulation at 70 km through cloud tracking with combined VIRTIS-M and VMC observations. Our comparative study is based on observations from 2009 and 2011 obtained with the 3.60 m Canada-France-Hawaii telescope (CFHT) and the Visible Spectrograph ESPaDOnS. We measure the winds using Doppler shifted solar lines and compare with previous measurements (Venus Express, Galileo, VLT/UVES. Our main purpose is to provide direct wind measurements in the northern and southern hemispheres from visible Fraunhofer lines scattered at Venus' cloud tops. This will also contribute for cross validation of the cloud tracking method used in many orbiter-based measurements.

1. Introduction

Since the Venus Express spacecraft operations started in 2006, a continuous effort has been made to coordinate its operations with observations from the ground using various techniques and spectral domains.
In the lower mesosphere (65-85 km), visible observations of Doppler shifts in solar Fraunhofer lines have provided the only Doppler wind measurements near the cloud tops in recent years [10, 11, 6]. The region is important as it constrains the global mesospheric circulation in which zonal winds generally decrease with height while thermospheric subsolar-to-antisolar (SS–AS) winds increase [1, 3]. Renewed interest in measuring the winds at clouds top from the ground has emerged in the course of the Venus Express mission supported by a recent reanalysis of Galileo observations [5, 8].

2. Observations and Method

We present an analysis of Doppler wind retrievals at Venus' cloud tops, based in observations made at the Canada France Hawaii 3.6-m telescope (CFHT) with the visible spectrograph ESPaDOnS. These observations consisted of high-resolution spectra of Fraunhofer lines in the visible range (0.37–1.05 μm) to measure the winds at cloud tops using the Doppler shift of solar radiation scattered by the cloud particles toward the observer's direction (R = 80000). The observations were made in 2009 and 2011 and were coordinated with observations from ESA's Venus Express mission (VIRTIS and VMC instruments).
The observations included various points of the dayside hemisphere at a phase angle of 67 degrees. Between +10 and -60° by steps of 10°in latitude, and +70°to -12°to sub-Earth meridian by steps of 12° in longitude (fig. 1.b).
The complete spectrum spanning the range 0,37–1,05 μm, was collected over 40 spectral orders at each point with 2-5 seconds exposures at a resolution of ~ 80000.

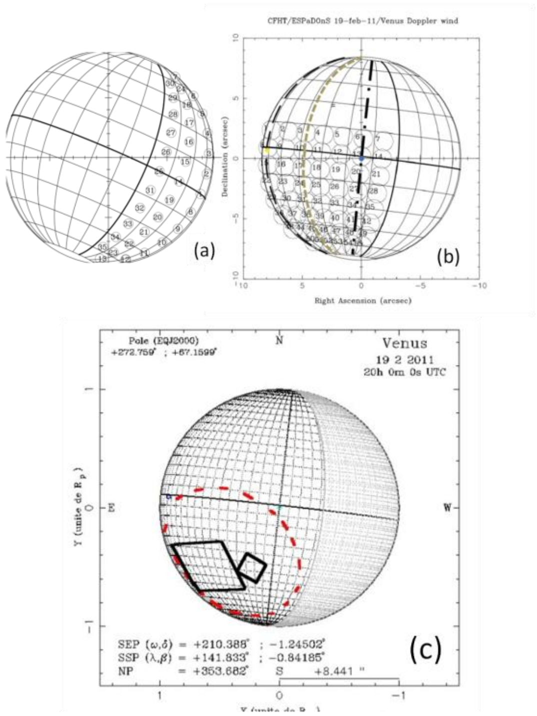

Figure 1: Geometry of the 2009 (fig. 1.a) observations and of the coordinated 2011 observations at CFHT (fig. 1.b), covering various points of the dayside hemisphere at a phase angle of 67 degrees, The complete optical spectrum was collected over 40 spectral orders at each point with 2-5 sec exposures, at a resolution of about 80000, that allowed to produce high-resolution spectra of Fraunhofer lines in the visible range (0.37–1.05 μm). The observations were made at 19-20 February 2011 and were coordinated with VMC (VMC field of view : red line in fig. 1.c) and VIRTIS (VIRTIS M field of view : black squares in fig. 1c) observations from ESA's Venus Express (VEx) mission.

The Doppler shift measured in scattered solar light on the Venus dayside results from two instantaneous motions: (1) a motion between the Sun and Venus upper cloud particles; (2) a motion between the observer and the Venus cloud. Therefore it varies with planetocentric longitude and latitude. In order to avoid the problem of maintaining a stable velocity reference during the acquisition we computed the relative Doppler shifts between two sets of absorption lines, while simultaneously monitoring the change in spectral calibration with time [11].This allows nominal accuracies of 5-10 m s^{-1}, and their signs and magnitudes are generally consistent with zonal winds inferred from cloud tracking. This is, currently, the only technique that can derive the absolute wind's velocity value and correlate them with winds determined from cloud tracking in the VEx VIRTIS-M and VMC UV images, and their temporal variation.

For Doppler velocimetry at visible wavelengths the optical depth reaches unity at 70 km [2], which is also the altitude studied with cloud tracking measurements based on imaging in the UV [9, 7]. This allows a direct comparison of magnitudes and spatial variations obtained with VLT/UVES and with Pioneer Venus, Galileo (SSI), and Venus Express.

3. Results and Prospects

The main purpose of our work is to provide variable wind measurements with respect to the background atmosphere, complementary to simultaneous measurements made with the VMC camera onboard the VEx spacecraft. We will present first results from this work, comparing with previous results by CFHT/ESPaDOnS and VLT-UVES spectrographs [6], with Galileo fly-by measurements [8] and with VEx nominal mission observations.

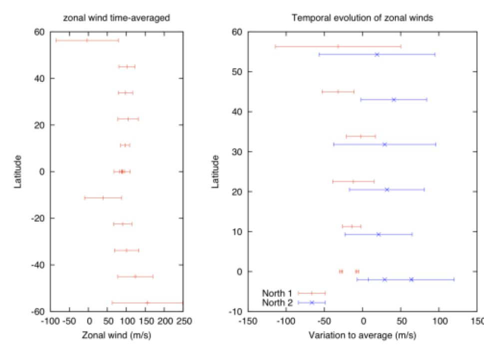

Figure 2: Preliminary results for the CFHT/ESPaDOnS 2009 observations. (a) Averaged zonal wind retrieved from the full data set. (b) Variation relative to the average for the two sequencies.

4. Summary and Conclusions

The data taken at CFHT/ESPaDOnS in 2009 and 2011, in coordination with Vex/VMC and Vex/VIRTIS measurements, were part of our program of monitoring the venusian wind variability and wave structure [10, 11, 6].

Our previous Doppler retrievals are in general good agreement with previous measurements based on cloud tracking [5, 8, 9, 7]. We have retrieved the same order of magnitude and latitudinal variation of Pioneer

Venus, Galileo and VEx/VIRTIS measurements, which cross-validates both techniques and provides reasonable confirmation that cloud tracking and Doppler methods both retrieve the velocities of air masses to first order.

Acknowledgements

The authors acknowledge support from Portuguese Foundation for Science and Technology FCT through projects PTDC/CTE-AST/110702/2009 and PEst-OE/FIS/UI2751/2011 and PM Phd grant (reference: SFRH/BD/66473/2009). PM and TW also acknowledge support from the Observatoire de Paris.

References

[1] Bougher S., Hunten D. and Philips R., Venus II, University of Arizona Press, Tucson, AZ, Bougher S.W, Hunten D.M. and Phillips R.J., Eds., p. 259-291, 1997.

[2] Ignatiev, N. I. et al., J. Geophysical Research 114, E00B43, 2009.

[3] Lellouch, E. et al., Monitoring of mesospheric structure and dynamics, in: VenusII. The University of Arizona Press, Tucson, AZ, Bougher S.W, Hunten D.M. and Phillips R.J., Eds., p. 295-324, 1997.

[4] Lellouch, E., and Witasse, O., A coordinated campaign of Venus ground-based observations and Venus Express measurements, Planetary and Space Science 56 1317–1319, 2008.

[5] Limaye S.S., (2007) Venus Atmospheric Circulation: Known and unknown, volume 112, E04S09, 2007.

[6] Machado, P., Luz, D. Widemann, T., Lellouch, E., Witasse, O, Characterizing the atmospheric dynamics of Venus from ground-based Doppler velocimetry, submitted to Icarus, 2012.

[7]Moissl, R. et al., J. Geophysical Research 114, E00B31, 2009.

[8] Peralta J., R. Hueso, A. Sánchez-Lavega, A reanalysis of Venus winds at two cloud levels from Galileo SSI images, Icarus 190, 469–477, 2007.

[9]Sánchez-Lavega, A. et al., Geophysical Research Letters, Vol. 35, 2008.

[10] Widemann, T., Lellouch, E., and Campargue, A. 2007, New Wind Measurements in Venus’ Lower Mesosphere From Visible Spectroscopy, Planetary and Space Science 55, 1741-1756, 2007.

[11] Widemann, T., Lellouch, E., Donati, J.-F., Venus Doppler winds at Cloud Tops Observed with ESPaDOnS at CFHT, Planetary and Space Science, 56, 1320-1334, 2008.