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Ground-based Doppler velocimetry using CFHT/ESPaDOnS and comparison with simultaneous cloud tracking measurements using VEx/VIRTIS

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Abstract

We present results based on inter comparison of ground-based Doppler velocimetry of cloud-top winds and cloud tracking measurements from the Venus Express spacecraft. Doppler wind velocimetry obtained with the 3.60 m Canada-France-Hawaii telescope (CFHT) and the Visible Spectrograph ESPaDOnS in February 2011 consisted of high-resolution spectra of Fraunhofer lines in the visible range (0.37-1.05 μm) to measure the wind velocity using the Doppler shift of solar radiation scattered by cloud top particles in the observer's direction. The complete optical spectrum was collected at a phase angle $\Phi = (68.7 \pm 0.3)^\circ$, at a resolution of about 80000. We compared our measurements with simultaneous observations using the Visible and Infrared Thermal Imaging Spectrometer (VIRTIS) instrument from the VEx orbiter. CFHT observations included various points of the dayside hemisphere, between $+10^\circ$N and 60°S, by steps of 10°, and from sub-Earth longitude $[\phi - \phi_E] = 0^\circ$ to -50° corresponding to 7:30a - 10:50a, while VIRTIS-M UV (0.38 μm) cloud tracking measurements extended on the dayside south hemisphere between 30 and 50°S and 9:05a - 10:50a at simultaneous spacecraft orbit VV1786. The retrieved Doppler winds are in good agreement with measurements based on cloud tracking from Venus Express. We observe zonal wind field variations in the latitudinal and temporal scales within stable mean background velocities of $\bar{v_z}$ = 117.35 ± 18.0 ms^{-1} on Feb. 19, and $\bar{v_z}$ = 117.5 ± 14.5 ms^{-1} on Feb. 21, respectively. We present the first detection from the ground of a poleward meridional wind flow on the morning dayside hemisphere, of 18.8 ± 11.5 m s^{-1} on Feb. 19, and 19.0 ± 8.3 m s^{-1} on Feb. 21. Wind temporal, local variation at the hour-scale of ±18.5 m s^{-1} is detected near morning terminator at low latitude. Our analysis technique allows an unambiguous characterization of the zonal wind latitudinal, local time profile and its temporal variability.

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. Both ground-based and Venus Express measurements show considerable day-to-day variability, which needs to be carefully assessed [6, 8, 3, 1, 4, 5].

The atmosphere of Venus is in superrotation, a state in which its averaged angular momentum is much greater than that corresponding to co-rotation with the surface. The circulation up to the cloud tops is characterized by an increasing retrograde zonal superrotating (RZS) wind (in the East-West direction). The wind starts to build up at 10 km and amplifies with altitude, reaching a maximum at cloud tops ($\sim$ 70 km). The RZS is accompanied by a Hadley-type meridional circulation from the equator to poles and both converge to an unique polar vortex circulation.

2. Method and results

The methods applied in recent planetary wind measurements using high-resolution spectroscopy in the visible range [2, 8, 4, 5] all address the fundamental problem of maintaining a stable velocity reference during the acquisition process. In order to measure the global circulation at cloud top altitude, we need to address wind amplitude variations (or wind latitudinal gradients) on the order of 5-10 m/s projected on the line-of-sight [7]. Such an accuracy cannot be achieved by single line fitting, even at high spectral resolution. Therefore, it becomes necessary to optimally measure relative Doppler shifts between two sets of absorption lines, while simultaneously monitoring the change in spectral calibration with time [8].

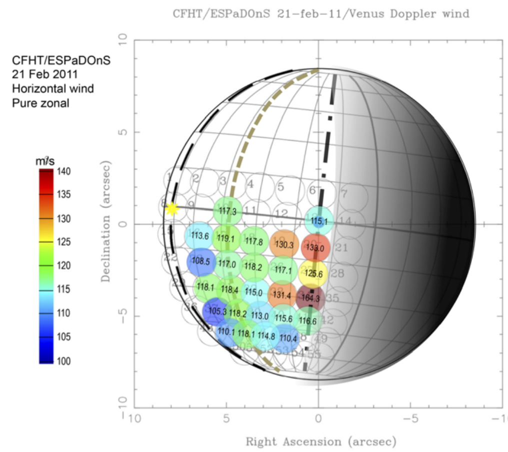

Figure 1: Results for zonal wind velocity reported at each offset position on Feb. 21, 2011.

The Doppler shift measured in solar scattered light on Venus dayside is the result of two instantaneous motions: (1) a motion between the Sun and Venus upper clouds particles, which scatter incoming radiation in all directions including the observer's; this Doppler velocity is minimal near Venus sub-solar point; (2) a motion between the observer and Venus clouds, resulting from the topocentric velocity of Venus cloud particles in the observers frame; this effect is minimal near Venus sub-terrestrial point. The measured Doppler shift is the sum of these two terms, and it varies with planetocentric longitude and latitude.

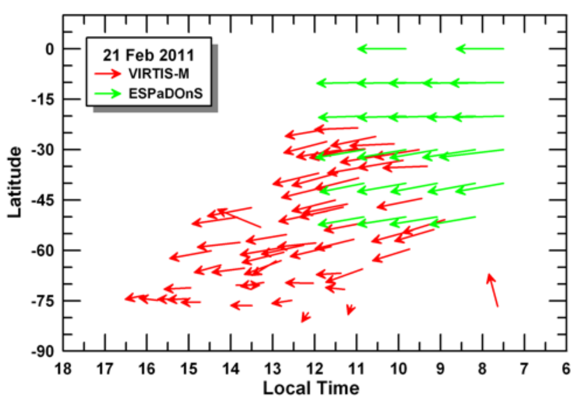

Figure 2: Wind vectors map showing simultaneous wind velocity measurements of VIRTIS-M UV (red arrows) and ESPaDOnS (green arrows).

We measured the winds using Doppler shifted solar lines and compared with our measurements with VLT/UVES [4] and with previous measurements with Venus Express, and Galileo. From these 2011 observations we also present the results of the synchronized coordinated observations made by the VIRTIS instrument from the Venus Express orbiter.

References

[1] Hueso, R., Peralta, J., Sànchez-Lavega, A., Assessing the long-term variability of Venus winds at cloud level from VIRTIS-Venus Express, Icarus, Vol. 217, pp. 585-598, 2012.

[2] Luz, D. et al. Characterization of zonal winds in the stratosphere of Titan with UVES: 2. Observations coordinated with the Huygens Probe entry, Journal of Geophysical Research, volume 111, CiteID E08S90, 2006.

[3] Luz, D. et al. Venus's Southern Polar Vortex Reveals Precessing Circulation, Science, Vol. 332, pp. 577-580, 2011.

[4] Machado, P., Luz, D. Widemann, T., Lellouch, E., Witasse, O, 2012, Characterizing the atmospheric dynamics of Venus from ground-based Doppler velocimetry, Icarus, Vol. 221, pp. 248-261, 2012.

[5] Machado, P., Widemann, T., Luz, D., Peralta, J., Wind circulation regimes at Venus' cloud tops : Ground-based Doppler velocimetry using CFHT/ESPaDOnS and comparison with simultaneous cloud tracking measurements using VEx/VIRTIS in February 2011, Icarus, (submitted).

[6] Sornig, M., Livengood, T., Sonnabend, G., Stupar, D., Kroetz, P., Direct wind measurements from November 2007 in Venus' upper atmosphere using ground-based heterodyne spectroscopy of CO2 at 10 μm wavelength, Icarus Vol. 217, pp. 863-874, 2012.

[7] Widemann, T. et al., New wind measurements in Venus lower mesosphere from visible spectroscopy, Planetary and Space Science, Vol. 55, pp. 1741-1756, 2007.

[8] Widemann, T. et al., Venus Doppler winds at cloud tops observed with ESPaDOnS at CFHT, Planetary and Space Science, Vol. 56, pp. 1320-1334, 2008.