VENUS WINDS WITH GROUND-BASED DOPPLER VELOCIMETRY AND COMPARISON WITH COORDINATED CLOUD TRACKING METHOD WINDS

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Introduction

A complete characterization of the venusian superrotation is crucial for understanding its driving mechanisms. 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 (Widemann et al., 2007, 2008, Machado et al., 2012). The region is important as it constrains the global mesospheric circulation in which zonal winds generally decrease with height while thermospheric subsolar–antisolar (SS-AS) winds increase (Bougher et al., 1997; Lellouch et al., 1997).

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.

We will present wind results 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 our measurements with VLT/UVES (Machado et al., 2012) and with previous measurements with Venus Express, and Galileo. For the 2011 observations we will present also the results from the synchronized coordinated observations made by the VMC and VIRTIS cameras from the orbiter Venus Express.

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 (Lellouch and Witasse, 2008). Both ground-based and Venus Express measurements show considerable day-to-day variability which needs to be carefully assessed.

ESPaDOnS and the sequential technique of visible Doppler velocimetry have proven a reliable way to constrain wind gradients in the lower mesosphere and global wind circulation models.

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.

Observations and method

We measure the horizontal wind field at the cloud top level of the atmosphere of Venus, near 70 km, in order to characterize the latitudinal zonal wind profile, to study variability, to constrain the effect of large scale planetary waves in the maintenance of superrotation, and to detect lower mesosphere additional wind regimes. This was done by tracking Doppler shift of solar lines over the dayside hemisphere.

We present an analysis of Venus Doppler winds at cloud tops based on observations made at the Canada-France-Hawaii 3.6-m telescope (CFHT) with the ESPaDOnS visible spectrograph. 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 cloud top particles in the observer's direction (Widemann et al., 2007, 2008). The observations were made during 19-21 February 2011 and were coordinated with Visual Monitoring Camera (VMC) observations by Venus Express. The complete optical spectrum was collected over 40 spectral orders at each point with 2-5 seconds exposures, at a resolution of about 80000. The observations included various points of the dayside hemisphere at a phase angle of 67°, between +10° and -60° latitude, in steps of 10°, and from +70° to -12° longitude relative to sub-Earth meridian in steps of 12°.

The Doppler shift measured in scattered solar light on 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 Venus clouds. The measured Doppler shift, which results from these two terms combined, varies with the planetocentric longitude and latitude and is null at the bisector's (half phase angle) meridian $V_N = V_{Sun} - V_{Earth}$, where the two components cancel each other in the case of a pure zonal regime. Due to the need for maintaining a stable velocity reference during the course of acquisition using high resolution spectroscopy, we measure Doppler shifts to relative V_N.

Results and Prospects

The main purpose of our work is to provide wind measurements and its variability with respect to the background atmosphere, complementary to simultaneous measurements made with the VMC camera onboard the Venus Express spacecraft. We will present first results from this work, comparing with previous results by the CFHT/ESPaDOnS (Widemann et al., 2007, 2008) and VLT-UVES spectrographs (Machado et al., 2012), with Galileo fly-by measurements and with VEx nominal mission observations (Peralta et al., 2007).

Summary and Conclusions

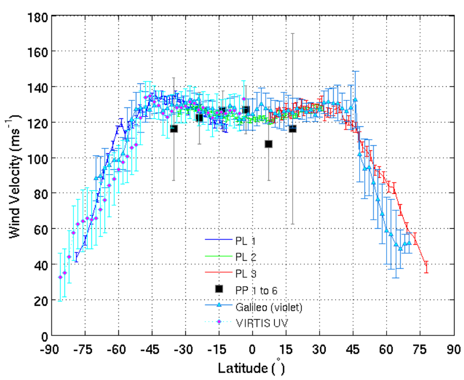

Fig 2 – Latitudinal wind profile, comparison between VLT/UVES Doppler instantaneous winds [6] and cloud tracking, space based, winds [7, 8].

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.

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