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Venus's winds and temperatures during the MESSENGER's flyby: towards a three-dimensional instantaneous state of the atmosphere

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Abstract

We present a three-dimensional global view of Venus's atmospheric circulation from data obtained in June 2007 by the MESSENGER and Venus Express (VEx) spacecrafts, together with ground-based observations [1]. Winds and temperatures were measured from 47 to 110 km from multi-wavelength images and spectra covering 40°N–80°S and local times 12h to 21h. Dayside westward winds exhibit day-to-day changes, with maximum speeds ranging 97–143 m/s and peaking at variable altitudes within 75–90 km, while on the nightside these peak below cloud tops at ∼60 km. Our results support past reports of strong variability of the westward zonal superrotation in the transition region, and good agreement is found above the clouds with results from the LMD Venus general circulation model [2].

1. Introduction

The general circulation of the Venus atmosphere consists of two main regimes: a Retrograde Superrotating Zonal circulation (RSZ) dominating the cloud region 40–90 km, a strong subsolar-to-antisolar circulation (SS-AS) above 120 km, and a complex transition region within 90–120 km. New General Circulation Models (GCMs) simulate the bulk atmosphere from the surface to the thermosphere [2] and current efforts are oriented toward "data assimilation" from space missions. Thus, acquiring detailed snapshots of the Venus winds at specific moments/epochs is essential to set realistic initial conditions and top/lower boundaries in GCMs with data assimilation. Unfortunately, wind measurements on Venus have been dispersed spatially and in time, and studies of long-term data have only focused on the three best known cloud levels and provide time averages, ignoring the time evolution for a given instantaneous 3-D state [3].

2. Observations and Methods

During the VEx mission a campaign of coordinated observations was performed in June 2007 when NASA's spacecraft MESSENGER made its second flyby of Venus towards Mercury [4]. A first realistic approximation to the instantaneous dynamic state of the Venus atmosphere is performed combining new and previously published wind measurements during the flyby, using data from eight instruments of MESSENGER, VEx, and Earth-based telescopes. The wind speeds and atmospheric temperatures of Venus were calculated for the afternoon and early night during several days around the flyby (see Figure 1) using three remote sensing techniques: Cloud-tracking winds (CT), and Doppler and thermal winds derived from the atmospheric spectra and inferred temperatures, respectively. The images for CT were acquired by the cameras MESSENGER/MDIS, VEx/VMC, and the imaging spectrometer VEx/VIRTIS-M [1]. Our images were taken with different filters to sense the atmospheric motions at several atmospheric levels [5]: the dayside upper clouds at ∼60 and ∼70 km from the scattered sunlight (350 and 996 nm), the oxygen nightglow (1.27 µm) at 95–100 km, the thermal emission of the night upper clouds (3.8 µm) at ∼65 km, and the night lower clouds' opacity to the deep thermal emission (1.74 µm) from ∼50 km. Our atmospheric spectra to estimate winds and temperature cover ultraviolet-visible wavelengths (VLT/UVES), the infrared range

(VEx/VIRTIS-M and the Heterodyne Infrared Spectrometer THIS), and submillimeter spectra from the radio-telescopes IRAM, JCMT and HHSMT [1,4].

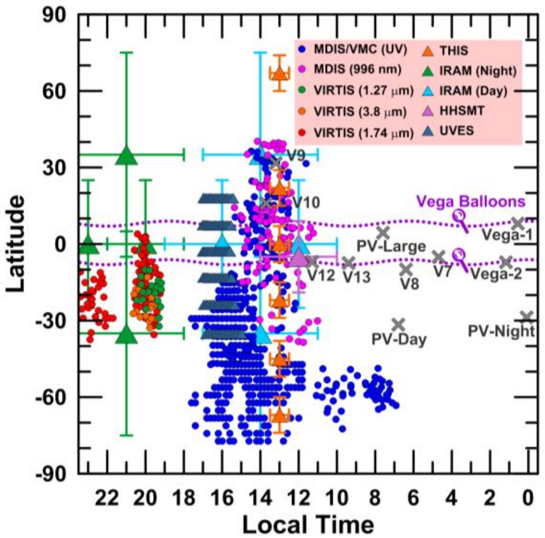

Figure 1: Spatial coverage of our measurements.

3. Results and Conclusions

Our wind measurements were combined to describe the vertical variation of the winds (Figure 2). For a coherent comparison, the zonal winds were averaged for the latitude range 0°–30°S and local times 12h–16h and 19h–21h. Figures 2A and 2B correspond to afternoon during 2–11 June 2007 and early night to 2–5 June. Thermal winds were calculated with the thermal wind equation and temperatures from JCMT and VIRTIS-M: for dayside, 3 days of JCMT thermal gradients were calculated, and only 1 day of VIRTIS-M. Zonal winds are compared with vertical profiles of VEGA, Pioneer Venus and Venera series at similar areas of latitude/local time. Zonal winds predicted by the Venus LMD GCM [2] are also exhibited. The GCM underestimates winds below 60 km, while above it predicts the dayside gradual decrease of the zonal wind towards weak eastward values and the night strong recovery up to winds faster than −140 m/s. The GCM does not predict the step decrease in the night thermal winds at the upper clouds (Fig. 2B), apparently related to a sudden breakdown of the cyclostrophic balance from ∼73 km [1]. Our results also show that both the height and maximum value of the zonal wind peak seem subject to significant changes on the dayside (Fig. 2A), with altitudes ±15 km about the cloud tops and speeds ranging from −97±8 m/s to −143±21 m/s. Regarding the nightside, the zonal wind peaks even deeper (∼60 km) with speeds weaker than on dayside. This behavior is also consistent with the interpretation of eventual vertical invasions of the SS-AS circulation down to deeper altitudes [1].

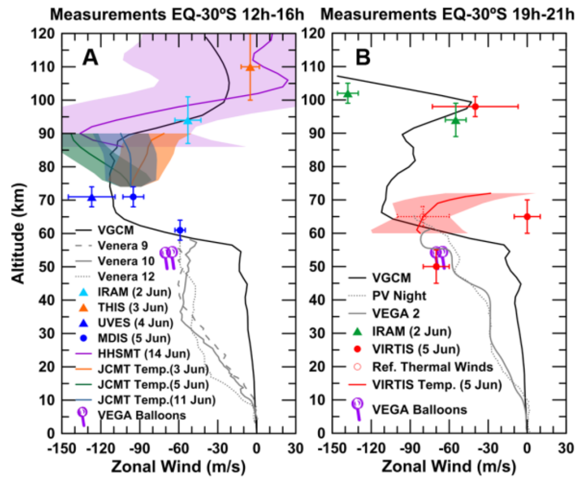

Figure 2: Vertical profiles of zonal wind in June 2007.

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