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Variations of the zonal flow at Venus cloud tops from VMC/VEX UV images in period from 2006 to 2014

I.V. Khatuntsev (1,2), M.V. Patsaeva (1,2), N.I. Ignatiev (1,2), D.V. Titov (3), W.J. Markiewicz (4), S.S. Limaye (5) and A.V. Turin (1)
(1) Space Research Institute (IKI), Russian Academy of Sciences, Moscow, Russia; (2) Moscow Institute of Physics and Technology, Dolgoprudny, Russia; (3) ESA/ESTEC, PB 299, 2200AG Noordwijk, Netherlands; (4) Max Planck Institute for Solar System Research, Justus-von-Liebig-Weg 3, 37077 Göttingen, Germany; (5) Space Science and Engineering Centre, University of Wisconsin, Madison, WI 53706, USA (khatuntsev@iki.rssi.ru / Fax: +74953332102)

Abstract

Venus Monitoring Camera [1] onboard Venus Express [2] made long-term UV observations (2006-2014) of upper cloud of Venus. Out of the 3000 orbits of Venus Express over which the images used in the study cover about 13 Venusian years. We tracked cloud features in UV images obtained in 140 orbits by a manual cloud tracking technique and by an automated digital method in 690 orbits. Both methods and main results are described in detail in [3]. The VMC observations indicate a long term trend for the zonal speed of the flow at low latitudes to increase from 85 m/s in the beginning of the mission to the maximum (about 110 m/s) by the middle of 2012 and decreasing up to 97 m/s at present time (middle of 2014). VMC UV observations also showed significant short term variations of the mean flow in low latitudes with a period of 4.1-5 days (4.83 days on average) that is close to the super-rotation period at the equator. The wave amplitude is ±4-17 m/s and decreases with latitude, a feature of the Kelvin wave. The VMC observations demonstrated a clear diurnal signature. A minimum in the zonal speed was found close to the noon (11-14 h) and maxima in the morning (8-9 h) and in the evening (16-17 h). The meridional component peaks in the early afternoon (13-15 h) at around 50ºS latitude. The minimum of the meridional component is located at low latitudes in the morning (8-11 h). Here we present the latest update of our result.

1. Introduction

Due to the long term observation series, high resolution and complete coverage of the Southern hemisphere the VMC/Venus Express imaging provided for the first time details of variations of the cloud motion field, thus making a significant step forward in understanding of the Venus cloud level circulation. The analysis of the measurements reveals both long-term and relatively short-term changes of the zonal flow field. Both periodic and aperiodic components can be distinguished in the long-term variations. The analysis of the long term trends, orbit-to-orbit variability of the mean flow, periodicities and diurnal variations of the cloud motion field are presented below.

2. Long term periodicities

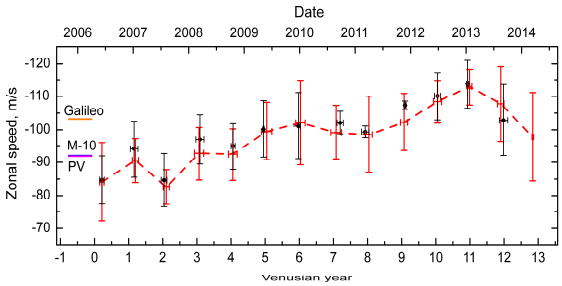

Figure 1: Long term trend of the mean zonal flow at 20º±2.5ºS over the mission time. Symbols show orbital averages derived by manual (black circle) and digital ("+" and red dotted line) methods. The results from the Mariner-10 (92 m/s), Pioneer-Venus (91.8±3 m/s) and Galileo (103 m/s) missions for the same latitude zone are presented at the left edge of the plot for comparison.

Cloud motion speed measurements at low latitudes are grouped in data sets of about Venusian year associated with VMC/VEX orbital observations (Figure 1). The analysis of the grouped data usually results in aliasing periods. For this reason for frequency investigations of u(t) we applied special technique based on Fourier analysis [4].

The time series u(t) contains a low frequency trend with a quasiperiod of about 3700-3800 days which origin is unclear. In this case it may be a

manifestation of influence of the solar activity on dynamics of the equatorial region of the Venusian atmosphere.

The trend was subtracted from the time series and analysis of the residual series was continued. We found periodic oscillations of the zonal flow speed with period of 117±5 days. It is close to solar day on Venus (116.8 days) suggesting that the long period variations of the mean zonal flow have solar-related behavior. All other long term periods are the aliasing of the found periods.

3. Short term variations

In the equatorial region the time variations of zonal flow have periodic behavior. Analysis [4] (see for details [3]) of all time series provides a period near the superrotation period of ~4.83±0.1 days with the amplitude ±4.28 m/s.

The maximum wave amplitude of about ±17 m/s was observed in the equatorial region for orbits #1329-1347. The corresponding period is equal to 4.5 days. Comparison of series of consecutive orbits suggests that the main parameters of the zonal flow oscillations remain stable for at least 85 days.

The wave amplitude decreases with latitude suggesting a propagating Kelvin wave [3].

4. Diurnal variability

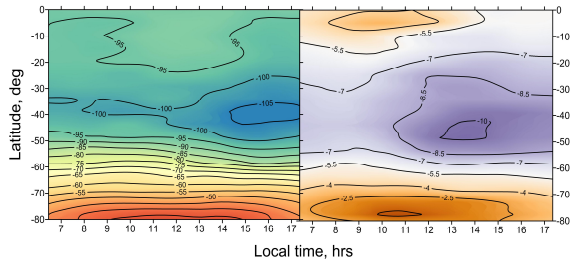

Figure 2: Diurnal variations of the mean zonal (left) and meridional (right) components of the flow.

Complete coverage of the day side in the Southern hemisphere by the VMC UV imaging enables the study of diurnal variations of the mean cloud motion pattern and search for solar locked features in the zonal and meridional flow components. The zonal flow field in low latitudes (Figure 2) shows semi-diurnal variations with minimum speed close to noon (11-14 h) and maxima in the morning (8-9 h) and in the evening (16-17h). The meridional component clearly peaks in the early afternoon (13-15h) at 40-50ºS. The minimum of the meridional component of the flow speed is located at low latitudes in the morning (8-11h).

5. Summary and Conclusions

Mean zonal speed of the flow demonstrates the long term variations. Mean zonal speed in the equatorial region changes in the range 85-115 m/s. A slow trend is observed over the time scale of 3700-3800 days that might be a manifestation of the solar activity.

The long-period variations have solar-related behavior with the period of 117±5 days.

In the equatorial regions short term oscillations of the zonal speed of the flow were detected. Short term oscillations are characterized by the mean period of ±4.83 days which is close to the superrotation period.

The VMC observations showed clear diurnal pattern of the mean circulation. Solar related signature was found in the averaged fields of the flow.

Acknowledgements

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