EPSC Abstracts
Vol. 5, EPSC2010-232, 2010
European Planetary Science Congress 2010

Dynamic regions versus latitude of the Venus lower cloud layer

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Abstract

The statistical meridional distribution of the different dynamic regions in the lower cloud layer of Venus is investigated here by using the VIRTIS (Visible and InfraRed Thermal Imaging Spectrometer) data over a period of 27 months. The lower cloud layer at about 47 km is effectively probed using the images at 1.74 μm. The dynamic recurrent patterns are investigated through a Fast Fourier Transform analysis of the images with a specific methodology: a set of parameters retrieved by the FFT Power spectrum is used to differentiate quantitatively a laminar flow, gravity wave on laminar flow, a transversal flow towards the zonal direction and a turbulent flow. Through a proper data representation we have obtained a plot of the dynamic behavior versus latitude for the whole data set. The method can be potentially applied also to other planets.

1. Method and Results

The hyperspectral imager VIRTIS onboard the Venus-Express spacecraft [1][2] in orbit around Venus has acquired a large data set of images of the Southern hemisphere. The typical projected field of view in nadir mode covers about 45 degrees both in latitude and in longitude from a distance of about 65000 km [2]. The radiance escaping from the deep atmosphere of Venus into space in the atmospheric window at 1.74 μm is modulated by the opacity of the lower clouds placed at about 47 km [3] and thus it can be effectively used to probe this cloud layer. The dynamic regimes exhibit very different cloud feature morphologies [4].

To obtain a self-consistent quantitative evaluation of the dynamic recurrent patterns we have developed a FFT image analysis method [5]. The FFT image is calculated along the zonal direction at a fixed latitude, since this mimics the main motion of the Venus atmosphere. The FFT power spectrum (FFTPw) is used to retrieve specific parameters that are able to differentiate the dynamic regimes. One of these parameters, named Diff, is the difference between two FFT spectral slopes at two different wavenumber ranges. Diff allows us to detect the presence of laminar or turbulent regimes by means of a critical value for which the observed dynamic behavior changes radically. From our data we found a critical value of 4.0 for this parameter. Another parameter, named Gap, is the difference between the FFTPw value of the first wavenumber and the mean value of the FFTPw of the higher wavenumbers: the Gap parameter reveals the presence of turbulence at the lower scale. The Gap critical value is 7.5 and it allows us to differentiate turbulence from transversal (towards the zonal motion) laminar flow or laminar from laminar flow with gravity waves. In summary, it is possible to identify four different dynamic regimes. We plot in Fig.1 the normalized Diff and Gap data, NDGL plot, by using:

NDiff = (Diff - 4.0) and

NGap = [6.0 (Gap - 7.5)] variables;

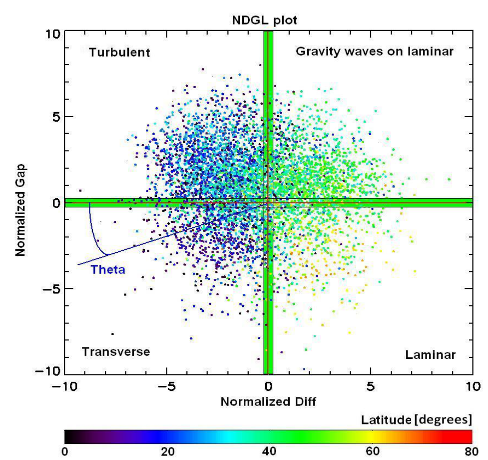

Figure 1: Each point on the NDGL plot is obtained from the FFT image sampled at fixed latitude. Each quadrant indicates specific dynamic condition.

the two wide 0.6 bands in correspondence with the two axes (in green) indicate the region in which we consider an ambiguous behavior. The NDGL plot is a 3D representation in which the 3rd dimension for the latitude is expressed by a color scale, nevertheless, in the NDGL plot the information about the dynamic condition is only given by the position in a certain quadrant and not by the distance from the origin. The position in a specific quadrant can be expressed without waste of information by using the polar coordinate Theta = [arctan(NGap/NDiff) - 180°].

The correspondence between a Theta value and one of the four dynamic conditions permits the use of this last parameter to represent the information on the dynamic condition versus latitude directly in a 2D plot, the TL plot shown in Fig.2. In such a plot, the critical Theta values are for 0, 90, 180, 360 degrees. The points included between -0.3 and 0.3 in the NDGL plot (green color bands along the two axes in Fig.1) now reported in the TL plot are not localized in a specific region even if the points are preferentially accumulated close to the critical Theta values (green points in Fig.2).

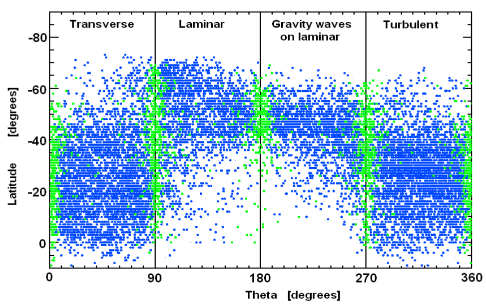

Figure 2: TL plot for the set of data obtained by 338 VIRTIS cubes acquired over a period of 27 months. It shows the statistical distribution in latitude of the dynamic behavior of the Venus lower cloud layer.

The TL plot represented in Fig.2 is obtained by using data retrieved by the FFT image analysis of 338 VIRTIS cubes acquired from June 2006 to September 2008. This set is the largest set of VIRTIS data available for this kind of study. The statistical distribution in latitude of the dynamic behaviors shows the existence of preferential zonal regions for specific dynamic regimes, and the presence of a dynamic transitional region between "kind laminar" and "kind turbulent" flows. The minimum latitude at about -75 degrees is imposed by the combination of the VIRTIS field of view, orbital geometry and the constraint due to the 1000 km of extension for the samples at each fixed latitude [5]. This TL plot gives a direct view of the statistical relationship between the latitude and the dynamic behavior of the clouds, and it can be summarized as follows [latitude in degrees]: turbulent flow region [–45 ÷ 0]; gravity waves on laminar flow region [–60 ÷ –40]; laminar flow region [–70 ÷ –40]; transverse flow region [–50 ÷ 0]; transition region between turbulet and laminar flows is [–45 ÷ –35].

2. Summary and Conclusions

The FFT analysis method here discussed can provide information about the dynamic conditions. It was applied to the Venus Southern hemispere images at 1.74 μm extracted from 338 cubes acquired by VIRTIS from June 2006 to September 2008. The results of this statistical study reveal the existence of persistent regions. These regions are [latitude in degrees]: laminar flow [–70 ÷ –40]; gravity waves on laminar flow [–60 ÷ –40]; transverse flow [–50 ÷ 0]; turbulent flow [–45 ÷ 0]. We observe the existence of a transition region between turbulent and laminar flows from –45 to –35 degrees. This method was developed to be applied to Venus but it can be employed, with the suitable changes, to study the atmosphere of other planets, providing valuable information for comparative planetology studies.

Acknowledgements

Venus Express is a mission of ESA (European Space Agency). VIRTIS was supported by ASI (Agenzia Spaziale Italiana), CNES (Centre National d'Etudes Spatiales) and DLR (Deutsches Zentrum für Luft und Raumfahrt). This work was supported by ASI.

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