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# Energy transportation of Venusian atmospheric turbulence evaluated by VEX/VMC UV images

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In the Venusian atmosphere, there are waves with various scales and the waves compose turbulence.

In order to evaluate the energy transportation of the turbulence in the Venusian atmosphere, we derived the power spectra of the cloud brightness distribution at the cloud top (altitude ˜65 km) using the UV images obtained by Venus Monitoring Camera (VMC) onboard Venus Express. VMC has provided the first uniform long-term data set of Venusian UV images, which covers over 4 years with high spatial resolution, ˜25 - 45 km/px, that has been never performed before.

According to the classical turbulence theory, power spectral intensity at the wavenumber k is expressed by $P(k)=C_k k^{-n}$ where the index ?n corresponds to the slope of the spectrum in the logarithmic plot and characterizes the power spectrum. In this study, we analysed the 44 images of Venus full disc obtained from May 2006 to January 2010. We derived the long-term characteristics of the power spectra from 0.0001 /km to 0.01 /km in the latitude from 20S to 70S. This wide wavenumber coverage enables us the comparison with the similar characteritics found in the terrestrial atmosphere. We also evaluated the correspondence between the slopes of the obtained spectra and the theoretical values (-3 and -5/3).

The main results obtained from this study are as follows:

(1) The power spectra of the cloud brightness distribution mostly show the inflection. The slope at lower wavenumbers is generally steeper than that at higher wavenumbers. Such a feature agrees with the characteristics in the kinetic energy spectra on Earth (Nastrom et al., 1984; Nastrom and Gage, 1985).

(2) The obtained slopes at planetary wavenumbers $K < 50$ (˜ 0.001 /km at the latitude of 20S) are intermediate value between the theoretical values (-3 and -5/3). It agrees well with the previous Venusian studies (Peralta et al., 2007) in which the slope at $K < 50$ was also in this range. Our results also confirmed that this feature is common over three years.

(3) Because of the high spatial resolution of VMC, the slope at higher wavenumbers (0.002 - 0.01 /km) can be derived. It sometimes shows close to zero, which is not seen in the terrestrial cases. Further checks and investigations are needed to fix the view.

(4) Here is the first attempt to identify the temporal/spatial changes of the slopes in short interval as several hours. This result also suggests that the PSD slope has a large variability in the individual latitude.

(5) The wavenumbers at the inflection point are 0.001 - 0.003(/km). The numerical study (Kitamura and Matsuda, 2006) suggests that the inflection point (wavelength ˜330-1000km) is the border between 2D and 3D turbulence. Thus, our result indicates that the enstrophy forward cascade of 2D turbulence occurs at lower wavenumbers and the energy forward cascade of 3D turbulence occurs at higher wavenumbers.

Tung and Orlando (2003) suggested that the injection would occur at synoptic-scale. However, due to the limitation of the longitudinal coverage of our measurements, it is hard to investigate in the range of synoptic-scale. As a future work, full-disc observations are indispensable in order to investigate the source of injection. At present, baroclinic instability wave and thermal tides are considered for the possible driving mechanism of injection. Specifying the injection cause will provide us important information on the energy and enstrophy transportation. Therefore composite of the multiple images will enable us to expand the longitudinal coverage and derive the spectra which cover synoptic-scale.

Furthermore, recent results using the same instrument successfully performed cloud wind tracking, which shows the highly variability of the Venusian dynamics (Moissl et al., 2009). The comparison of the cloud brightness spectra with the kinetic energy spectra derived from wind velocity is expected to achieve more precise understanding of Venusian turbulence.

Keywords: Venus, UV, cloud top, spectral analysis