Japan Geoscience Union Meeting 2011
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U003-P01 Room:Convention Hall Time:May 26 16:15-18:45

Momentum transport and mean zonal flow induced by thermal tides in the Venus atmosphere

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In the Venus atmosphere, the zonal wind velocity increases with height and reaches 100m/s at 65km. This phenomena is called superrotation, which is one of the most important unsolved problems.

There are clouds of sulfuric acid between 45 to 70km, and solar heating excites thermal tides at the top of these clouds.

The momentum transport by thermal tides is thought to play an important role in the generation and maintenance of the superrotation.

Various parameters such as the wind velocity of basic state and the Brunt-Vaisala frequency determine the vertical structure of thermal tides and momentum flux.Changes of the altitude region where thermal tides are excited would also cause changes in the momentum transport and the resultant zonal wind acceleration.

In this study momentum transport is calculated for various atmospheric parameters using a two-dimensional (longitude and height) model.We will discuss the sensitivity of the momentum transport to these parameters.

Keywords: Venus, thermal tides, superrotation

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U003-P02 Room:Convention Hall Time:May 26 16:15-18:45

A plan to study the Venus cloud structure based on the several Venus observations

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Venus is our nearest neighbor, and has a size very similar to the Earth's. However, previous spacecraft missions discovered an extremely dense (92 bar) and CO_2 atmosphere with H_2SO_4 clouds floating at high altitudes. H_2SO_4 clouds covered whole planet. The CO_2 atmosphere brings about a high atmospheric temperature (740 K) near the surface via greenhouse effect. The atmospheric circulation is also much different from the Earth's. The mechanisms which sustain such conditions are unclear. To understand such Venus climate, radiative transfer calculation including both sunlight absorption and scattering by cloud particles and atmosphere is performed. 'Cloud model' is necessary for this calculation. The 'cloud model' is vertical distribution of optical thickness of each cloud particles (mode1, 2 and 3). The 'Pollack model' is famous and often used. However, I think Pollack model should be improved for several reasons. The purpose of my study is make new realistic cloud model. For this purpose, previous entry probe, ground-based spectroscopic observation and Venus Express observation will be used to make new cloud model.

Keywords: Venus, cloud

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U003-P03 Room:Convention Hall Time:May 26 16:15-18:45

Derivation of two-dimensional wind velocity distribution in south polar vortex of Venus from VEX/VMC

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Vortical structures called "polar vortices" exist on the poles of Venus. Polar vortices also exist on other planets in the solar system such as Earth, while the vortices of Earth are low-temperature regions, the temperature structures of the vortices of Venus observed in infrared region are characterized by high-temperature regions called "polar dipoles" on the poles, and low-temperature regions called "polar collars" or "cold collars" surround the dipoles.

The vortices on Venus are unique in their dipole- or oval-like shaped high-temperature regions and significant longitudinal non-uniformity. These dipoles rotate with periods of 2.5 to 3 days, which are extremely faster than rotation period of solid planet (243 days). It is known to blow a zonal wind called "super-rotation" at mid- and low-latitude areas with a period of 4 days at equator. Its period at latitude of 70 degrees is about 3 days, which is consistent with the period at the edges of the vortices [Markiewicz et al., 2007]. This suggests that the rotations of the dipoles and the super-rotation are successive. On the other hand, the collars do not rotate quickly as dipole and the lowest temperature region is at dawnside. This means that the structure of the dipoles is wavenumber 2 and the collar is 1, in addition, the dipoles vary considerably in shape, from single mode to mode 3, or even more complex shapes [Piccioni et al., 2010].

Pioneer Venus Orbiter (PVO) in 1978 and Galileo in 1990 observed the vortex, but they observed only north, and for short periods. Venus Express (VEX) which injected into Venus orbit in 2006 observed south vortex for the first time, and continues to obtain data until now. VEX mounts instruments named Venus Monitoring Camera (VMC) and Visible and Infrared Thermal Imaging Spectrometer (VIRTIS). VIRTIS observed wide range at near-infrared regions, at which we can observe the well-marked structures of dipoles and collars. This is thermal emission from the cloud top, which reflects the distribution of temperature. Meanwhile, UV channel of VMC is at 365nm, at which distinct features are observed, and believed to reflect the distribution of unknown UV absorbers at about up to 70km altitude which represent above the cloud layer. We can see features also on the pole at this channel, but the dipole and collar are unclear.

The study aims to derive two-dimensional wind velocity distribution in the south vortex by analyzing VMC data at 365nm by cloud tracking method. Markiewicz et al. [2007] and Moissl et al. [2009] derived the distribution by using VMC data, and Sanchez-Lavega et al. [2008] did it by using VIRTIS data. These researches, however, derive latitude distribution of zonal-mean wind velocities, and average the velocities latitudinally with some degrees width . Therefore, it is not suitable for studying the structure of the dipole which has notable longitude non-uniformity, and we cannot discuss about the fine latitudinal structures. We still do not know that longitude non-uniformity like dipoles and collars at infrared regions is also observed on the motion of the unknown UV absorber at the polar region. Thus, we require to derive two-dimensional wind velocities with higher resolution than previous studies to confirm the non-uniformity.

Furthermore, the cloud trackings on previous studies use the manual tracking method which identifies similar features by visual check, but this method has limitations of objectivity and throughput. We will apply the cross correlation method developed to derive the latitudinal wind velocity distribution at mid- and low-latitude [Kouyama et al., 2009] to high-latitude region, and consider the possibility of automatic wind velocities derivation with objective criteria. There are proper difficulties at high latitude that the clouds do not go straight but rotate, low contrast and streak features of clouds. Therefore, we need to resolve these problems to derive wind velocity distribution of the vortex.

Keywords: Polar vortex, Venus, wind velocity distribution, Venus Express, VMC, Venus Monitoring Camera

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U003-P04 Room:Convention Hall Time:May 26 16:15-18:45

Superrotation Strength Estimated from Algebraic Equations

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We estimate the strength of equatorial superrotation of planetary atmospheres by solving a set of algebraic equations based on Gierasch's model. Gierasch (1975) explained that the equatorial superrotation of Venus is maintained by upward and equatorward angular momentum transport by means of meridional circulation and strong horizontal eddy diffusion, respectively. The parametric dependence of this model was explored by Matsuda (1980). However both Gierasch and Matsuda ignored the effect of meridional thermal advection. By taking account of the effect, we extend their studies.

We derive a set of algebraic equations from the primitive equations of the steady axisymmetric Boussinesq fluid, by substituting unknown scalar variables for unknown functions (i.e., zonal and meridional velocity, and temperature). Coefficients of the algebraic equations consist of the thermal Rossby number, the vertical and the horizontal Ekman numbers, and the relaxation time constant of Newtonian heating and cooling.

Solutions of the algebraic equations are compared with representative values of numerical solutions of the primitive equations for a parametric range of many orders of magnitude. The superrotation strength obtained from the full primitive equations (i.e., latitudinally averaged zonal velocity at the top divided by the planetary rotation velocity at the equator) can be estimated from the solutions of the algebraic equations; the accuracy of the estimates is better than 70% in most cases. The superrotation strength is proportional to the cubic root of the thermal Rossby number for the cases that the dominant balance is between the centrifugal acceleration and the pressure gradient that is weakened by the meridional thermal advection.

Keywords: superrotation, atmospheric general circulation, planetary atmospheres, atmospheric dynamics, geophysical fluid dynamics

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U003-P05 Room:Convention Hall Time:May 26 16:15-18:45

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

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U003-P06 Room:Convention Hall Time:May 26 16:15-18:45

Latitudial distribution of HDO above the Venus's clouds

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The abundance of HDO in the Venus' dayside atmosphere above the clouds was measured by ground-based 2.3 um spectroscopy for 4 days. The latitudinal distributions found show no significant structure. The latitudinal average of mixing ratio of 2.3 ppm at a presentative height of 62-67 km is consistent with previous measurements. According to previous measurements, the HDO/H2O ratio in the height region 30-40 km and higher than 80 km in Venus' atmosphere is 120 times and 250 times telluric ratio respectively. In this works, the ratio of HDO/H2O in the height region 62-67 km calculated with Pollack's model is 160 times that on Earth and the vertical distribution is found.

Keywords: Venus, HDO

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U003-P07 Room:Convention Hall Time:May 26 16:15-18:45

Constructing a new Venus cloud model using a multiple scattering method

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Venus clouds lie at an altitude from 45km to 90km in the Venus atmosphere and cover the whole planet. It is relevant that the Venus clouds consist of main cloud deck which composed of upper, middle, and lower regions and a tenuous haze above and below. Before now, several cloud models are constructed, but it is relevant that there are several problems in these cloud models. For example, when using a cloud model made by Pollack(1993), a big difference of cloud height is occurred along the lines of longitude which is not matched past observations.

To resolve these problems, I will make a new cloud model using CO2 spectroscopic data performed by using IRTF at Mauna Kea with CSHELL spectrometer.

Keywords: Venus, cloud model

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U003-P08 Room:Convention Hall Time:May 26 16:15-18:45

Characteristic features seen in a temperature distribution at nightside cloud top of Venus

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The Longwave Infrared Camera (LIR) onboard Akatsuki succeeded to obtain an infrared image of Venus nightside for the first time. LIR visualizes thermal infrared radiation emitted from the upper cloud layer of sulfuric acid, and a temperature distribution at the cloud top altitude is obtained by converting the infrared radiation to brightness temperature.

Characteristic features seen in the temperature distribution are summerised, and the obtained temperature is compared with the past observations. The remarkable features are low temperature regions in the polar regions and the polar collars, limb darkening due to difference in optical path length, zonal structures seen in the middle and low latitudes, and smaller scale structures. An altitude profile of optical depth will be derived from the limb darkening effect. The temperature distribution obtained by LIR will give constraint to theoretical studies of atmospheric dynamics and cloud chemistry in the cloud top altitude region.

Keywords: Akatsuki, venus, LIR

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U003-P09 Room:Convention Hall Time:May 26 16:15-18:45

Vertical distribution of UV absorber in the Venusian cloud layer inferred from cloud images

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Various UV features are observed on the Venus. The features are attributed to at least two UV absorbers; one is SO_2 and the other is unidentified.For studying the characteristics of the second absorber and its role in the atmospheric energy balance, the vertical distribution of the absorber needs to be determined.

The vertical distribution will be reflected in the brightness distribution on the sunlit disk. For example, limb darkening feature depends on the location of the absorbing layer relative to the cloud top. We will constrain the vertical distribution of the absorber by comparing Venus images taken by Venus Express VMC and radiative transfer calculations.