The atmosphere of Venus observed by HINODE on the 2012 transit of Venus
「ひので」衛星が 2012 年金星日面通過に観測した金星大気

M. Kanao[1], M. Nakamura[1,2], T. Imamura[1,2], T. Shimizu[1,2]
1.ISAS, 2. University of Tokyo

1. Introduction

The solar observation satellite, HINODE, observed the transit of Venus in 2012. The Solar Optical Telescope (SOT) onboard HINODE had acquired the image of Venus from the start to the end of the transit with the highest accuracy of 0.3 *arc sec*. Venus atmosphere including the H_2SO_4 cloud particles absorbs the solar UV below 0.4 μm wavelength. Mode 1 particles are suggested to be the UV absorber from the polarization observation due to the Mie scattering. The molecules of SO_2 and SO have the absorption cross section of ~10^{-18} cm^2 for 320 nm. The observation by SPICAV-UV onboard Venus Express showed that the number density of SO_2 and SO increase above 90 km altitude whereas they decrease around 80km altitude. The temperature increases due to the photo dissociation of H_2SO_4 and SO_2 around the region. Our final purpose is that the sulphur compounds dynamics above the top of the cloud is revealed.

2. Observation

The transit is observed from 5th 22:25:30 to 6th 04:40:00 in 2012 by using the broadband filter instrument (BFI) of the SOT. The images obtained from 2nd contact to the 3rd contact are used in this study. BFI has the 6 interference filters, the wavelengths of which are 388.3, 396.8, 430.5, 450.4, 555.0, 668.4 nm. The images are acquired as 2048 x 1024 pixels using 2 x 2 summed pixels with the field of view of 218 x 109 *arc sec*. The exposure times are 0.0768, 0.205, 0.0512, 0.0768, 0.0768, 0.0512 *sec* respectively.

3. Method

First, the data was corrected by the process including the dark subtraction, flat fielding, the CCD readout, and bad pixel correction. The solar limb darkening is also removed. In the second step, the intensity around Venus of images is normalized by that at the solar disk. In the third step, the position of Venus is determined with the accuracy of 0.02 pixels by least square fitting to the radius for the residual to be minimum. The Venus radius, L is the length between the center and the limb in a unit of pixel for every 1 *degrees* of θ, the angle around Venus center. The limb is determined where the transmittance T is 0.5. Finally, the radius in a unit of pixel is converted to the altitude, A, using the plate scale of the BFI, P *(arc sec pixel*$^{-1}$*)*:

$$A(\theta)\ (km) = L(\theta)(pixel)P\ (\mathrm{arcsec}\, pixel^{-1})6051.8km/S\ (arc\ sec) - 6051.8\ km \quad (1)$$

The plate scales, P are re-calculated by correlating the radius with the altitude observed by SPICAV-IR and SPICAV-UV, but the details are not shown here. S (arc sec) is the predicted semidiameter of Venus by Dr. Soma.

4. Result

The atmospheric height as the transmittance T of 0.5 for the wavelength of 430.5 nm, A is displayed to the latitude in Figure 1. The 13 images where the position of Venus is within 120 pixels are used:

$$\bar{A}_{435}(\theta) = \frac{1}{n}\sum_n A_{435}(\theta) \quad (2)$$

The latitude in the evening section and the morning section is calculated from θ. The error bar in the top panel of Figure 1 is:

$$SE(\theta) = \frac{1}{n}\sqrt{\sum_n \left(A(\theta) - \bar{A}(\theta)\right)^2} \quad (3)$$

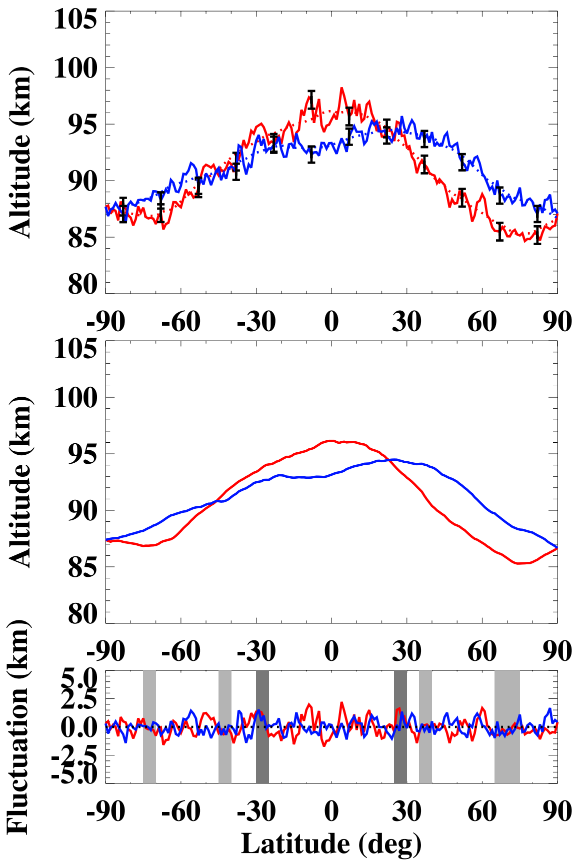

Figure 1. The height of the atmosphere where *T=0.5*. The blue is the profile in the morning section (local time of 6 a.m.) and the red line is that in the evening section (local time of 6 p.m.) respectively.

The red dotted lines in the top panel and the solid lines in the middle panel of

Figure 1 are the moving average of the altitude for every 21 degrees of latitude, A_{a435}:

$$A_{a435}(\theta) = \frac{1}{21}\sum_{\theta=\theta-10}^{\theta+10} \bar{A}_{435}(\theta) \qquad (4)$$

The basic tendency that the altitude in the equator is higher than that in the pole is similar to the basic result of the cloud altitude recently revealed by Venus Express observations and the simulation as shown in *e.g.* Ignatiev et al. (2009), Titov et al. (2008). The difference in the evening sector 9.1km is larger than that in the morning section 6.1 km by 3km. The asymmetry of the altitude is significant in comparison with the error bar. The difference between the height and the moving averaged height is the fluctuation, *F*:

$$F(\theta) = \bar{A}_{435}(\theta) - A_{a435}(\theta) \quad (5)$$

is shown in the bottom panel of Figure 1. The small fluctuations profiles are shown with the amplitude of from 0.2 to 1.5 km. At the equator of the latitude smaller than 30 degrees, the amplitude of the fluctuation would be larger in the evening than that in the morning. The amplitude is small around the latitude of 70 degrees and 45 degrees both in the morning and evening sections, as shown as the light gray color in Figure 1.

5. Consideration

5.1. Global structure of the height

To explain the altitude difference between the evening section and the morning section shown in the middle figure of the Figure1, we assumed one simple hypothesis for the dynamics. In the dayside, from the morning to the evening, the CO_2 atmosphere with the haze moves upward and/or to the equator at the altitude of ~90 km, as a result of the solar heating. In the nightside the atmosphere moves downward and/or to the polar without the heating. The latitude of the inflection point for altitude profile in the morning section is similar to that of the zonal wind shown in *e.g.* Belton et al. (1991) and Khatuntsev et al. (2013).

The gradient of the height of the evening section is also opposite in the polar regions. The height is minimum around the latitude of 75 degree in the evening section. We cannot see the cave region in the morning section. This tendency continues throughout the transit. The height difference between the evening section and the morning section is 1.35 km in the southern pole and 3.01 km in the northern pole.

5.2. The Fluctuation of the altitude

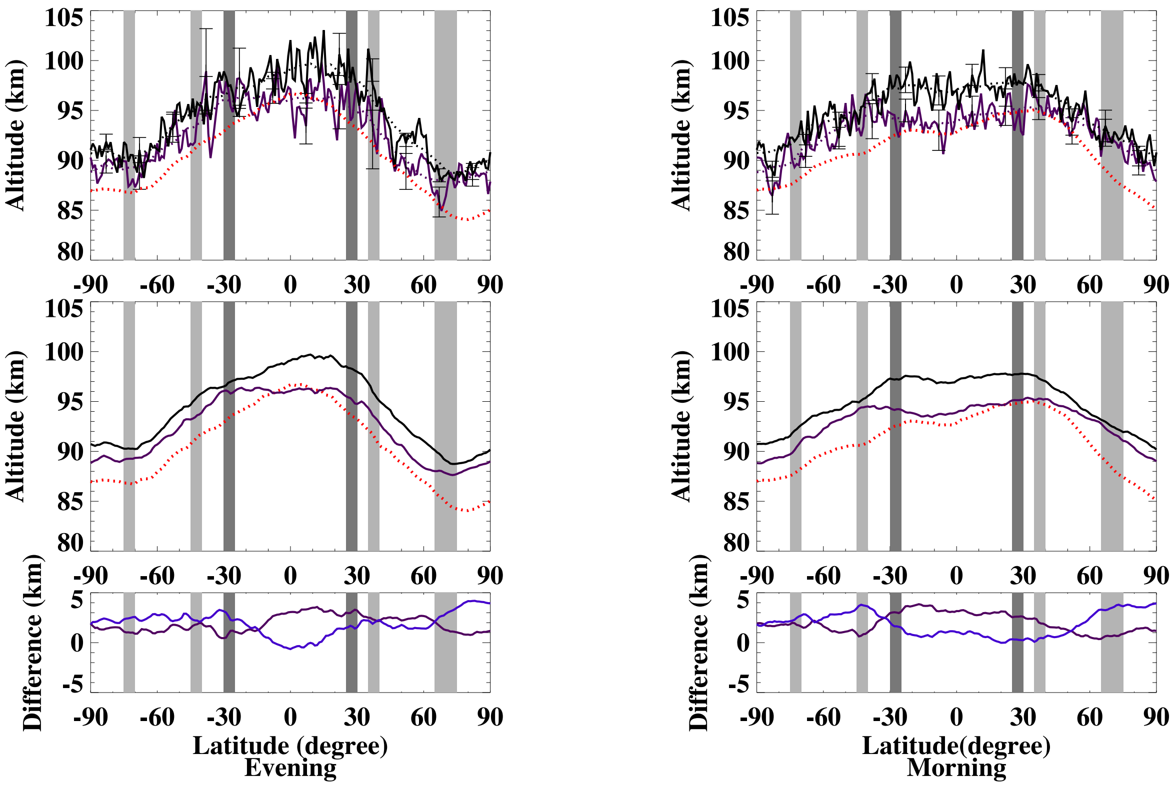

Figure 2. The altitude profile at the wavelength of 388.35 nm, $\bar{A}_{388}$ (the black line) and 396.85 nm, $\bar{A}_{397}$ (the purple line), and the moving average of visible wavelength A_{aopt} (red pointed line): top panel. The moving average of A_{a388} (black line) and A_{a397} (purple line): middle panel. The altitude difference between A_{a388} and A_{a397} (purple line) and that between A_{a397} and A_{aopt} (violet line): bottom panel.

There are the small fluctuations with the global asymmetric structure using the wavelength of 430.5 nm shown in the bottom panel of Figure 1. The amplitude of the fluctuation is largest around the equator in the evening section. One of the possible reasons for the fluctuation is that the wind to the equator makes the ridges at the stagnation point. Another possible reason is that the components of the aerosols are evaporated in places around the equator. We cannot know whether the evaporation is occurred in the haze layer as the observation in this study or is at more low latitude such as the cloud top and is propagated upward as the gravity wave. The source evaporation structures would be cells or strains shown in Titov et al. (2012).

Figure 2 showed the altitude profile where *T=0.5* at the wavelength of 388.35 nm (purple line) and 396.85 nm (black line) with the moving average (red pointed line) of the optical three continuum bands of red (668.4 nm), green (555.05 nm) and blue (450.45 nm). The height of 388.35 nm is constantly higher than that of 395.85 nm in the equator of the morning section. The difference would come from the scatter of the haze around 90km altitude. The profile in the evening sections displays the large fluctuation around the equator (<30 degrees). The perturbation would show that the UV absorber, such as SO, SO_2 and SO_3 is disturbed by the solar irradiance. We will need further study of the result about such as the absorption cross section in the UV wavelength and the source of the evaporation.

6. Summary

We studied the altitude profile of Venus using the G-band images observed by Hinode during the transit of Venus. The height is determined using the transmittance of 0.5. The altitude is higher in the evening section than that in the morning section at the equator. It suggests that the atmosphere would move upward and transport the perturbation to the haze in the equator of the evening section.