A model to study the Venus cloud structure based on several Venus observations, wherein SOIR solar occultations on Venus Express

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1 Abstract

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 at the surface) and CO_2-rich atmosphere, with H_2SO_4 clouds located at altitudes between 40 and 70 km. These clouds cover the whole planet. A cloud model was proposed by Pollack et al. (1993), with a vertical distribution of optical thicknesses of the different cloud particles (modes 1, 2 and 3). However, this model might be improved using new data obtained in the recent past from ground-based observations (IRTF telescope in Hawaii) and in-situ measurements from spacecraft observations (SOIR on Venus Express). A new cloud model, correcting for some Pollack model 's problems, is proposed using data from previous entry probes [Takagi & Iwagami, 2011]. However, this model does not describe the global Venus cloud structure. The purpose of this work is to construct a more realistic cloud model. Ground-based spectroscopic observations of the Venus low-latitude region and Venus Express/SOIR observations of high-latitude will be used to construct this new cloud model.

2 CloudT2x

Cloud model is a vertical structure of cloud optical thickness. The Venus cloud model Pollack et al.(1993), constructed in using Pioneer Venus mainly, is very famous. Howvever, optical thickness of upper haze in 'Pollack model' is too thick compared with previous observations. Moreover, Pollack model is not believable because the time and location of observations used to construct are limited. The improvement of Pollack model is shown in Takagi & Iwagami.(2011) and new Venus cloud model ' cloudT2x ' (Fig.1) is constructed in using some previous Venus probe (Venera, Pioneer Venus) observational results. Fig.2 shows example of the comparison of absorption spectrum derived from ground-based observation and radiative transfer calculation. The absorption line shape derived from calculation with cloudT2x and observation are very similar, so cloudt2x is more realistic than previous Venus cloud model. In Taguchi et al.(2012), the fitting analysis of rimb darkening between observation and calculation with cloudT2x is performed. The calculation with cloudT2x re-creates the observation well. In Matsui et al.(2012), the fitting analysis of absorption line shape between observation and calculation with cloudT2x is performed. The calculation with cloudT2x re-creates the observation well.

CloudT2x is constructed from some Venus entry probes ' results. However, the most of probes observe only below the upper cloud layer. In cloudT2x, the part of upper haze layer is made from only one probe. So, upper haze of cloudT2x is not believable.

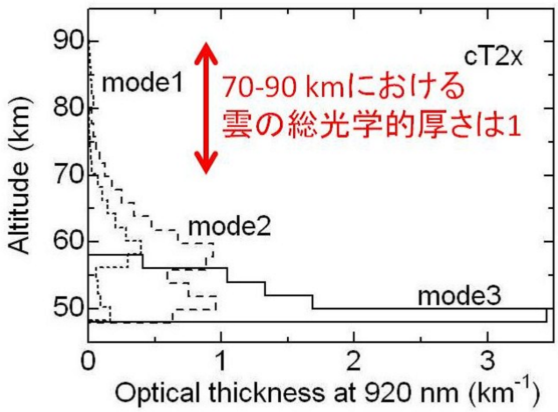

Fig.1 Venus cloud model 'cloudT2x' based on previous Venus probes[Takagi & Iwagami.(2011)]

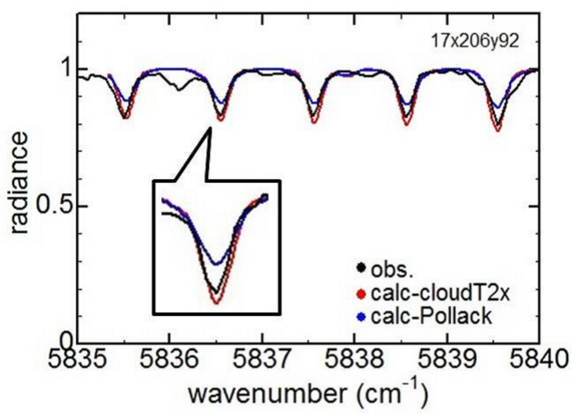

Fig.2 Comparison of absorption lines derived from ground-based observation and radiative transfer calculation(black: ground-based observation, red: radiative transfer calculation with cloudT2x, blue: calculation with Pollack.).

3 Observation and analysis

Venus Express is a planetary mission of the European Space Agency(ESA) that was lanunched in November 2005 and inserted into a polar orbit around Venus in April 2006. Solar Occultation at InfraRed(SOIR), which is a part of the spectroscopy on board Venus Express, is designed to measure at high spectral resolution($\lambda/\Delta\lambda \sim$20000) the atmospheric transmission in the IR (2.2-4.3 μm) using solar occultations. SOIR observes Venus atmosphere and cloud at high altitude (60-220 km), any latitude and longitude continually. In this study, SOIR data obtained in the 2006-2009 is analyzed. Number of all data is 404; at morning is 213, at evening is 191, at high latitude is 276 and at evening is 128.

4 Results

4.1 Latitude distribution of upper haze optical thickness

Optical thickness of upper haze is derived from SOIR data obtained from 2006 to 2009. Fig.3 shows the derived latitude distribution of upper haze from SOIR data. As shown in Fig.3, there are some features as below.

・Optical thickness at low latitude is thicker than that at high latitude in both morning and evening(gray dashed line in Fig.3). This trend is similar to SO_2 latitude distribution based on SPICAV on board Venus Express(Fig.4) shown in Marcq et al.(2011).

・ At higher than 50 ° , the gradient is steep in both morning and evening(red circle in Fig.3) same as cloud top altitude(Fig.5) shown in Ignatiev et al.(2009)

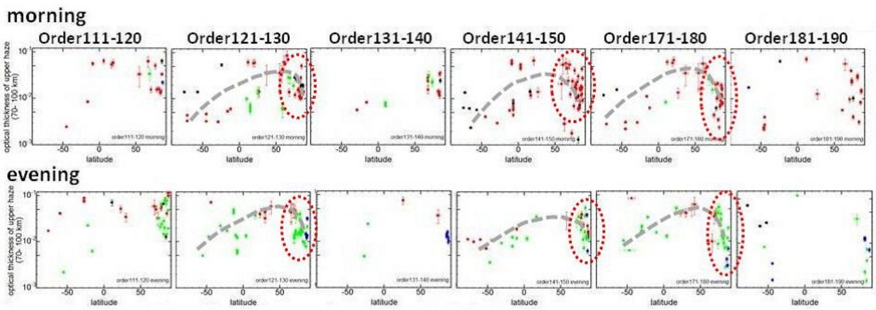

Fig.3 Latitude distribution of upper haze optical thickness derived from SOIR(upper : morning, lower : evening). Blue: lon. 0-90, black: 90-180, red: 180-270, green: 270-360.

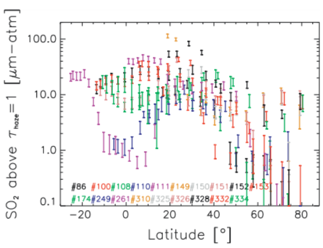

Fig.4 SO_2 Latitude distribution derived from SPICAV[Marcq et al., 2011].

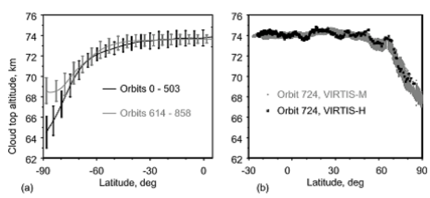

Fig.5 Latitude distribution of cloud top altitude derived from VIRTIS[Ignatiev et al., 2009].

4.2 Time variation of upper haze optical thickness

Fig.6 shows derived time variation of upper haze from SOIR data obtained from 2006 to 2009. As shown in Fig.6, there are some features as below.

・Variable upper haze exists constantly in both high and low latitude.

・Upper haze optical thickness increase from 2007 to 2008 suddenly(between two dashed lines in Fig.6). This trend is similar to SO_2 time variation(Fig.7) shown in Marcq et al.(2011).

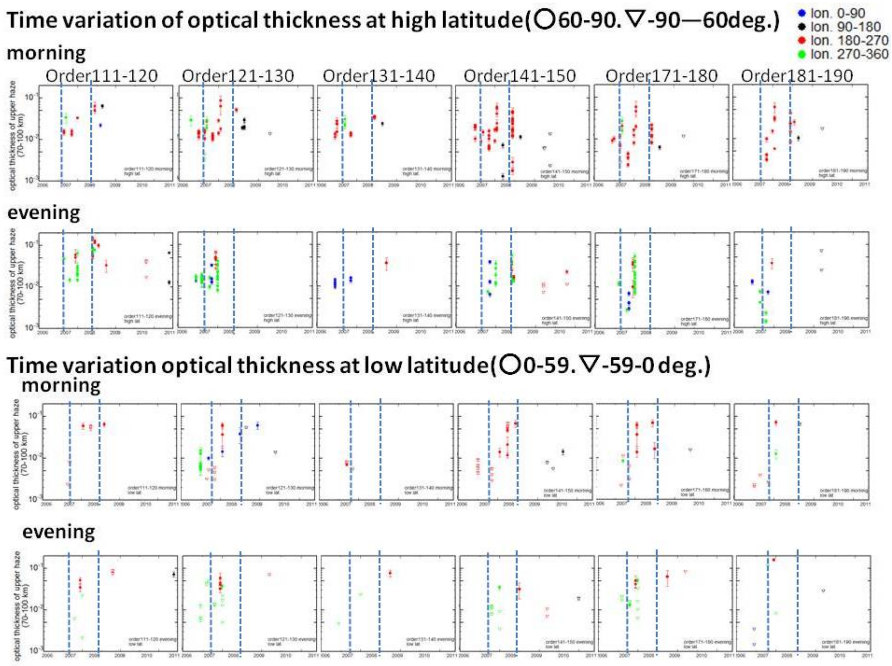

Fig.6 Time variation of upper haze optical thickness erived from SOIR(upper: morning, lower: evening). Blue: lon. 0-90, black: 90-180, red: 180-270, green: 270-360

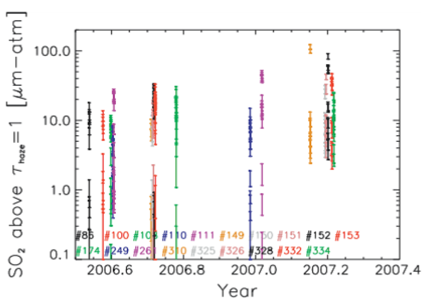

Fig. 16. Variations of N_{SO_2} with terrestrial year for several orbits. Note the sudden increase in SO_2 in early 2007.

Fig.7 SO_2 time variation derive dfrom SPICAV[Marcq et al., 2011].

5 Discussion

As described in section 4.1, latitude distribution of upper haze optical thickness derived from SOIR(Fig.3) and SO_2 latitude distribution based on SPICAV(Fig.4) are similar. Also, time variation of upper haze observed by SOIR and SO_2 time variation observed by SPICAV show same trend. From these features, it would appear that composition of upper haze is sulfide. SO and SO_2 are made from upper haze without H_2SO_4, considering H_2SO_4 is not present at around 100 km showed in Sandor et al.(2012).

As described in section 4.2, upper haze optical thickness increase between 2007 and 2008 same as SO_2 time variation (Fig.7). The most probable cause would be a convective event during 2007.

As described in section 4.1, optical thickness of upper haze and cloud top altitude decrease at polar regions. This depression coincides with the eye of the planetary vortex.

6 Summary

Latitude distribution and time variation of upper haze optical thickness are derived from SOIR data obtained in the 2006-2009. From these analysis, it would appear that composition of upper haze is sulfide. Chemical reaction and physical mechanism are able to be speculated from this study.