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Origins of Contrasts in Venus Seen at Thermal Infrared and Near-Infrared Wavelengths

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The middle atmosphere (60-100 km) of Venus plays an important role in determining its own environment. Venus is completely shrouded by a curtain of dense clouds (50-70 km) with total optical thickness of 20-40 at visible wavelengths. The upper sulfuric acid (H_2SO_4) clouds reflect ~76% of the incident solar radiation back to space. More than 70% of the solar energy absorbed by Venus is deposited at altitudes higher than 64 km mainly due to absorption of unknown UV absorbers mixed in the upper cloud. This horizontally and vertically unusual heating in the cloud layer excites the thermal tides, which are key process to understand the atmospheric super-rotation. In order to elucidate this mysterious atmospheric phenomenon, it is fundamental to investigate horizontal and vertical thermal structure in the middle atmosphere.

Mitsuyama et al. observed Venus at three thermal infrared (hereafter TIR) wavelengths (8.59, 11.24, and 12.81 micron) with the Cooled Mid-Infrared Camera and Spectrometer (COMICS), mounted on the 8.2-m Subaru Telescope, during the period of October 25-29, 2007. Thermal radiations at these wavelengths are most sensitive to altitudes of ~70 km. The spatial resolution of images was ~500 (km/pixel). This was the first time that such high spatial resolution full-disk images had been obtained. After processing images with high-pass filter, they found a horizontal Y-shape structure, which was similar to that seen in UV, varying its shape from day to day.

In this study, to understand what determine the observed contrast (1-2 K) of thermal radiations in equatorial latitudes at these TIR wavelengths, we investigate sensitivity of atmospheric parameters with radiative transfer calculations. A cloud model (Eymet et al., 2009) which is based on the results of Venera 15 (Zasova et al., 2007) is adopted in our calculations. There are four candidates that can be responsible for this contrast: temperature profile, cloud top altitude, and optical thicknesses of mode 1 and mode 2 particles. Conversely, optical thicknesses of mode 2' and mode 3 particles are not sensitive to thermal radiations at these TIR wavelengths. To narrow down the contrast source, we also examine the contrast of reflectance at 968 nm (hereafter NIR) obtained by Galileo Solid State Imager (SSI). From the calculation, the optical thicknesses of all the considered four cloud particles (mode 1, mode 2, mode 2', and mode 3) can reproduce the observed contrast of reflectance (1-2%) while the other parameters (temperature and cloud top altitude) are insensitive to reflectance. We find that variations of optical thicknesses of mode 1 and mode 2 particles can satisfy the observed contrasts both of TIR and of NIR simultaneously. However, it has been pointed out that the altitudes that contribute most to the observed radiance at NIR (58-64 km) are lower than those at UV (62-70 km) based on the results of cloud-tracked zonal velocity [e.g., Sanchez-Lavega et al., 2008]. It would suggest that optical thicknesses of mode 1 and mode 2 particles are less variable in equatorial latitudes and the obtained thermal contrasts seen in TIR result from the variation of temperature profiles and/or cloud top altitudes rather than those of optical thicknesses of mode 1 and mode 2 particles.

Keywords: Venus, Thermal infrared, Near-infrared