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Microphysical properties of Venusian upper hazes observed with an Imaging-Polarimetry system " HOPS "

ENOMOTO, Takayuki[1*] ; SATOH, Takehiko[2] ; NAKATANI, Yoshikazu[3] ; SATO, Takao M.[1] ; HOSOUCHI, Mayu[4] ; NAKAKUSHI, Takashi[5]

[1]SOKENDAI, [2]ISAS/JAXA, [3]Kyoto University, [4]University of Tokyo, [5]Wakayama University

The high albedo of Venus is due to optically very thick main cloud deck which covers the whole planet. The small particles (hazes) which were distributed above the main cloud deck were discovered by the observations from Pioneer Venus Orbiter (PVO) which arrived at Venus in December 1978. Kawabata et al. [1980] found, from the data of Orbiter Cloud Photopolarimeter (OCPP) onboard PVO, that abundant sub-micrometer sized particles " hazes " were distributed above the main cloud deck mostly in polar regions. The optical thickness of the haze layer was reported to reduce during the PVO mission period [Sato et al., 1996]. Coincidently, decrease of the SO_2 abundance was also reported [Esposito, 1985]. After the PVO mission, however, the variation of the optical depth of the hazes has not been studied, so it is not clear what this correlation means for the generation and maintenance of hazes and whether a similar correlation between them exist today. Our study provides the latest information about the microphysical properties of hazes by ground-based monitoring observations which have not been done since PVO.

To monitor the distribution of the Venusian upper hazes, we developed an imaging-polarimetry system " HOPS " (Hida Optical Polarimetry System) and performed observations by attaching it to the 65cm refracting telescope at Hida Observatory of Kyoto University. As HOPS provides spatially resolved polarization map, polarization in an arbitrary area can later be obtained just by summing up the corresponding pixels for comparison with previous measurements. This is the biggest advantage of imaging polarimetry against the aperture measurements. HOPS is a " two beam type " polarimetry instrument which enables high accurate measurements against variable atmospheric conditions. The effect of variable atmospheric transparency, non-uniformity of sensitivities over the CCD pixels and different throughputs of two beams can be corrected through arithmetic operations in image processing.

The observations were carried out at solar phase angles around 39deg. (Jul., 2013), 56deg. (Aug., 2013), 58deg. (Oct., 2012), 85deg. (Aug., 2012) and 129 deg. (May, 2012) at 4 selective wave lengths 438nm (B), 546nm (G), 650nm (R) and 930nm (IR); G and IR data can be compared with similar wavelength data of PVO/OCPP. We averaged observed degree of linear polarization over the polar regions (latitudes higher than 60 deg.) and compared with the report of PVO. A clear difference is seen in IR data. The neutral point of our data is found to be at around 75 deg. while the point of PVO/OCPP is around 40 deg. This difference may indicate the different situation of the distribution and size parameters of hazes.

To analyze the obtained polarization data, we developed a radiative transfer calculation code using Adding?Doubling method with the Stokes parameters fully treated [de Haan et al., 1987, Hovenier et al., 2004]. It is possible to analyze three wavelengths IR, R, and G neglecting the Rayleigh scattering effect because Rayleigh scattering cross-sections for IR, R G and B are about 0.21, 0.083, 0.041, 0.0096μm^2 while Mie scattering cross-sections for a main cloud particle are the order of 7μm^2. We treated haze particle effective radius r_{eff} and optical depth τ_h as free parameters, respectively. The effective variance of hazes was fixed to 0.18 and parameters for main cloud layer were taken from Hansen and Hovenier [1974]. Single scattering albedos were assumed to be 1 for both haze and cloud layers. The resultant parameters for northern and southern polar region are r_{eff} = 0.22, 0.20μm, τ_h = 0.09, 0.05 at IR, respectively. The optical depth is smaller compared with the initial observations of PVO τ_h = 0.25 but comparable with those observed during the declining phase. Such declination of the abundance of SO_2 is also observed by Venus Express orbiter [Marcq et al., 2012], so our results are consistent with the report of the correlation with it.

Keywords: Venus, Hazes, Imaging-Polarimetry, Radiative transfer analysis