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Longitudinal variation in the Venusian cloud optical thickness associated with a Kelvin wave

#Hiroki Karyu[1)],Takeshi Kuroda[2)],Naoki Terada[3)],Yasumasa Kasaba[2)],Masaru Yamamoto[7)],Masaaki Takahashi[4)],Kohei Ikeda[5)],Norihiko Sugimoto[6)]
[(1]TU,[(2]Tohoku Univ.,[(3]Dept. Geophys., Grad. Sch. Sci., Tohoku Univ.,[(4]AORI, Univ. of Tokyo,[(5]NIES,[(6]Physics, Keio Univ.,[(7]Kyushu University

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We have investigated, using a Venus Global Climate Model (VGCM), a large-scale longitudinal variation in the optical thickness of the Venusian cloud caused by a Kelvin wave and its relation to a sharp disruption feature reported by Peralta et al. (2020) [1]. They suggested that optically thick region is generated by vertical wind caused by a nonlinear Kelvin wave, making small particles abundant there. On the other hand, Ando et al. (2021) [2] showed that temperature fluctuation by a Kelvin-like gravity wave generates cloud thickness contrast using the AFES VGCM coupled with cloud physics. In addition, they argued cloud particle size should be larger in the thick cloud region.

Our VGCM is based on MIROC [3]. The model resolution is T21L52, the altitude range is from the surface up to 95 km, and topography is included. The radiation scheme and horizontal and vertical eddy diffusion for momentum and heat are based on Yamamoto et al. (2019) [4]. Our VGCM calculates the space and time evolution of cloud size distribution, which was not taken into account in the previous study [2]. Another difference is cloud particle modes [5] considered in the cloud physics parameterization. Although Ando et al. (2021) took into account Mode 1 and Mode 2, our VGCM takes into account Mode 3 and Mode 2’ particles in addition to Mode 1 and Mode 2.

We calculated the optical thickness at 2.26 microns with the simulated cloud distribution to compare our results with IR images taken by Akatsuki. In the low latitudes, optical thickness sometimes changes sharply in the west-east direction, which is similar to that reported by the observation [1]. In general, the optical thickness variation has a wavenumber-1 structure and moves in the same direction as the super-rotation. Fourier analysis showed that a wavenumber-1 Kelvin wave structure is synchronized with the optical thickness variation. We also investigated a phase relationship among the variation of temperature, the vertical wind caused by the Kelvin wave, and cloud production rate. Cloud production rate is more in phase with the vertical wind than temperature. Therefore, contrary to Ando et al. (2021), our results suggest that vertical wind is the main cause of cloud optical thickness variation. Moreover, the simulated particle size is smaller in the optically thick region. It is expected that vertical wind transports sulfuric acid vapor from the sub-cloud region and small particles are generated there, which is consistent with the observation [1].

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[2] Ando, H., et al., 2021, Journal of Geophysical Research: Planets, 126(6), e2020JE006781.
[3] K-1 model developers, 2004, K-1 Technical Report No. 1, The Univ. of Tokyo.
[4] Yamamoto, M., et al., 2019, Icarus, 321, 232-250.
[5] Crisp M., 1986, Icarus, 67, 484-514.