Study of the horizontal distribution of Venusian sulfuric clouds using a general circulation model: Comparison with the Akatsuki data

*Akiba Takehiko[1], Takeshi Kuroda[1,2], Kohei Ikeda[3], Naoki Terada[1], Yasumasa Kasaba[1], Arihiro Kamada[1], Masaaki Takahashi[4], Takao M. Sato[5], Takehiko Satoh[5], Makoto Taguchi[6], Shigeto Watanabe[7]

1. Tohoku University, 2. NICT, 3. NIES, 4. AORI, University of Tokyo, 5. ISAS, 6. Rikkyo University, 7. Hokkaido Information University

Venus is covered with sulfuric acid clouds in about 48 and 70 km altitude, though the global cloud distribution and circulation systems have not been studied very well. To understand them, we have developed a Venus General Cirulation Model (VGCM) which takes the formation and advection of clouds into account based on CCSR/NIES/FRCGC MIROC. Up to now, *Kuroda* (2013), *Nitta* (2013), and *Kato* (2014) implemented the cloud processes (condensation/evaporation of sulfuric acid vapor/clouds, advection and gravitational sedimentation of clouds), and *Itoh* (2016) implemented the chemical processes related to sulfuric acid vapor, into the VGCM developed by *Ikeda* (2011) towards the interpretation of observational results from the Japanese Venus Climate Orbiter Akatsuki.

Itoh (2016) suggested that SO_2 is lifted upward into the upper cloud layer in the equatorial atmosphere and change into sulfuric acid clouds there followed by the transport poleward by meridional circulation, but the radiative effects of clouds did not reflect the simulated cloud distributions considering the horizontally uniform cloud distributions with observed vertical distributions for each mode (*Haus and Arnold,* 2010)
In this study, we have improved the radiative processes of sulfuric acid clouds in the VGCM to interact with the simulated cloud distributions. It is the first trial on the VGCM which allows to understand the interactions between radiative effect of the clouds and the cloud distribution in the both aspects of atmospheric circulation and cloud formation.

The simulation is started from the equilibrium states of wind, pressure, and temperature fields simulated by *Itoh* (2016) and horizontally uniform cloud distributions with observed vertical distributions shown by *Haus and Arnold* (2010) (hereafter Simulation A). Note that Simulation A aborts in 3/4 Venusian days from the initial state in the current simulation, so here we report the results before the abort.
The results are focused on the cloud formation and SO_2 distribution which is affected by the sulfuric acid clouds, and compared with the one of *Itoh* (2016) (hereafter Simulation B).

On Simulation A, upper clouds (~70km altitude) are separated to the both hemispheres at the sub-solar longitude, which is not shown in Simulation B. Also the very strong solar heating is appeared above 80 km altitude, which may cause the distribution due to the excitation of cloud transportation to poleward. The results are in good agreement with the Akatsuki IR2 (2.02 μm) images which are sensitive to the cloud top altitude.

On the cloud bottom, large cloud particles exist in low- and mid-latitudes on both Simulations A and B, which suggests that the radiative effects of lower-altitude clouds are small.Focusing on the optical depth of the cloud layer, both Simulations A and B results that optically thick clouds concentrate to the equator region, which corresponds to the Akatsuki IR2 (2.32 μm) images sensitive to the cloud optical thickness. Also SO_2 is distributed above the cloud top at the sub-solar longitude because of the solar decomposition

in both Simulation A and B, which corresponds to the Akatsuki UVI (283 nm) images sensitive to the SO_2 above the cloud top.

Keywords: Venus, Akatsuki, GCM, cloud