Sensitivity Tests of the Venusian Atmospheric Model Parameters Toward Akatsuki Data Assimilation

*Tatsuro Iwanaka[1], Norihiko Sugimoto[2], Takemasa Miyoshi[1], Jianyu Liang[3]

1. RIKEN Center for Computational Science , 2. Department of Physics, Keio University, 3. Centre for Climate Research Singapore

Observations by the Japanese Venus orbiter Akatsuki have significantly advanced our understanding of Venusian atmospheric dynamics. Data assimilation integrates observational data with general circulation models (GCMs) and would enhance the use of Akatsuki data (Sugimoto et al., 2019; Fujisawa et al., 2022). However, the model parameters such as the solar heating rate and vertical and horizontal eddy diffusion coefficients in the Venusian GCMs remain highly uncertain. The solar heating rate is primarily determined by the distribution of clouds, which reflect nearly 80% of incident solar energy, and that of the unidentified UV absorber, which accounts for 30–50% of the remaining absorbed energy. Thermal tides generated by this solar heating supply momentum and maintain super-rotation (Horinouchi et al., 2020), and their uncertainty is directly tied to that of GCMs. Although a full representation of these dynamics requires precise photochemical and cloud microphysical models, it would be possible to indirectly constrain the model parameters by assimilating cloud-tracked wind vectors derived from Akatsuki's Ultraviolet Imager (UVI) images and temperature distributions retrieved from Akatsuki's Longwave Infrared Camera (LIR) observations.
In this study, we quantitatively evaluated the sensitivities of the atmospheric dynamics to uncertain model parameters toward estimation of solar heating rates by assimilating UVI cloud-tracked winds and LIR temperature distributions. Using the Venusian GCM known as the AFES-Venus (Sugimoto et al., 2014), we investigated the sensitivity and temporal scales of response of zonal and meridional winds and temperature at the cloud-top (approximately 70 km altitude) to the fluctuations in the zonal mean (Q_z) and tidal (Q_t) components of the solar heating rate. Our results show that the zonal winds are primarily sensitive to Q_z with a response time of 14–22 hours, with a small sensitivity to Q_t. The meridional winds showed no significant sensitivity to either Q_z or Q_t. The temperature is significantly sensitive to both Q_z and Q_t, with a typical response time of 22–32 hours. Based on these response scales, taking assimilation windows to at least 22 and 32 hours, respectively, would enable the constraint of solar heating rates through the assimilation of observed wind vectors and temperature distributions. These results suggest a possibility to estimate the uncertain heating distribution in the Venusian atmosphere through data assimilation of Akatsuki's UVI cloud-tracked winds and LIR temperature distributions.

Keywords: Venus, data assimilation, AFES-Venus

