Feasibility of the future observations by mid-infrared heterodyne spectroscopy for Wind and Temperature in Venusian mesosphere and lower thermosphere

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Venusian mesosphere (70 - 90 km) and lower thermosphere (90 - 120 km) are the transition layers. It is important for understanding of atmospheric coupling to study these regions. The understanding of thermal structure in the upper atmosphere have been recently advanced using the instruments onboard Venus Express (VEX). However, space-born observations often have limitations in spatial coverage attributed to observing methods, orbits and orbital periods. On the other hand, ground-based observations have capability to give complementary spatial coverage and provide long term monitoring over lifetime of spacecraft. In contrast, the dynamics in upper atmosphere is divided three regions, retrograde superrotaional zonal wind (RSZ) at the cloud layer, subsolar to antisolar (SS-AS) flow in the lower thermosphere and transition region in the altitude range of 70 - 90 km. The transition region is hardly observed due to its difficulty for measurements. Hence, the dynamics in this region has not been well understood theoretically or observationally. This study established new mesospheric wind and temperature retrieval method proposed theoretically by Nakagawa et al. (2016). Here, we evaluated the new method for observational spectra.

Observing targets in this study are absorption spectra at 10 μm band formed by the atmospheric CO_2 absorption of background radiation from the cloud top. Wind velocity and temperature between the cloud top and the mesosphere are retrieved from fully resolve the spectra with spectral resolution of 1 MHz observed by mid-infrared (mid-IR) heterodyne spectrometers and with radiative transfer and inverse analysis. In addition, mid-IR heterodyne spectroscopy has capability to constantly resolve Venusian disk changing between 10 - 60 arcsec by moderate spatial resolution of 4 arcsec with 60 cm telescope at 10 μm.

We used absorption spectra obtained by THIS developed by Cologne University on March 20 - 29 and by HIPWAC developed by NASA on May 18 - 20 in 2012. We retrieved line of sight wind velocity and vertical profile of temperature in the mesosphere from the observations. The retrieval of the wind velocity had sensitivities to the altitude range between 85 and 100 km with 10 km interval and uncertainties between ±33 and ±54 m/s. On the other hand, retrieval of the vertical profile of temperature resolved with 5 km interval in the altitude range between 70 and 95 km and uncertainties between ±0.6 and ±13 K. These uncertainties were also determined by estimating the a priori dependency of our inverse method.

We compared our results of temperature with previous measurements in order to evaluate our retrieval method. Our results of vertical temperature profile well agreed with previous studies of mid-IR heterodyne spectrometers (Stangier et al., 2015) and radio occultation VeRa/VEX in the altitude range of 75 –90 km. The wind retrieval showed an extensive distribution between -163 m/s and 143 m/s. Note that the positive quantity of wind velocity meant the direction coming toward observer and the negative quantity

meant going away from observer. In addition, we found existence of SS-AS flow and RSZ in the mesosphere for one possibility of the retrieved wind directions.
We will apply this retrieval method to our Mid-Infrared Laser Heterodyne Instrument (MILAHI) inserted to our dedicated Tohoku University 60 cm telescope located at the summit of Mt. Haleakala. The constant observation will be conducted with cooperative observations of Venus spacecraft Akatsuki in order to understand atmospheric coupling comprehensively.

Keywords: Venusian mesosphere, Heterodyne, Wind velocity, Temperature

