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Mesospheric wind/temperature measurements in the terrestrial planetary atmosphere using the IR heterodyne spectroscopy

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The terrestrial planetary mesosphere is the transition region between thick lower atmosphere and thin upper atmosphere. The change of momentum between the surface and the mesosphere which occurs through breaking gravity waves perturbs wind and temperatures in the mesosphere, and potentially affects on atmospheric escape. Therefore, mesosphere provides us important information to understand atmospheric coupling between lower and upper atmosphere. However, there are still unsolved problems in the terrestrial planetary mesosphere due to the lack of observations. On Mars, the unexpected large amount of heavy ions (CO_2^+, O_2^+) was observed in the upper atmosphere [Carlsson et al., 2006]. The mechanism to propagate such heavy ions from lower atmosphere to upper atmosphere is necessary. On Venus, the characteristics of the transition region between retrograde zonal superrotation in the cloud layer and subsolar-to-antisolar flow in the upper atmosphere are not yet solved. Previous studies pointed out that the atmospheric waves have an important role on the transportation of momentum, energy and materials. The detailed measurement of atmospheric waves is required.

Ultra-high resolution heterodyne spectroscopy of CO_2 at mid-IR wavelengths is one of the powerful tools to study wind and temperatures in the terrestrial atmospheres. Kinetic temperature can be calculated from the width of the observed lines and the doppler shift due to the wind is estimated from the difference between the measured line frequency and the CO_2 rest frequency. In contrast to existing sub-mm observations, IR heterodyne spectroscopy offers a much higher spatial resolution allowing detailed study of temperature variations with latitude and local time. The IR heterodyne spectroscopy can achieve the spectral resolution $\sim 10^7$ and high spatial resolution of 3.5 arcsec with 60cm telescope at 10μm.

The purpose of this study is to investigate the methods to derive wind and temperature and its error estimation on Venus. Observations were carried out using Tuneable Heterodyne Infrared Spectrometer (THIS). The data was obtained in the east limb 33S on Venus in 4th June 2009 at the McMath- Pierce Solar Telescope of the National Solar Observatory on Kitt Peak in Arizona. Integration time is about 20 minutes. Because the exact altitude of the emitting region is predicted by the model to be $\sim$ 110km with a half width of 10km, we can directly derived the wind and temperature in its altitudinal region. Our results indicated that the accuracies of derived wind and temperature were $\pm$11m/s and $\pm$12K respectively. These errors were defined from $\chi^2 \leq 1$ of Gaussian fitting of the emission line. The estimated errors are sufficient to discuss disturbance of temperature on Mars and Venus (Mars:5-35K, Venus:5-40K [Deming and Mumma ,1983]) . The estimated error of the wind basically agreed with the expected values from the spectral resolution ($\pm$10m/s). The obtained mesospheric temperature 184$\pm$12K shows a good agreement with the in-situ measurement by Pioneer Venus([Clancy et al.,2008]).

We developed the new IR heterodyne instrument for the dedicated telescope at the top of Mt. Haleakala, Hawaii. Using the methodology shown here, we plan to perform the continuous monitoring of wind and temperature in the Venus/Mars mesosphere.

Keywords: mesosphere, infrared, heterodyne, error, Mars, Venus