Venus' upper mesosphere / lower thermosphere :
Variability, modeling and observational constraints

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The structure and dynamics of Venus' upper mesosphere/lower thermosphere transition and its rapid variability are investigated by (1) temperature measurements relying on inversion of molecular band or line profiles (sub-millimeter, mid-IR), radio occultation, solar and stellar occultations ; (2) direct zonal and SSAS wind measurements from the ground, and their rapid variability ; (3) the vertical, longitudinal distribution and temperature derived from linewidths and distribution of rotational line intensities of airglow emissions. Remote an in-orbit observations offer complete coverage of the planet's hemispheres, at different time scales, over complementary latitudinal ranges and techniques.

In the lower thermosphere, nightside shifts of He and H density maxima, temperature minimum and NO emission suggest retrograde super-rotation with wind speeds of 50-100 m/s, while mid-IR 10-μm measurements near 110 km suggest zonal wind speeds < 30 m/s. Rotational and kinetic temperatures retrieved from heterodyne mid-IR observations of non-LTE, CO_2 on the dayside constrain the thermal structure, non-LTE emission processes, and their temporal and spatial variability (Sonnabend *et al.* 2008, PSS 56, 1407).

In the mm/sub-mm range, the optically thick ^{12}CO line absorption constrains CO abundance at 70-90 km and temperatures from 80-115 km. Retrieved temperature profiles exhibit strong diurnal variation in lower thermospheric temperatures, with variable CO mixing profile gradients. Ground-based measurements of H_2O, based upon mm and sub-mm HDO line, indicate global, extremely large decadal variability (Sandor and Clancy 2005, Icarus 177, 129-143). Comparison with SOIR measurement geometry (Vandaele et al. 2008, JGR 113, E00B23) reveal possible latitudinal structure of mesospheric H_2O. Sub-millimeter SO and SO_2 lines exhibit rapid, global variations on weekly, diurnal, and interannual timescales, with an altitude derived from pressure-broadened lines shape showing an increased mixing ratio above 1 mbar. The optically thin ^{13}CO line absorption constrains CO abundance at 85-105 km. Large-scale (hemispheric) changes in CO and temperatures extend deep into the mesosphere (to below 1 mbar, 85 km), and are presumably related to hemispheric-scale changes in nightside O_2 ($^1\Delta_g$) airglow.

Trace species in Venus' upper mesosphere are subject to spatial redistribution by the global wind system. In the lower thermosphere, diurnal variations of O, N, He and H are primary tracers of the circulation, while in the upper mesosphere, this role is played by photolysis products of CO_2 and N_2 at mesospheric / thermospheric levels on the day side. Emission in the $a^1\Delta_g$ $-X_3\Sigma^-_g(0–0)$ band of molecular oxygen at 1.27 μm is a prominent feature of the Venus nightside spectrum, as well as NO at 1.224 μm. The low correlation coefficients of both the altitude and the intensity of the NO and O_2 airglow layers indicate that the transport of O and N atoms considerably deviates from a steady state vertical flow, even in the region close to the antisolar point (Gerard et al. 2009, JGR 114, E00B44). Considerable constrains on the O_2 airglow distribution, variability and temperature are brought by ground-based observations (Bailey et al. 2008, Icarus 197, 247, Krasnopolsky 2010, Icarus 207, 17).

Results from different techniques and time-scales reveal both spatial and temporal variability of temperature field, trace species and wind circulation, constraining the validity and vertical, as well as latitudinal extension of the cyclostrophic balance approximation, across this transition region. We will review those different methods of investigation, recent results as well as modeling effort to identify the dominant planetary-scale waves, their effect on dynamical tracers, and suggest directions for the future coordination of upper mesosphere/lower thermosphere observations of Venus.