Zonal thermal winds in Venus mesosphere derived from Venus Express temperature soundings

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Venus mesosphere is a region of transition between two different regimes: a zonal super–rotation flows between the surface and the lower mesosphere reaching a maximum speed of ~100 m s^{-1} at the cloud tops (~70 km altitude) while a solar–antisolar circulation with wind speeds of ~120 m s^{-1} is observed above 110 km altitude. The main mechanisms responsible for maintaining the zonal super–rotation and its transition to the solar–antisolar circulation are still poorly understood (Schubert et al.,2007). Leovy, 1973 first noted that on a slowly rotating planet, like Venus, the strong zonal winds at the cloud tops are well described by an approximation of the thermal wind equation: the cyclostrophic balance in which the equatorward component of centrifugal force is balanced by the meridional pressure gradient. This equation gives a possibility to reconstruct the zonal wind u if the temperature field is known, together with a suitable boundary condition on u.
The temperature structure of Venus mesosphere is investigated by two experiments on board Venus Express: VIRTIS (Visible and Infrared Thermal Imaging Spectrometer) and VeRa (Radio Science Experiment). In addition, Venus Monitoring Camera (VMC/VEx) is providing UV images used to measure cloud-tracked winds at cloud top. In the frame of this work, zonal thermal winds were derived from the VIRTIS and VeRa temperature sounding by applying the thermal wind equation and were compared to the cloud-tracked winds to validate the cyclostrophic assumption. Thanks to Venus Express capabilities, the variability of zonal wind with latitude, altitude and local time was analyzed in detail. The main features of the retrieved winds are: (1) a midlatitude jet with a maximum speed up to 140 ± 15 m/s which occurs around 50°S latitude at 70 km altitude; (2) the fast decrease of the wind speed from 60°S toward the pole; (3) the decrease of the wind speed with increasing height above the jet (Piccialli et al., 2008). Cyclostrophic winds showed satisfactory agreement with the cloud-tracked winds derived from the Venus Monitoring Camera (VMC/VEx) UV images at 30 – 70° latitudes, meaning that the cyclostrophic balance governs the circulation at these latitudes. A disagreement is observed at the equator and near the pole where the cyclostrophic approximation ceases to be valid.
Knowledge of both temperature and wind fields allowed us to study stability of the atmosphere with respect to convection and turbulence. The Richardson number Ri was evaluated from zonal field of measured temperatures and thermal winds. The atmosphere is characterized by a low value of Richardson number from ~45 km up to ~60 km altitude at all latitudes that corresponds to the lower and middle cloud layer indicating an almost adiabatic atmosphere. A high value of Richardson number was found in the region of the midlatitude jet indicating highly stable atmosphere. The necessary condition for barotropic instability was verified: it is satisfied on the poleward side of the midlatitude jet, indicating the possible presence of wave instability.