Study of Venus atmosphere dynamics using cloud tracking technique

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Abstract

The cloud tracking method with cross correlations is the most practical mean of measuring the wind velocity with extensive spatial and temporal coverage for a cloudy planet like Venus. To study the atmospheric dynamics of Venus, an improved cloud tracking method for deriving wind velocities from successive planetary images was developed. In this method, to reduce measurement errors in wind velocities, we combined several techniques: redetermining the camera pointing information by fitting an ellipse to the Venus limb in each image; calibrating optical distortions using Venus images taken after the orbital insersion of the spacecraft; and correcting erroneous cloud motion vectors by re-determining the most plausible correlation peak among all of the local maxima on the correlation surface by comparing each vector with its neighboring vectors.

The newly-developed method was applied to the Venusian violet images obtained by Solid State Imaging system (SSI) onboard the Galileo spacecraft during its Venus flyby and Venus Monitoring Camera (VMC) onboard Venus Express. Two-dimensional distributions of the horizontal wind vector were successfully obtained.

From the SSI data, it was found that the solar-fixed component of the wind velocity field in 1990 was similar to that in 1982 obtained by the Pioneer Venus orbiter. This suggests that the structures of the mean circulation and the thermal tides were largely unchanged between these epochs. The deviation of the instantaneous zonal wind field from the solar-fixed component shows a distinct wavenumber-1 structure in the equatorial region. On the assumption that this structure is a manifestation of an equatorial Kelvin wave, the momentum deposition by this Kelvin wave, which is

subject to radiative damping, would induce a westward mean-wind acceleration of ~0.3 m s^{-1} per Earth day.

From VMC data over four years, an indication of a periodical, long-term oscillation of the super-rotation was suggested for the first time. The estimated period of about 260 d is longer than one Venus year, and thus the oscillation will not be a seasonal cycle. When the mean zonal wind is relatively fast, its latitudinal profile is nearly flat from low to mid-latitudes, while distinct mid-latitude jets emerge when the mean wind is relatively slow. Since the amplitude of the long-term variation is larger at lower latitudes, the mid-latitude jets are emphasized during the slow wind period.

Kelvin wave-like perturbations are observed when the background wind is relatively slow, while Rossby wave-like perturbations are observed when the background wind is relatively fast. We investigated the influence of the variation of the background zonal wind speed on the upward propagation of Kelvin and Rossby waves at altitudes 60-100 km assuming that radiative damping is the principal dissipation process. Results from a linearized primitive equation model suggests that Kelvin waves can reach the cloud top height in the slow background wind period and that Rossby waves can reach the cloud top in the fast wind period, being consistent with the observations. The horizontal wave structures of the modeled Kelvin and Rossby waves are also in agreement with VMC observations.

Since the momentum deposition by these waves can accelerate and decelerate the mean flow, these waves will contribute, at least partly, to the periodical oscillation of the super-rotation. The Kelvin wave in our model showed significant acceleration in low latitudes and it can be a candidate of the increasing of zonal wind speed. However, because the Rossby wave decelerates mainly in mid-latitudes, other mechanisms are required to decelerate to the zonal wind speed in low latitudes, and the advection flow may play a key role of the deceleration.