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Potential Vorticity of the South Polar Vortex of Venus

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Abstract

The atmospheric vortex at the southern pole of Venus is highly variable in morphology and unpredictable in its dynamical behavior. Using infrared images from the VIRTIS-M instrument onboard Venus Express we have built maps of Ertel's potential vorticity at the lower and upper clouds (altitudes ~41-45km and ~55-62km above the surface). For this purpose, we have combined the wind field at both clouds' levels and the three-dimensional thermal structure that we previously measured [1, 2].

1. Ertel's Potential Vorticity

We have considered three widely different vortex morphologies (see Figure 1) in order to better understand the relation between the vortex's morphology, its dynamical properties and its variations at short and long timescales.

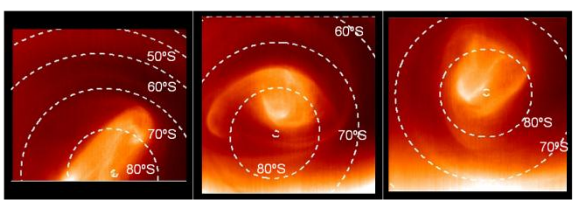

Figure 1: Three different configurations of the South Polar Vortex of Venus as observed by the VIRTIS-M-IR instrument in ~5µm images. Reference [2] shows that these radiance images are highly correlated with the thermal structure of the atmosphere at the cloud top.

For an inviscid atmospheric flow (neglecting friction) and in the absence of sinks of sources of potential vorticity from diabatic heating, the Ertel's potential vorticity (EPV) is a conserved quantity that can be used as a tracer of fluid motions [3] being therefore an appropriate quantity for diagnostic studies of the atmospheric dynamics [4]. The general definition of Ertel's potential vorticity (EPV) under the hydrostatic approximation can be written as [3, 4]:

$$q = \frac{\overrightarrow{\omega_R} + 2\vec{\Omega}}{\rho} \nabla\theta \sim (\zeta_\theta + f)\left(-g\frac{\partial\theta}{\partial P}\right) \quad (1)$$

where $\overrightarrow{\omega_R} = \nabla \times \vec{U}$ is the vorticity of the wind vector $\vec{U}$, $\vec{\Omega}$ is the angular rotation speed of the planet, ρ is the density, and θ is the potential temperature. $f = 2\Omega \sin\phi$ is the Coriolis parameter (with ϕ being latitude), ζ_θ is the relative vorticity calculated on an isentropic surface (constant θ), P is the pressure, and g is the gravitational acceleration.

Therefore, the horizontal spatial structure of EPV depends on $\zeta_\theta(x,y)$ through the wind velocity field and on $\frac{\partial\theta}{\partial P}(x,y)$ through the temperature field. The later term is related with the static stability of the atmosphere and is always negative on the area covered by the Venus vortex [2, 5].

2. Results

Our analysis shows that the vortex is a vertically depressed structure when observed in isentropic surfaces between 55 and 85km altitude. At the upper cloud's level (55-62km) the vortex sinks 2-3km over horizontal distances of 240-330km (Figure 2), with smooth altitude variations inside the warm vortex that correlate with structures seen in the thermal images.

The EPV value range obtained at the upper cloud's level is -1–5 (x10^{-6} K m^2 kg^{-1} s^{-1} ≈ 1 P.V.U., *potential vorticity unit*), while at the lower cloud's level (~41-45km) the EPV decreases two orders of magnitude (-2–8 x10^{-2} P.V.U.).

The horizontal distribution of EPV at the upper cloud’s level does not retain the structure seen in the radiance images or in the temperature maps (Figure 1), but resembles the distribution of the relative vorticity, which is determined purely from tracked motions [1]. At the lower cloud’s level, where the radiation coming from space hardly penetrates, the thermal structure is computed from latitudinal analyses of Pioneer Venus, VIRA and Venus Express radio occultation data [5] and tends to homogenize the structure seen in the relative vorticity maps. In both cloud layers, the kinetic component dominates with respect to the thermal structure.

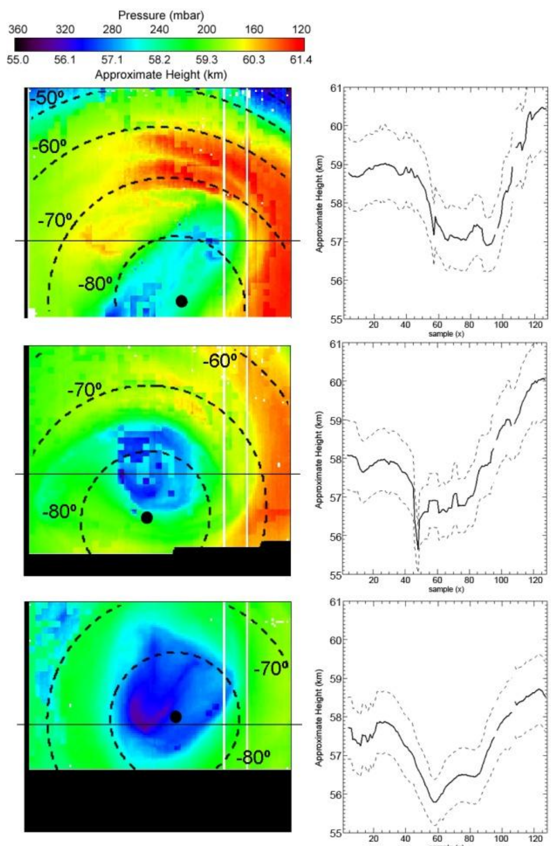

Figure 2: Altitude variation of the 330K isentropic surface (left) and over the solid lines displayed in the left columns (right) on orbits 038 (top), 310 (middle), and 475 (bottom). Dashed lines depict the altitude uncertainty range.

3. Conclusions

The global structure of the EPV at the upper cloud’s points to a weak ring of potential vorticity without any strong latitudinal gradient, as should be expected in the presence of a mixing barrier. However, local minima and maxima of EPV are found close to each other with differences of up to 4 P.V.U. The annular shape in potential vorticity is a trait shared in common with Mars’ polar vortices, while the vertically extended structure of the Venusian vortex is in common with Earth’s polar vortices. Apparently, Venus’ South Polar Vortex is a feature intermediate in its characteristics between Mars’ and Earth’s polar vortices.

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References

[1] Garate-Lopez, I., Hueso, R., Sánchez-Lavega, A., Peralta, J., Piccioni, G., and Drossart, P.. A chaotic long-lived vortex in Venus’ southern pole. Nature *Geoscience* **6**, 254-257 (2013).

[2] Garate-Lopez, I., García-Muñoz, A., Hueso, R., and Sánchez-Lavega, A.. Instantaneous three-dimensional thermal structure of the South Polar Vortex of Venus. *Icarus* **245**, 16-31 (2015).

[3] Pedlosky, J.. Geophysical Fluid Dynamics (2nd edition). *Springer*. (1987).

[4] Sánchez-Lavega, A.. An Introduction to Planetary Atmospheres. Taylor & *Francis*. 587 pp. (2011).

[5] Tellmann, S., Pätzold, M., Häusler, B., Bird, M.K., and Tyler, G.L.. Venus neutral atmosphere as observed by the Radio Science experiment VeRa on Venus Express. *Journal of Geophysical Research* **114**, 1-19 (2009).