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Morphology and dynamics of the South Polar Vortex in Venus from VIRTIS-VEX infrared images

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Abstract

We present a study of the variable morphology of Venus' South Polar Vortex [4] and its dynamics in terms of the wind field in the vortex retrieved from semi-automatic cloud tracking over an ample set of images obtained with the VIRTIS instrument onboard Venus Express. We present results from night-side images in the near-infrared (1.74μm) sensitive to the lower clouds (~45km), and from thermal infrared (3–5μm) images sensitive to the upper clouds (~65km) and able to study both the day and night-side of the planet [5]. We have obtained wind fields in 25 orbits during the Venus Express nominal mission. In 20 of these orbits we were able to obtain simultaneous measurements in both height levels. We obtained a total number of 7080 tracers for the lower clouds and 5160 for the upper clouds. This has enabled us to explore the different dynamics associated to the varying morphology of the vortex.

1. Morphology

The data from the VIRTIS-M instrument permit to obtain images of Venus' atmosphere in particular observation windows that sample different layers of the atmosphere. In this work we have focused on high-resolution images of the South Polar Vortex on 3 wavelengths. At 1.74μm, we see the thermal radiation from the lower atmosphere filtered by the deep clouds and at 3.80 and 5.10μm we observe the thermal emission from the upper clouds. In the latter two cases, we get information about the same height-level but with different contrast and different capability to observe the polar day and night-side.

The South Polar Vortex shows a constantly changing appearance (figure 1). In some cases these morphologies are stable over tens of days and in others we can observe large-scale changes in the morphology occurring in time-scales of 1-2 days. In image-sequences corresponding to the same orbit (2–6 hrs), it is possible to see the slow variation of the cloud structures and measure the local wind fields, but usually the morphology changes completely from orbit to orbit (~24 hours) [3]. In 35% of the orbits, the vortex presents a dipolar shape similar to that observed in the early Venus Express mission [1]. In a similar amount of orbits it appears as an oval, being elongated (25%) or nearly circular (10%). Most of the other observations show the vortex as a transition feature between these two basic configurations with some reduced number of cases where a tripole structure is observed.

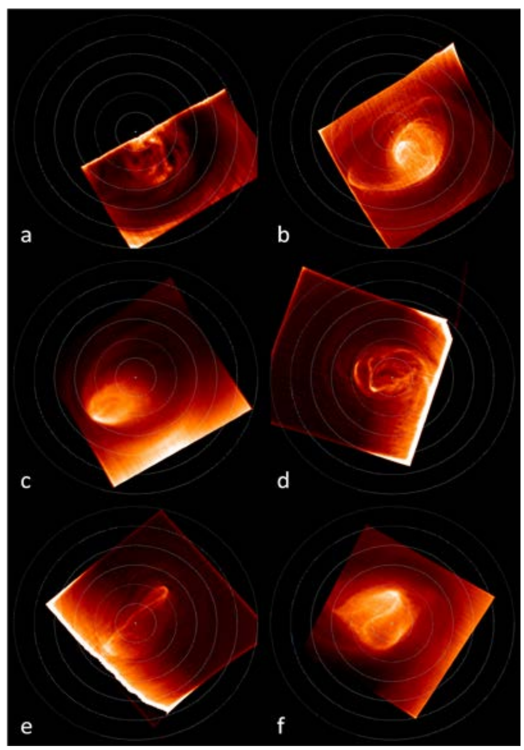

Figure 1: Views of the South Polar Vortex: (a) lower clouds at 1.74 μm, orbit 310; (b) upper clouds at 5.1 μm orbit 310, (c) upper clouds at 5.1 μm, orbit 251, (d) lower clouds at 1.74 μm, orbit 355, (e) upper clouds, 3.8 μm, orbit 394, (f) upper cloud, 5.1 μm orbit 475. Latitudes go from the South Pole to 60ºS.

2. Semiautomatic cloud correlation

We assume that the clouds drift with the local wind. We have used an image-correlation algorithm [1] to study the motions of these clouds. We project sequence of images in a polar geometry. For a small section of the first image (a template typically of size 500km x 500km) the program proposes the best equivalent region in the second image that maximizes the correlation function between both the template and its match. Since the images are typically noisy we supervise all the measurements and we decide to apply or change this measurement looking at a 2D map of the correlation function. This process of supervision avoids spurious measurements "on the fly" or having to incorporate numerical filters to the wind data.

3. Wind results

The ensemble of our measurements shows that Venus' South Polar atmosphere has almost no vertical wind shear between both sampled levels (figure 2). This is in agreement with previous studies that did not study the polar region with detail [5]. Simultaneous measurements of cloud motions in the vortex in both levels are very similar but the dynamics at each layer are slightly different due to stronger differences of the motions in the upper cloud with respect to the global atmosphere. Global wind intensity maps show that at 75°S the regular circulation of mid-latitudes separates from the variable circulation of high-latitudes in both height levels.

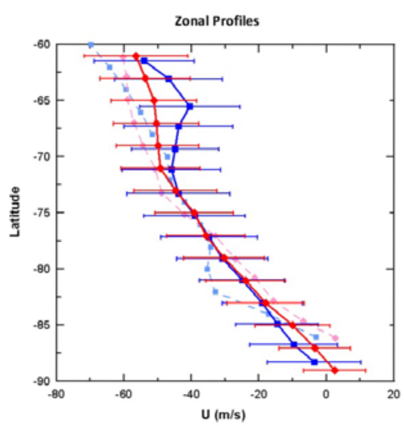

Figure 2: Zonal profiles of the wind field for the lower clouds at 1.74µm (red), and for the upper clouds at 3.80µm and 5.10µm (blue). Profiles are compared with those of Hueso et al. (2012) [2].

Vorticity maps were calculated for each image pair. In most of them there are not outstanding features and local maxima in the vorticity are found correlated with the vortex morphology only in some particular cases. In the upper cloud where the vortex is observed with more contrast the vorticity maxima do not generally coincide with the morphology of the vortex and the brightest features tend to locate surrounding the regions of maximum local vorticity.

4. Conclusions

Venus' South Polar Vortex is a weak cyclonic and warm vortex superimposed to the general cyclonic circulation. The vortex is not centered at the pole and is advected by the general circulation depending on its excursions out of the pole. We confirm previous results about its precession around the pole [3] which seems to be largely variable. The complex relations between the vorticity and retrieved wind fields and the cloud morphology show connections that are difficult to disentangle.

Acknowledgements

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