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Three-dimensional Thermal Structure of the South Polar Vortex of Venus

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Abstract

Our current knowledge of Venus' south polar vortex is based mainly on its cloud morphology and motions. In order to interpret its dynamical nature, it is critical to characterize the thermal structure of the vortex, which remains poorly constrained. We have obtained high resolution thermal maps of the Venus south polar region between 55 and 85 km altitudes for three different dynamical configurations of the polar vortex using VIRTIS-M-IR data. From the temperature maps, we also studied the vertical stability of different atmospheric layers.

1. Introduction

The Venus Express mission is well equipped to study the thermal structure of the atmosphere. Some of the instruments on board Venus Express can characterize the vertical temperatures at a single location at a time, e.g. VeRA and SPICAV. More importantly for our goals, the VIRTIS instrument allows to obtain the thermal field of a large area at a particular time.

Grassi et al. [3] developed a method for obtaining thermal profiles in the Venusian mesosphere from radiances measured by VIRTIS-M (the mapping arm of the instrument). This method has been used to retrieve moderate resolution thermal maps of the polar area on a day [3] and to obtain average temperature fields as a function of latitude, local time, and pressure from the analysis of VIRTIS infrared data [4, 5]. These thermal maps of the vortex area at different altitudes showed a smooth distribution of temperature with a maximum difference of about 30 K between the vortex and its surroundings at ~65 km.

2. Thermal Structure

Instead of a statistically-averaged study of thermal temperatures in the polar region we aim here to relate the instantaneous dynamics from the wind field to the particular thermal structure of the vortex on different days. We apply the atmospheric model described by García Muñoz et al. [2] and a variant of the retrieval algorithm detailed in Grassi et al. [3] to obtain high resolution (2x2 $pixels^2$) thermal maps of the Venus south polar region between 55 and 85 km altitudes. These maps are discussed in three different dynamical configurations of the vortex whose dynamics in terms of cloud motions has been previously obtained [1]. We also study the imprint of the vortex on the thermal field above the cloud level.

Using the maps of vertically-resolved temperatures, we studied the vertical stability of the atmosphere dividing the 55 – 85 km vertical range in seven layers of approximately 4 km thick (about one scale height). It is always positive ($S_T > 0$) in this altitude range in the whole polar vortex. However, our temperature retrieval is not sensitive to the altitude range where the static stability is low (45 – 55 km).

3. Results

The South Polar Vortex is represented by a vertically extended hot region close to the pole (constrained to latitudes > 75º) and squeezed by the cold collar between altitudes 55 and 67 km but spreading equatorwards at about 74 km. Both the temperature maps at different pressure levels and the zonal average thermal fields show that the top limit of the thermal signature from the vortex is at ~80 km altitude.

The cold collar is clearly distinguishable centered at ~62 km (~100 mbar) and being more than 15 K colder than the pole, on average.

The upper part of the atmosphere (67 – 85 km) is more homogeneous and has long-scale horizontal temperature differences of about 25 K. The lower part (55 – 67 km), on the other hand, shows more fine-scale structure with thermal differences of about 50 K over the same pressure level. This lower part of the atmosphere is highly affected by the effects of the upper cloud deck.

Temperature maps retrieved at 55 – 63 km show the same structures that are observed in the ~5 µm radiance images. This altitude range coincides with the optimal values of the cloud top altitude at polar latitudes and we conclude that the magnitudes derived from the analysis of ~5 µm images are measured at 56 – 62 km altitude range.

The layer between 62 and 67 km resulted to be the most stable. The cold collar is clearly the most statically stable structure at polar latitudes, while the vortex and subpolar latitudes show lower stability values. Furthermore, the hot filaments present within the vortex exhibit even lower stability values than their surroundings.

The static stability analysis carried out above ~55 km is in good agreement with previous radio occultation analyses [6], and we postulate that the convective regions ($S_T < 0$) that they found within the middle cloud deck constitute a key point towards the understanding of the dynamics of the highly variable vortex.

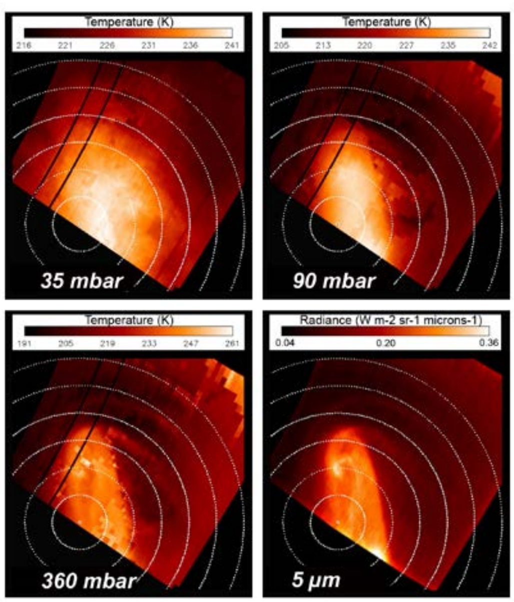

Figure 1:. Retrieved temperature maps at three different atmospheric pressure levels and radiance image (~5 µm) over the south polar region of Venus on orbit 038.

4. Outlook

Temperature maps retrieved in this work, together with previously measured wind fields [1], are being used to study the spatial distribution of potential vorticity in the south polar vortex for the three dynamical configurations analyzed here. That will allow to improve our understanding of the dynamical characteristics of the vortex and its unpredictable character.

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