VENUS NIGHTSIDE ATMOSPHERE MAPPED IN THE INFRARED ATMOSPHERIC WINDOWS AND THERMAL EMISSION AS SEEN BY VIRTIS ON VENUS EXPRESS

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Abstract

In this study we make use of the complete dataset of the Visible and InfraRed Thermal Imaging Spectrometer mapping channel (VIRTIS-M) on board Venus Express, with a wide spatial and long temporal coverage in the period from 2006 until 2009, to produce global mean radiance maps integrated through the main infrared atmospheric windows centered around 1.74µm and 2.35µm, and mean thermal emission at 3.8µm and 5.0µm.

These maps provide an unprecedented global view of the overall Venus' atmosphere opacity and clouds top temperature at both hemispheres, showing very interesting trends and dependences with latitude, local time and longitude, diagnostic of the global circulation flow and dynamics. The maps provide important visual patterns as well as quantitative parameters to be used in support to the study of the Venus global circulation and related models at various altitude layers, from about 45 up to 70 km over the surface.

1. Venus Express mission

Venus Express was ESA's first mission to Venus. Launched on 9 November 2005 from Baikonur, the spacecraft arrived at Venus on 11 April 2006 and observed the planet until December 2014.

The spacecraft had an elliptical orbit of 24 hour period, with pericenter at 250 km altitude over the north pole, and the apocenter at 66000 km altitude over the south.

The main objective of the mission was to study the complex morphology, dynamics and chemistry of the atmosphere from a global point of view, from the interactions with the surface up to the ionosphere and magnetosphere.

2. VIRTIS instrument

The Visible Infra Red Thermal Imaging Spectrometer was the instrument that allowed Venus Express to map details of the Venus atmosphere from the surface up to the ionosphere.

The instrument had two channels: M (mapping) devoted to hyper-spectral imaging and H for high-resolution spectral measurements. The observations obtained in the M-Infrared channel covered a wide spectral range (1µm-5µm) with very good sampling capabilities (~10nm), highly valuable for the study of morphology, dynamics and composition of the atmosphere and infer surface properties.

The southern hemisphere has very good coverage, due to the Venus Express elliptic orbit, with apocentre near the south pole. The more limited coverage in the northern hemisphere causes gaps with regions that were never observed during the mission.

3. Infrared Atmospheric Windows

The radiation in the two main near infrared atmospheric windows, centered around 1.74 [1.68µm-1.78µm] and 2.35µm [2.19µm-2.52µm], comes mainly from below the cloud layers, as shown by radiative transfer models that indicate that the radiation at these bands originates about 10–20 and 20–30 km above the surface, respectively. This thermal radiation from the lower layers goes up through the cloud layer and is attenuated mostly by the lower clouds with differing optical depths. Therefore, the features observed at these wavelengths show mainly the spatial variations in the opacity of the lower clouds, around 40-50 km altitude. These clouds are known to be composed mainly by sulphuric acid covering the whole planet, dynamically elongated by the strong zonal winds coming from the super-rotation and travelling towards the poles with the meridional winds.

3.1 Results

The global maps show the mean radiances in the windows at 2.3µm and 1.74µm. Both bands are well correlated with the same global characteristics, in particular the increase of radiance at mid-latitudes, with a relatively good symmetry in both hemispheres. The more patchy distribution in the north is likely caused by the more limited coverage.

The increase of radiance at mid latitudes indicates more transparent clouds, very likely associated to down-welling due to the meridional cell. On the contrary, the low radiance in the equatorial region and in both polar regions is where the clouds thickness is maximum.

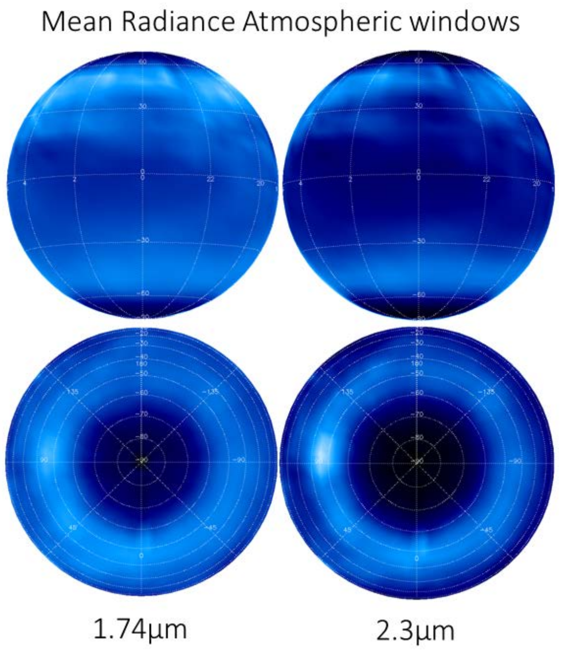

Figure 1. *Global maps of integrated radiance over Venus Nightside shown in Latitude vs Local Solar Time, centered at the equator at midnight (top) and Latitude vs Longitude seen from the south pole (bottom).*

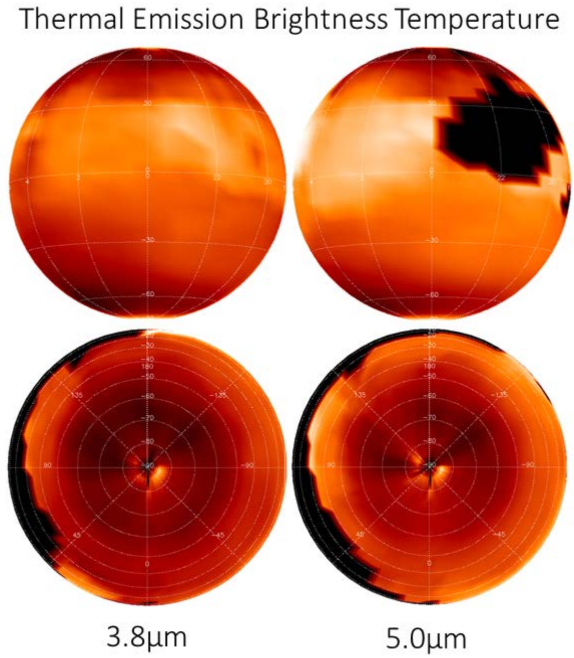

Figure 2. *Global maps of mean thermal brightness over Venus Nightside shown in Latitude vs Local Solar Time, centered at the equator at midnight (top) and Latitude vs Longitude seen from the south pole (bottom).*

The maps and profiles also show small and important differences, in particular in the different contrast at high latitudes, due to the cold collar around the polar region and the higher abundance of large particles, which enhances a lot the contrast in the 2.3µm with respect to 1.74µm

4. Thermal Emission

VIRTIS-M can also observe in the thermal range from 3 to 5µm, where also the main CO_2 absorption band resides. In this work we focus on the emissions at two specific wavelengths around 3.8µm [3.73µm-3.82µm] and 5.0µm [5.01µm-5.10µm]. VIRTIS observations usually show a strong correlation between the details observed at these two wavelengths, as the radiance at these bands depend on the thermal emission from the clouds top at about the same level. Radiative transfer calculations set the main source of the radiance at these wavelengths as coming from a layer at about 65-70 km altitude, corresponding to the upper cloud layer. Moreover, these wavelengths are of particular interest because they allow the study of the polar vortex morphology and dynamics.

The global maps show accumulated projections of the mean thermal brightness seen around 3.8µm and 5.0µm.

Note the large gap in the northern hemisphere for the 5.0µm map, due to saturation of long exposure observations which reduce the coverage significantly.

The two bands have a very similar global appearance, with very interesting features present in both maps. The most prominent is the Y-shaped region of high temperature in the equatorial belt, with clouds top temperature of about 235K. In contrast, we can see the cold collar region at +/-60° of latitude, with temperatures from about 220K in the morning terminator, increasing smoothly up to about 232K toward the evening side. An increase of temperature is also visible on both poles due to the polar vortex.

5. Acknowledgements

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6. References

[1] A. Cardesín-Moinelo, G. Piccioni, A. Migliorini, et al.. "*Long Term Mean Global Maps of the Venus Nightside Atmosphere using the Infrared Atmospheric Windows and Thermal Emission as observed by VIRTIS on Venus Express*". ICARUS 2019 (submitted)