Venus atmospheric cloud opacity, particle size and cloud top temperature mapped in the nightside with VIRTIS Venus Express

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ABSTRACT:

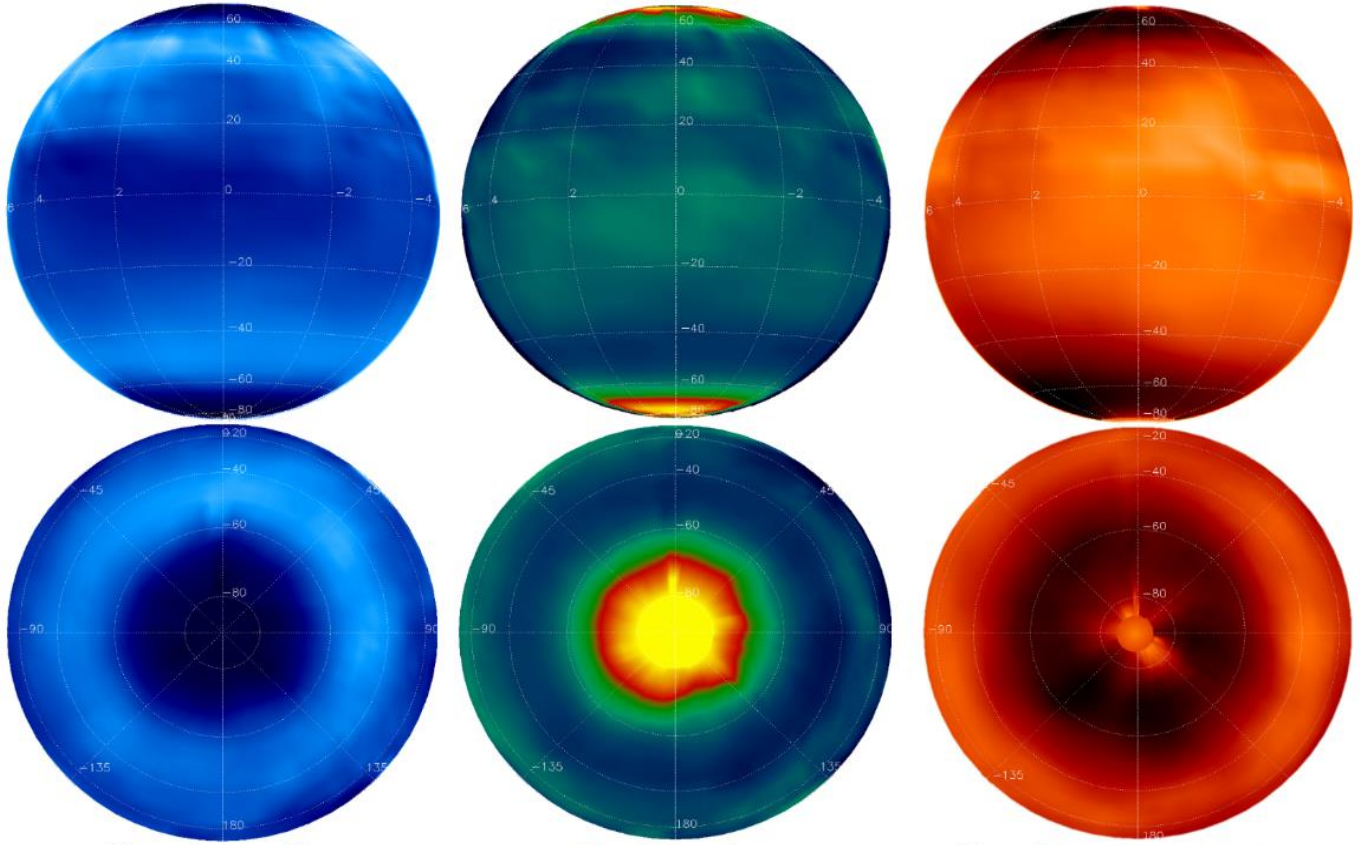
We present global maps of Venus nightside atmosphere seen in the infrared by VIRTIS/Venus Express between 2006-2008.

We first provide a global view of the nightside cloud opacity in the lower clouds (44-48 km altitude) mapping integrated radiance around 1.74 µm and 2.25 µm.

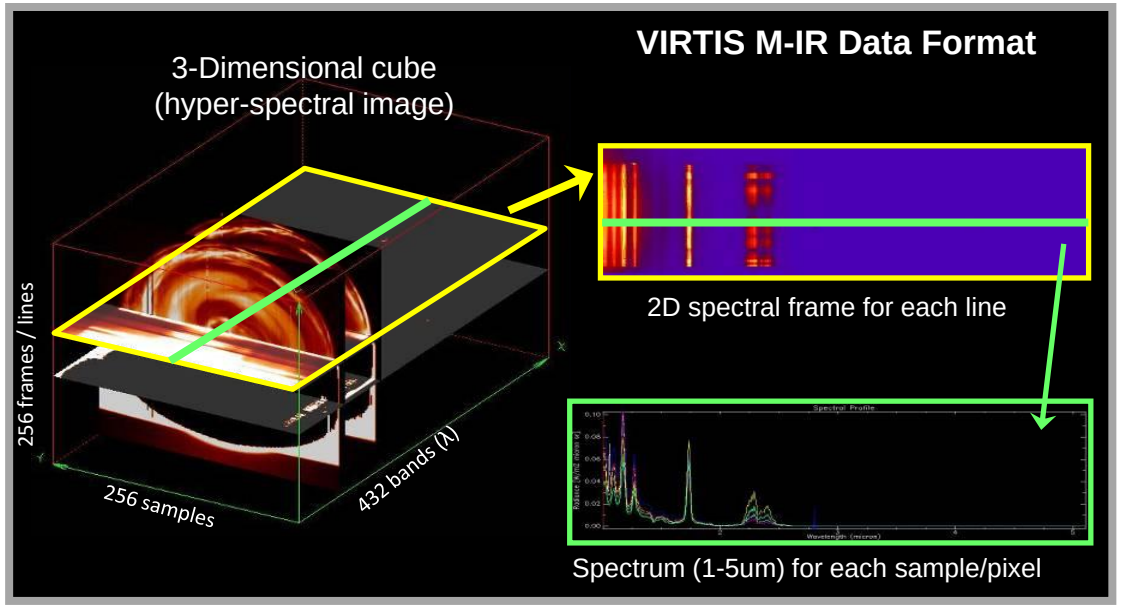
The ratio between these bands provides an indirect estimation of the particle size distribution for the whole planet.

We have then produced maps of brightness temperature at the cloud tops (60–70 km altitude), measured at 3.8 and 5.0 µm.

The latitudinal and local time profiles show the different atmospheric regions and provide details of the global circulation dynamics with high symmetry in both hemispheres.



Context: Venus Express + VIRTIS Imaging Spectrometer



Venus Express mission arrived at Venus in April 2006 and observed the planet until December 2014, from an elliptical orbit of 24 hour period, with pericenter at 250 km altitude over the north pole, and apocenter at 66000 km altitude over the south.

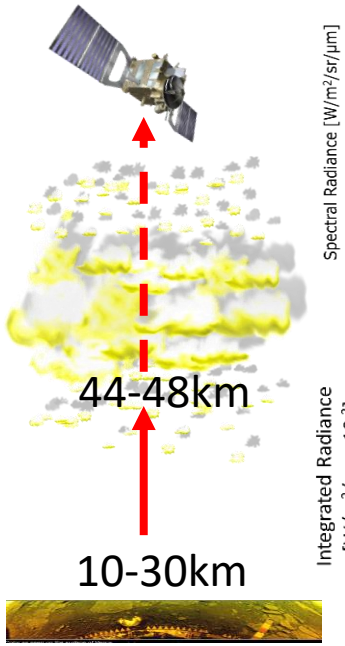
The main goal was to study the morphology, dynamics and chemistry of the atmosphere.

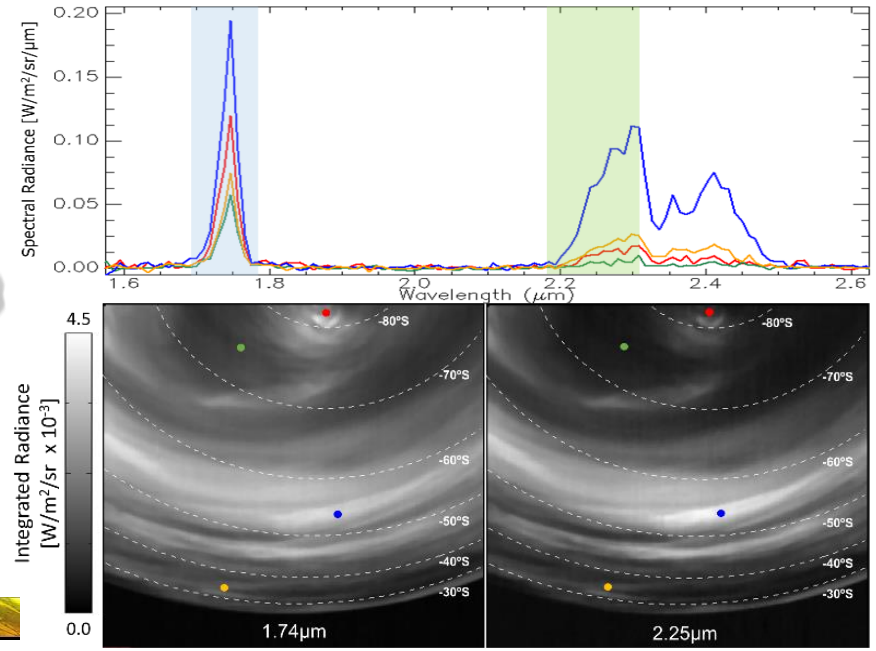
VIRTIS (Visible Infra Red Thermal Imaging Spectrometer) mapped details of the Venus atmosphere from the surface up to the ionosphere.

VIRTIS-M-IR was devoted to hyper-spectral imaging with a wide spectral range (1.0µm-5µm) and very good sampling capabilities (~10nm). This Infrared channel operated until 2008 when the instrument cryocooler failed, producing a great dataset of the Venus atmosphere.

Venus nightside atmosphere observed in the VIRTIS IR spectral regions. Data selection, filtering and processing

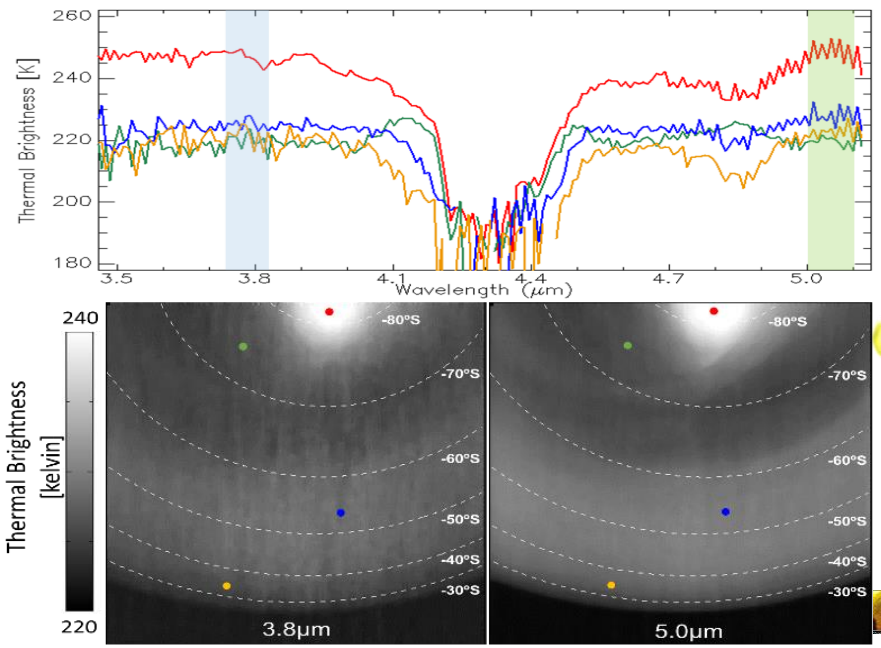
Lower cloud opacity, seen in atmospheric windows 1.74 & 2.25 µm

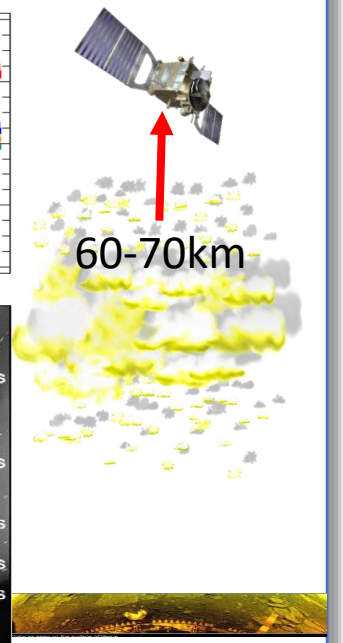




Atmospheric window	1.74µm	2.25µm
Wavelength range for radiance integration	[1.68µm-1.78µm] (+/-10nm) bands 70-80	[2.18µm-2.30µm] (+/-10nm) bands 122-135
Wavelengths used as reference for continuum subtraction	[1.67µm, 1.79µm] (+/-10nm), bands 69,81	[2.17µm,2.51µm] (+/-10nm) bands 121-157
Incidence angle filter	>100°	>100°
Emission angle filter	<80º (to avoid limb observations)	<80º (to avoid limb observations)
Limb darkening correction	R / (0.34 + 0.66 · cos(EA)) R: Radiance EA: Emission Angle	R / (0.23 + 0.77 · cos(EA)) R: Radiance EA: Emission Angle
Exposure time filter	>0.1 seconds (exclude dayside observations)	>0.1 seconds (exclude dayside observations)
Total observations used	**3133**	**3133**

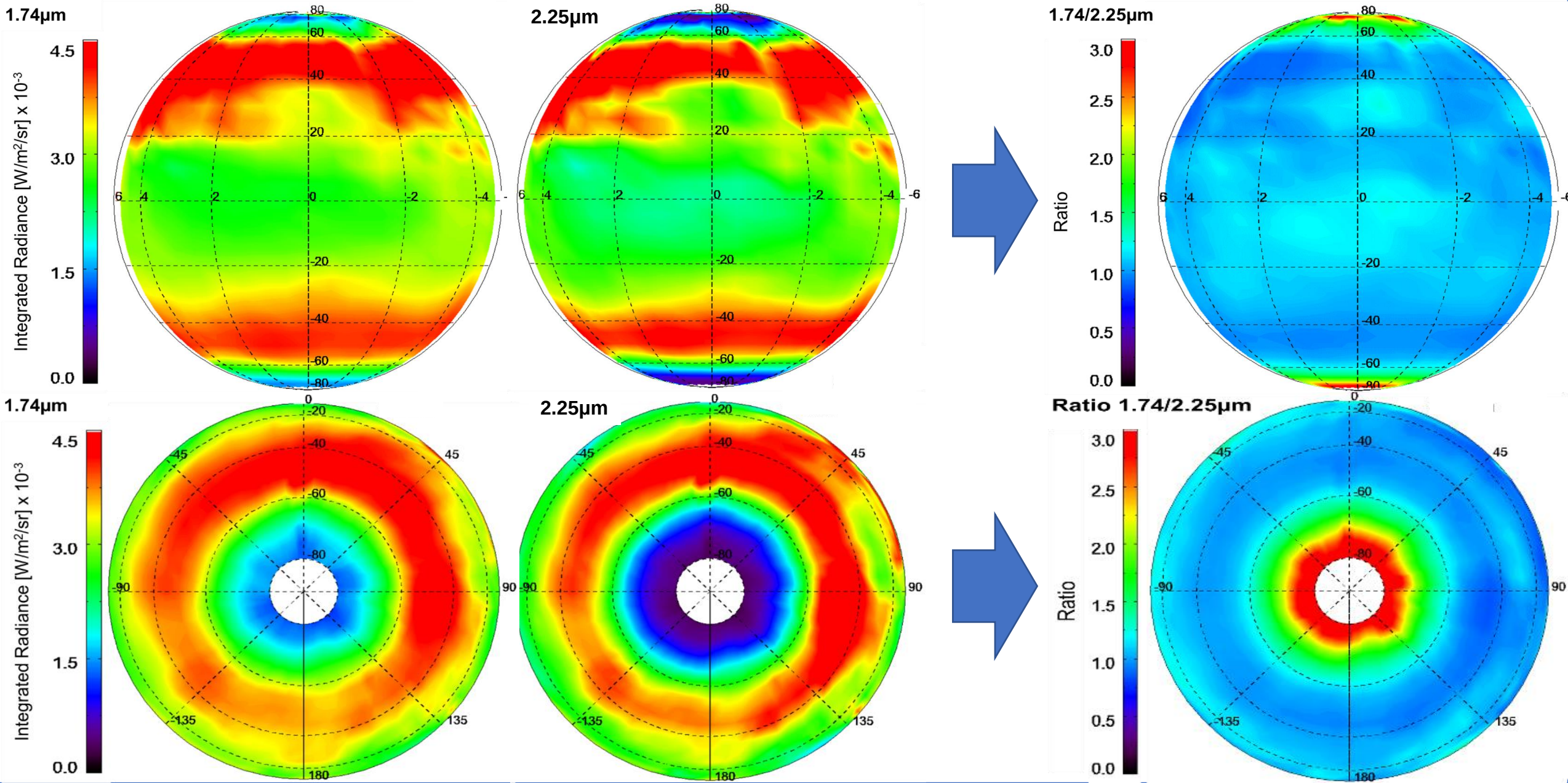
Top of the clouds temperature brightness seen at 3.8 & 5.0 µm



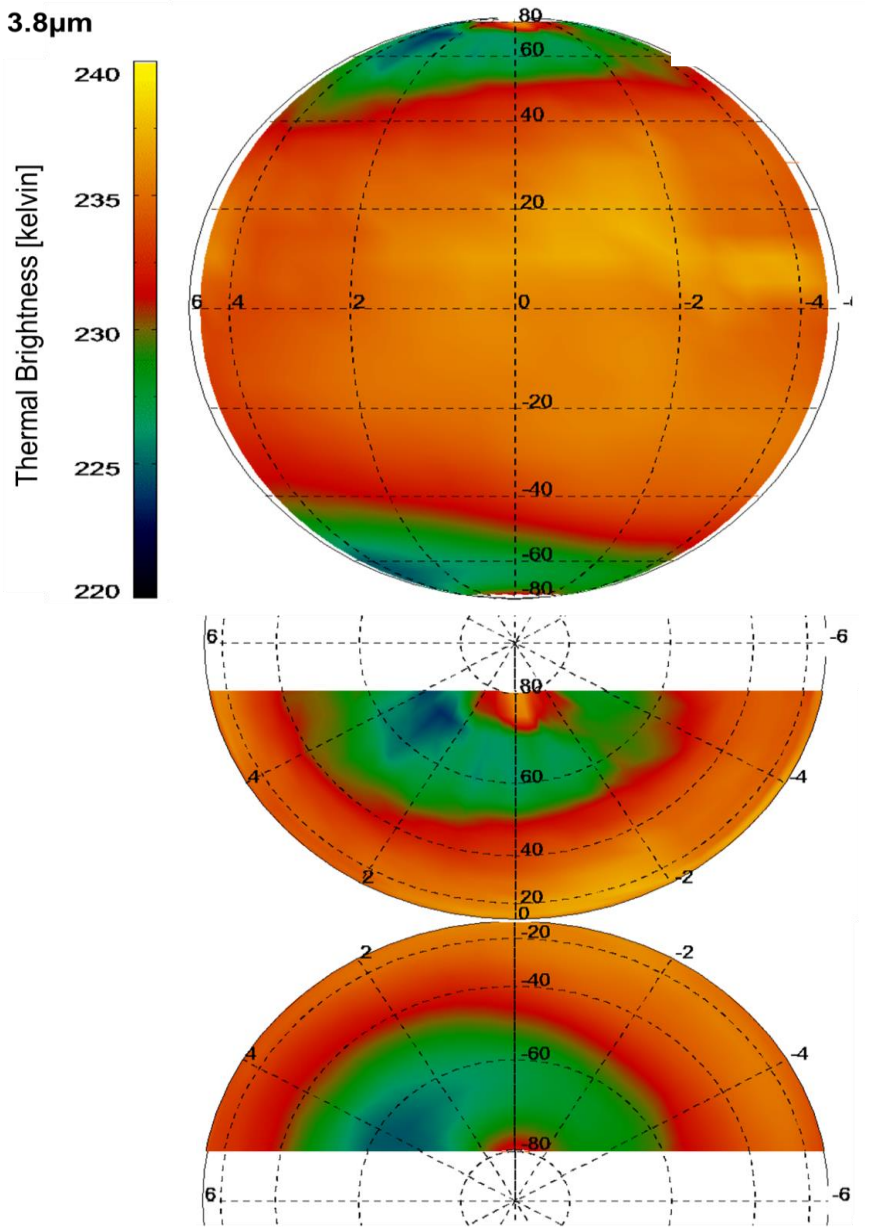


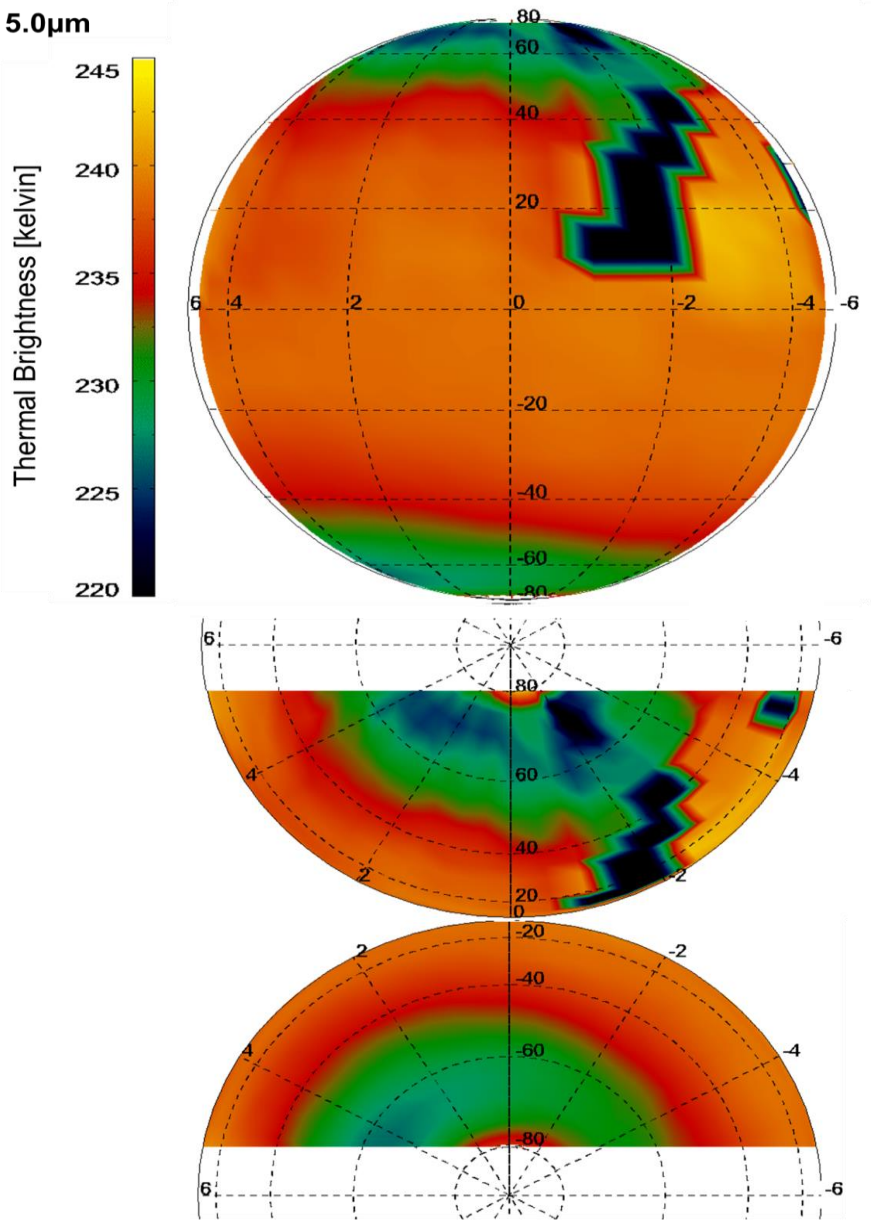
Thermal emission region	3.8µm	5.0µm
Wavelength range for thermal emission	[3.73µm-3.82µm] (+/-10nm), bands: 287-296	[5.01µm-5.10µm] (+/-10nm), bands: 421-431*
Mean Thermal Brightness	Converted into Thermal Brightness and then averaged together	Converted into Thermal Brightness and then averaged together
Incidence angle filter	>100°	>100°
Emission angle filter	<60º (to reduce limb darkening)	<60º (to reduce limb darkening)
Limb darkening correction	R / (0.13 + 0.87 · cos(EA)) R: Radiance EA: Emission Angle	R / (0.20 + 0.80 · cos(EA)) R: Radiance EA: Emission Angle
Exposure time filter	>0.1 seconds (exclude dayside observations)	0.1-2 seconds (to avoid data saturation)
Total observations used	**3034**	**1524**

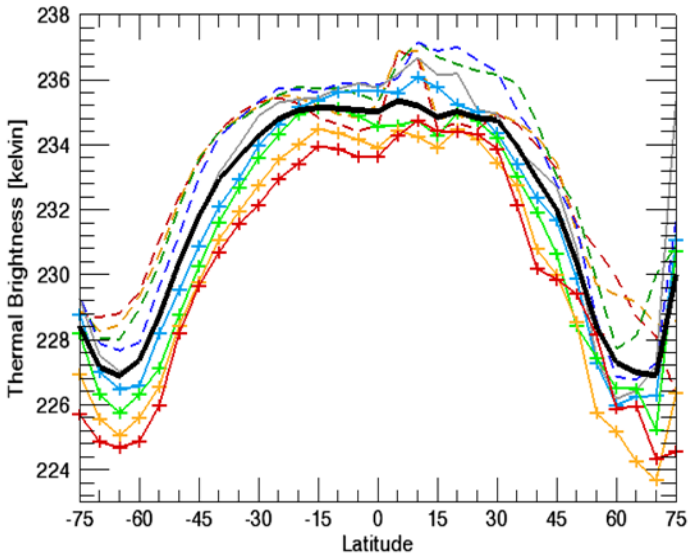
Results I: Maps of cloud opacity. Good symmetry north/south. No local time variations.
→ Ratio indicates particle size distribution

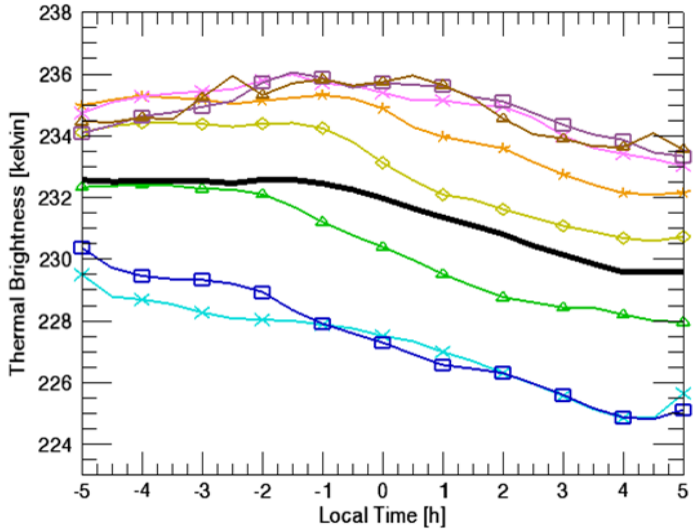


Results II: Maps of cloud top temperature
High latitudinal symmetry north/south, especially in cold collar local time profile









Impact and prospects for the future

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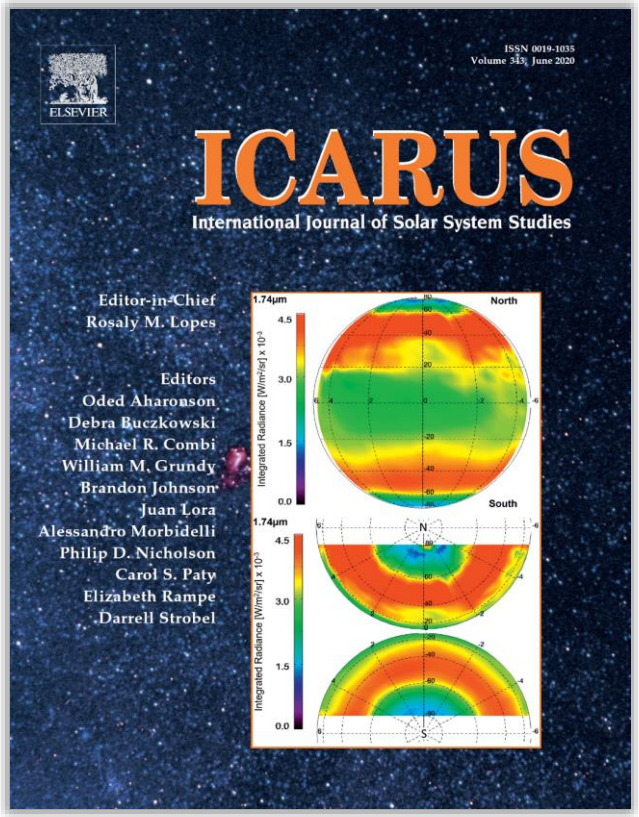
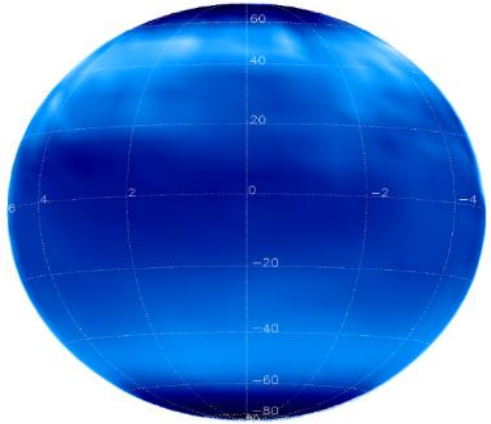
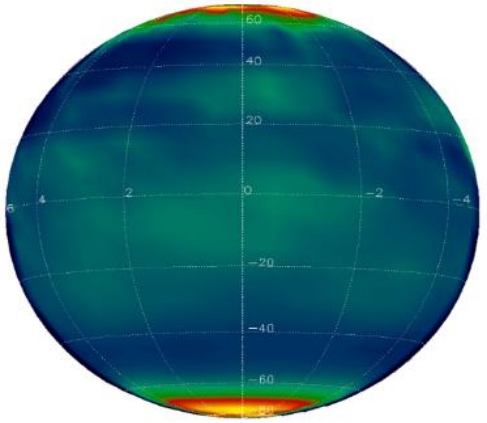


CONCLUSIONS:

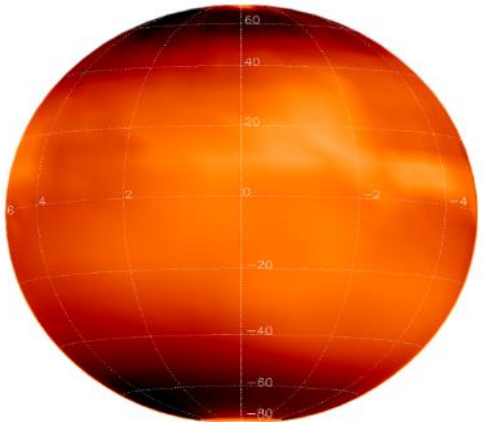
- "Mean state" of the atmosphere for cloud opacity, particle size and clouds top temperature
- High symmetry between both hemispheres, including local time cooling profiles
  - Equatorial clouds: uniform mid-high opacity, cloud tops show gradual cooling with local time
  - Mid-latitude clouds: lowest opacity and lowest particle size distribution (lower in the North?)
  - Cold-collar: highest opacity and particle size, evening-morning cooling both North and South



Cloud opacity



Particle size



Cloud top temperature

FUTURE:

- Input to Global Circulation Models
- Extension to VIRTIS-VIS dataset (@1.0μm) to study possible long term variations (2006-2014)
- Generation of full hyperspectral cube of Venus (infrared, visible, local time, longitude, …)