Thermal structure of Venus upper atmosphere by a *ground-to-thermosphere* VGCM: a preliminary study

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A BRIEF INTRODUCTION:

Venus GCM (Lebonnois et al. 2010) used to study specific processes of Venus atmosphere from the surface up to 100 km.

GCM basic characteristics

- Dynamical core based on LMDZ Earth model (Hourdin et al. 2006)
- Key features: Topography, diurnal cycle, dependence of the specific heat on temperature, consistent radiative transfer module

Venus GCM extension
(from 100 to 150 km altitude)
and improve the quality of the model

1. Model development
   - Martian "inheritance"
   - LATMOS collaboration

2. Data analysis

Motivation: understand and interpret recent Venus Express and ground-based measurements of the Venus upper atmosphere

Venus GCM extension

PROCESSES TO BE CONSIDERED in the upper atmosphere (100-150 km):

- In the mesosphere (90-130 km) NIR heating,15 um cooling

- In the thermosphere (above 130 km) absorption of EUV and thermal conduction, molecular viscosity

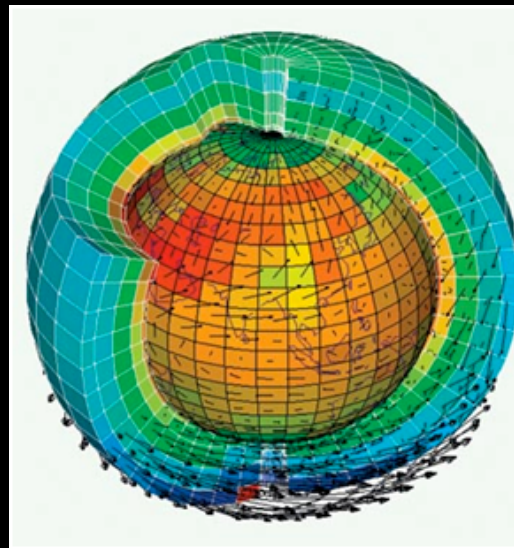- Active photochemistry and molecular diffusion

Limitation:

• Complexity of non-LTE model and non linearity of non-LTE situations. Full simulations too expensive for a GCM.

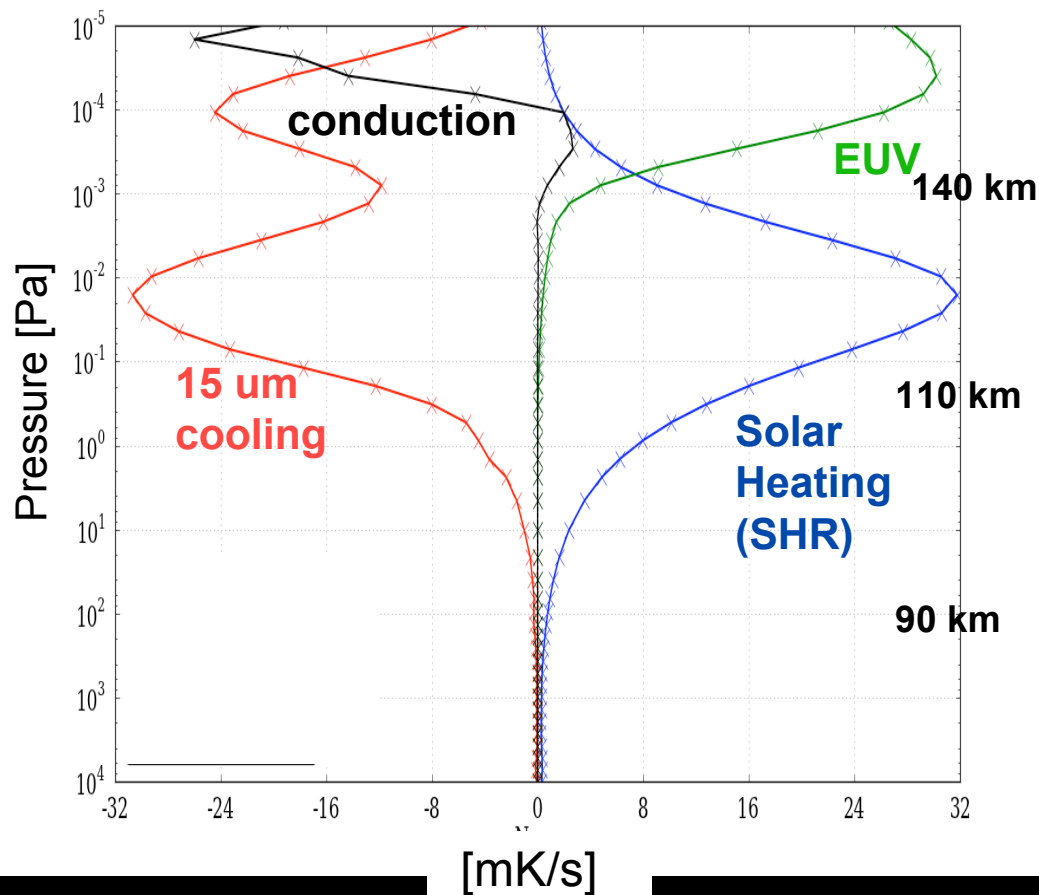Simplifications and parameterizations required

Methodology:

• Non-LTE Mars GCM parameterisation adapted to VGCM

• Integration into the Venus GCM of "martian" modules
(Angelats i Coll et al. 2005, Gonzalez-Galindo et al. 2009, 2014)

• Validation against non-LTE model *(Roldan et al. 2000)*

VGCM predictions in the upper atmosphere: preliminary results

Venus GCM extension

Thermal balance: noon, equatorial regions, after 3 Vdays

Plot axes: Pressure [Pa] (vertical) vs [mK/s] (horizontal). Curves labeled: conduction, EUV, 15 um cooling, Solar Heating (SHR). Altitude markers: 140 km, 110 km, 90 km.

- NIR (1-5 μm) CO_2 non-LTE heating

$$\frac{\partial T}{\partial t}(p, r, \mu) = \frac{\partial T}{\partial t}(p_0, r_0, 0) \times \frac{r_0^2}{r^2} \sqrt{\frac{p_0}{p}}\, \tilde{\mu} \left(1 + \frac{p_1}{p}\right)^{-b}$$

- 15 μm CO_2 non-LTE cooling

  5 transitions between molecular levels
  (instead of 92 for the full model)

- EUV heating

  5 species (CO_2, CO, O, N_2, N)
 efficiency 21 %

- Thermal conduction
- Molecular viscosity

- Molecular diffusion (not yet included)
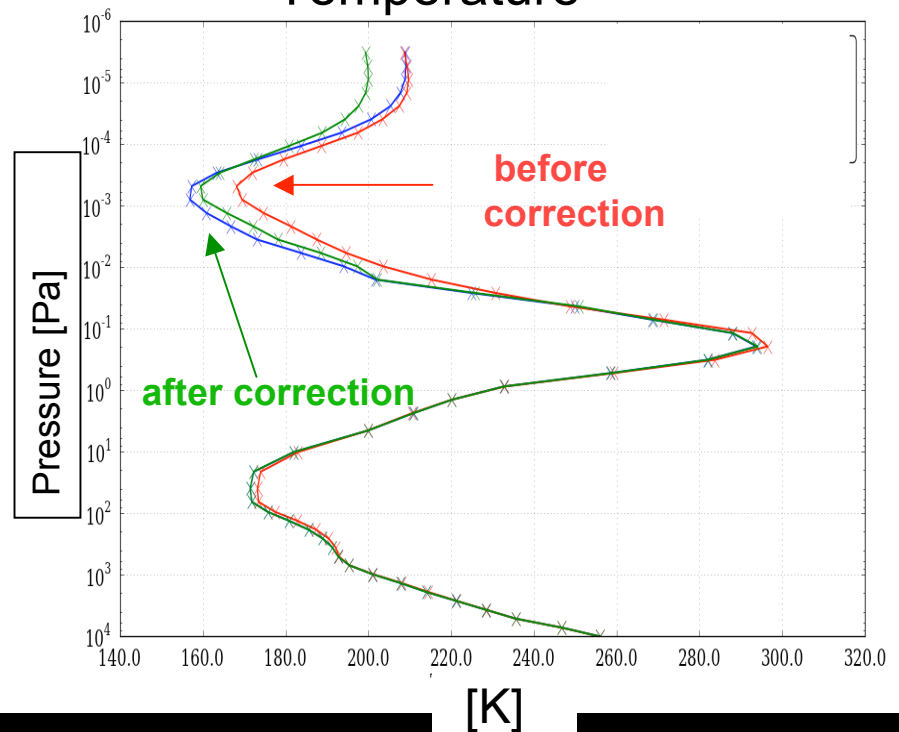
Venus GCM extension

Recent improvements:

Inclusion of *correction factors* to take account of the dependence of SHR to several parameters (i.e Kv-v, atomic oxygen abundances), as also previously done on Mars GCM.
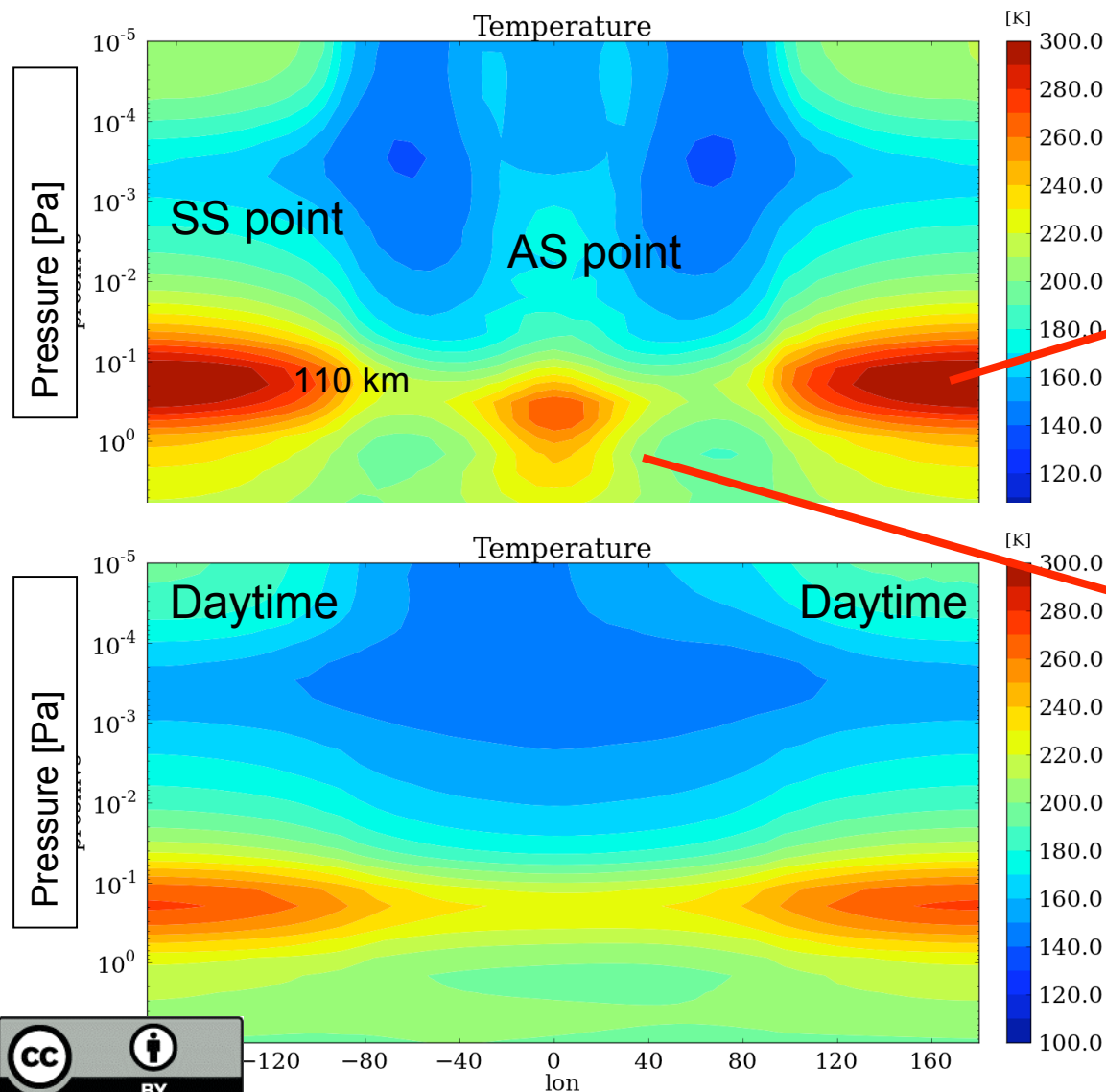

Thermal balance

Cooling after correction

SHR after correction

Temperature

before correction

after correction
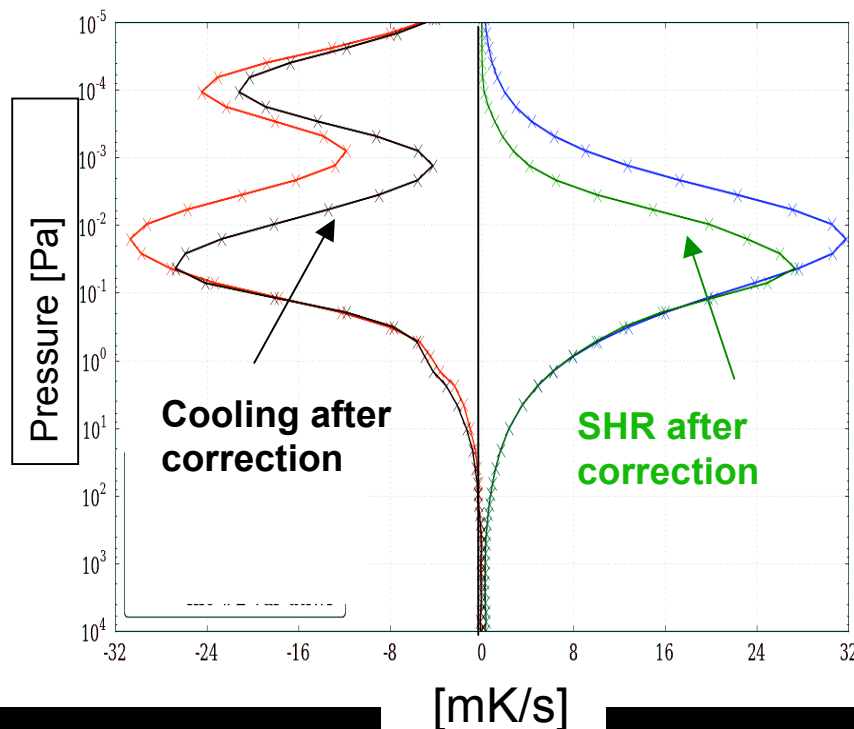
- Important effect of atomic oxygen on the SHR (at the altitude of its peak and above)

- O/CO_2 taken from literature (Hedin et al.1983)

EPSC 7-12 Sept. 2014, Estoril, Portugal

Venus GCM extension

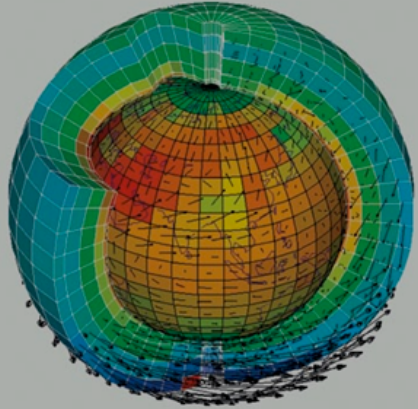## Thermal structure (after 2 Venus days of simulations)

Lat: 30S-30N

Maximum at the SS point:
radiative processes
(solar absorption by CO_2 bands in NIR)

Warm layer in the night
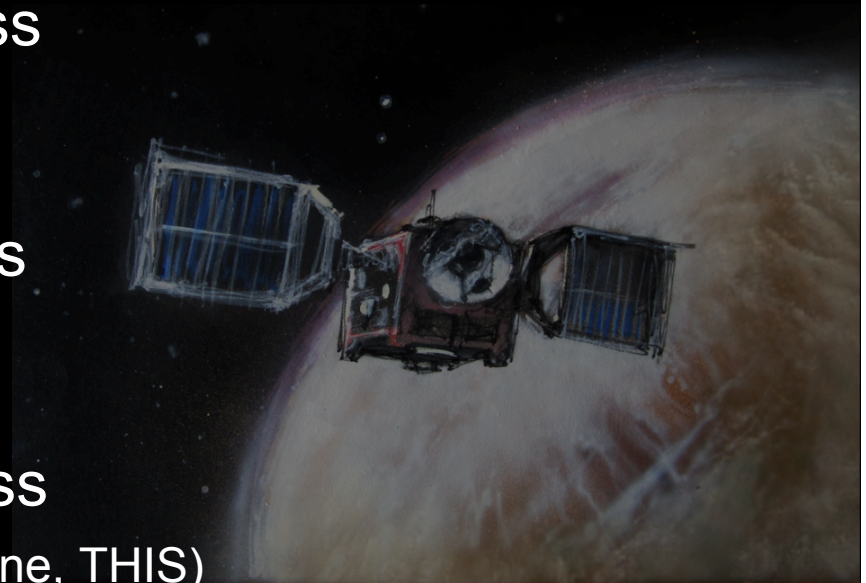side: dynamical effect
(subsidence)

Lat: 60N-90N

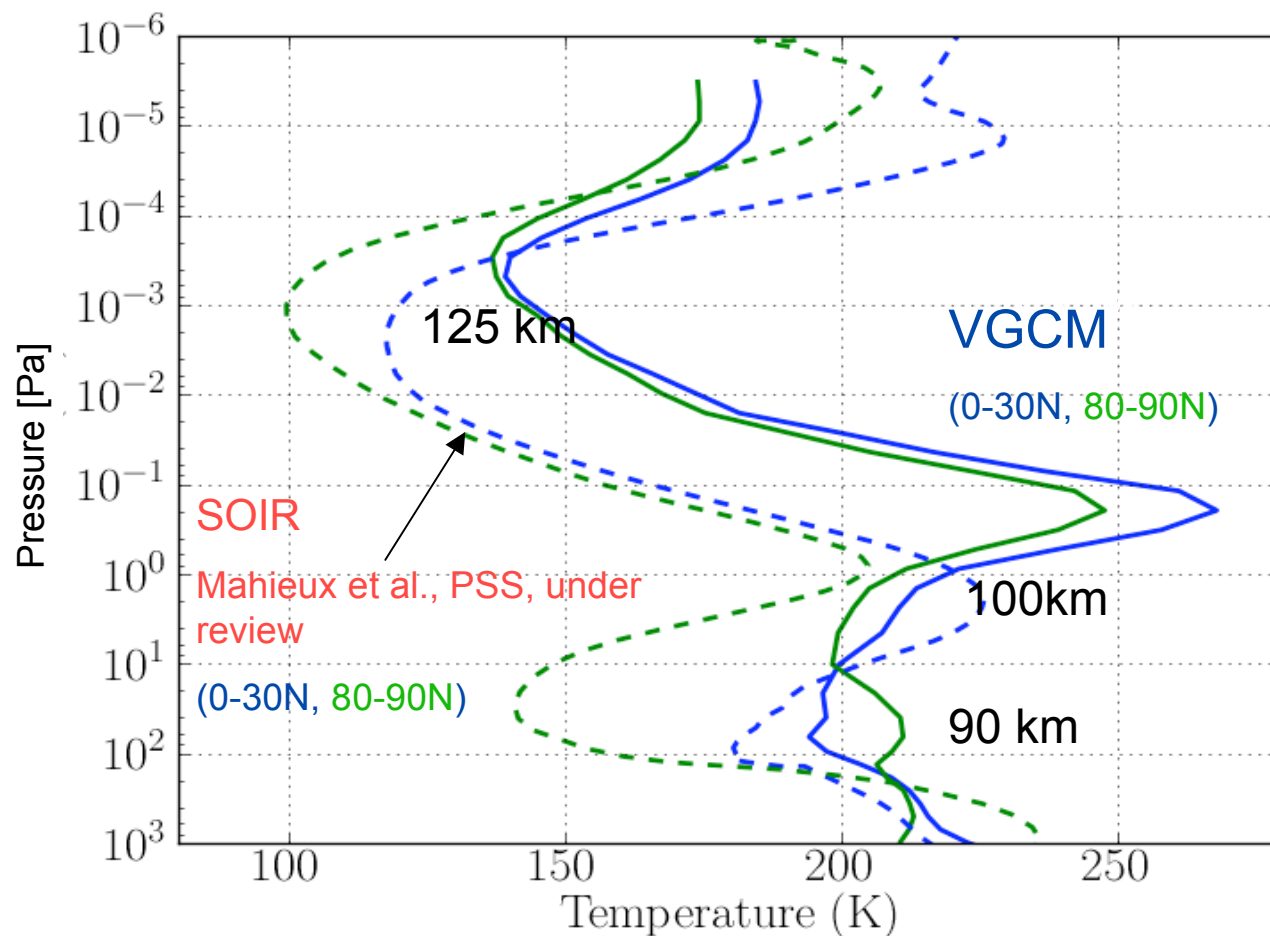# VGCM versus observations

Terminator: SOIR/Venus Express

Nightime: SPICAV/Venus Express

Daytime: VIRTIS-H/Venus Express
    ground-based (IR-heterodyne, THIS)
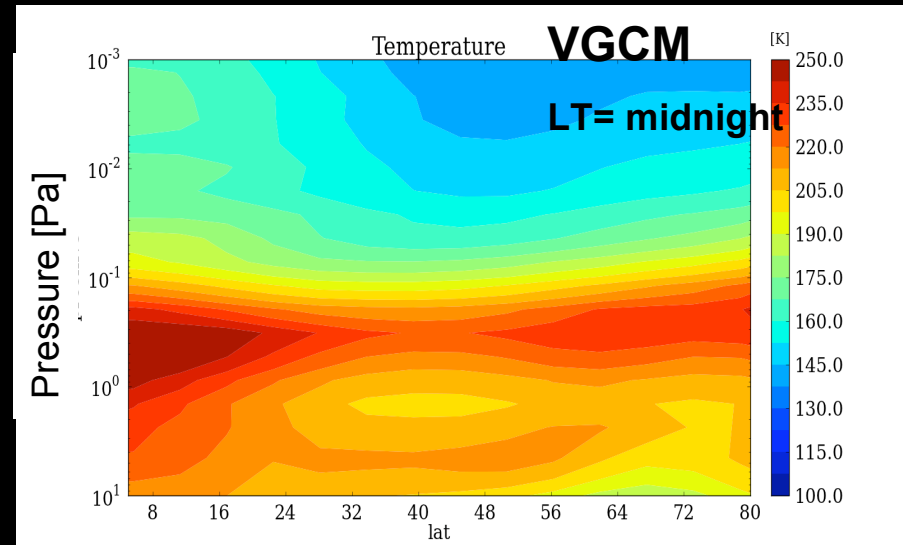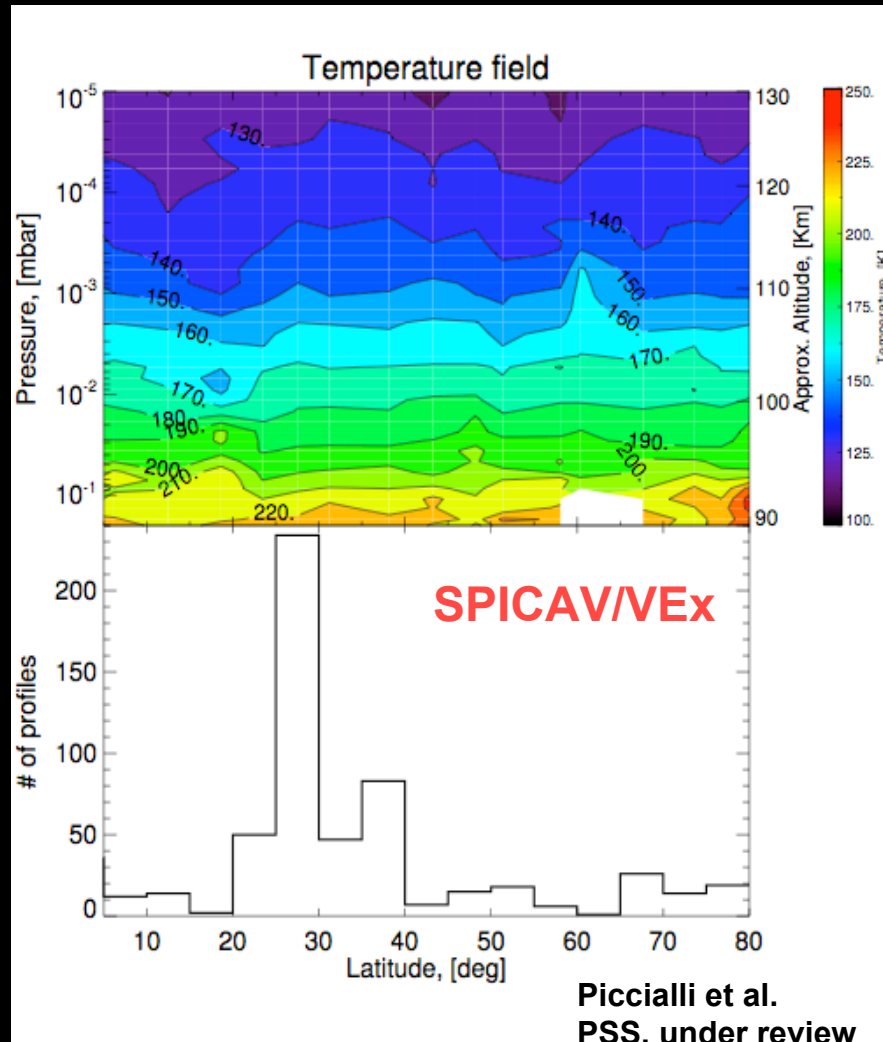
VGCM-data comparison: SOIR

Morning **Terminator** LT: 6h

Features

1. Warmer layer (30-40K warmer and 10 km higher on GCM)

2. 2 local minima (around 125 km 40-50K warmer on GCM)

3. Latitudinal variation (smaller in the GCM)

VGCM-data comparison: SPICAV
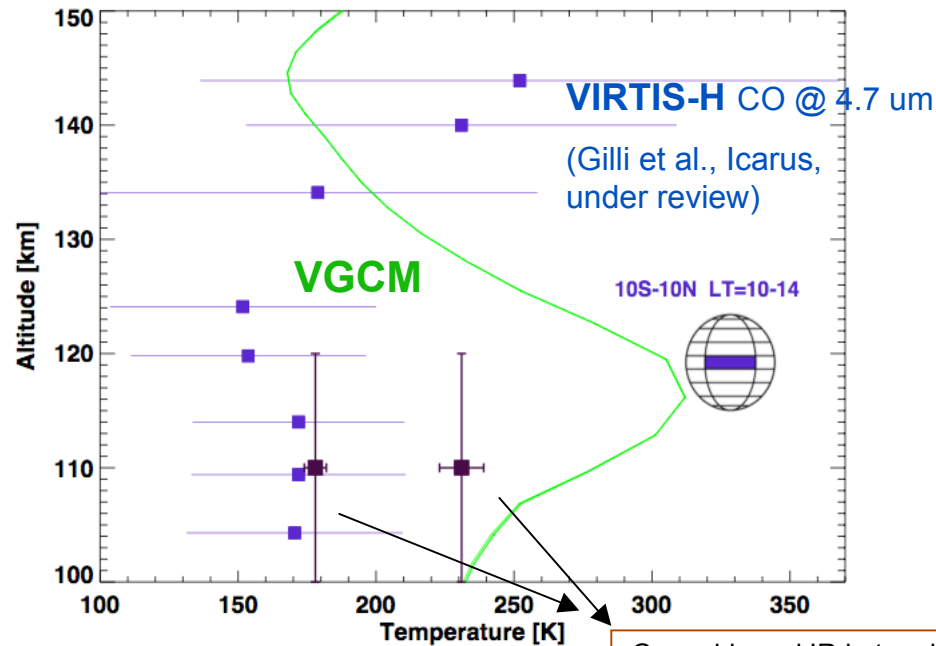
Night time: dynamical effect?

- localized warm region around 1- 0.1 Pa
- Night time latitudinal variations: predicted by VGCM (warmer T in the equatorial region, and near poles), not observed by SPICAV
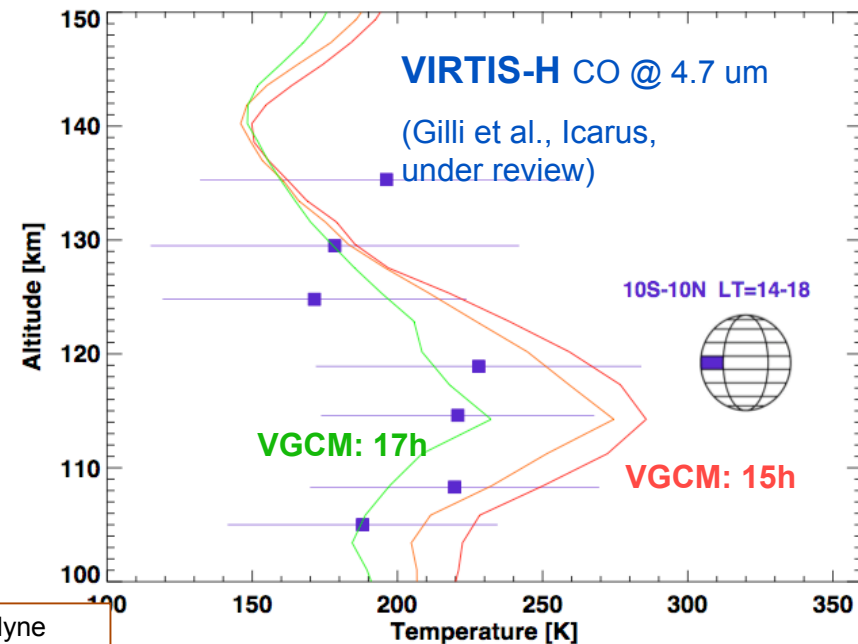
VGCM-data comparison: VIRTIS-H

Daytime

Near SS point   **Afternoon, equatorial regions**

VIRTIS-H CO @ 4.7 um
(Gilli et al., Icarus, under review)

VGCM

10S-10N LT=10-14

Ground-based IR-heterodyne
(M. Sorning private communication)

VIRTIS-H CO @ 4.7 um
(Gilli et al., Icarus, under review)

10S-10N LT=14-18

VGCM: 17h

VGCM: 15h

1. **VIRTIS-H values at SS point in contrast to a "pure radiative" balanced atmosphere**

2. **VGCM at noon too hot between 110-130 km**

3. **Ground-based lower value agrees with VIRTIS-H, but not with VGCM.**

1. **VGCM variability is within the (large) VIRTIS-H error bars**

2. **A hint of "warm layer" between 110-120 km** (but not observed by VIRTIS at noon!)

Puzzling thermal structure of Venus upper atmosphere

- S-shape (min-max) observed structure predicted by VGCM

- Discrepancies model-data are under investigation:

  - altitude and intensity of warm layer observed by SOIR

  - role of atomic oxygen on heating/cooling (further non-LTE study)

  - night time warm layer (predicted but not observed by SPICAV)

- Pending questions in the lower atmosphere:

  - predicted upper cloud regions too warm compared to VEx

  - Role of gravity waves

Future work

- coupling the LMD-VGCM with: 1. photochemical model (LATMOS)

                                                         2. cloud model (LATMOS)

- stabilize the model to study lower-upper atmosphere interaction
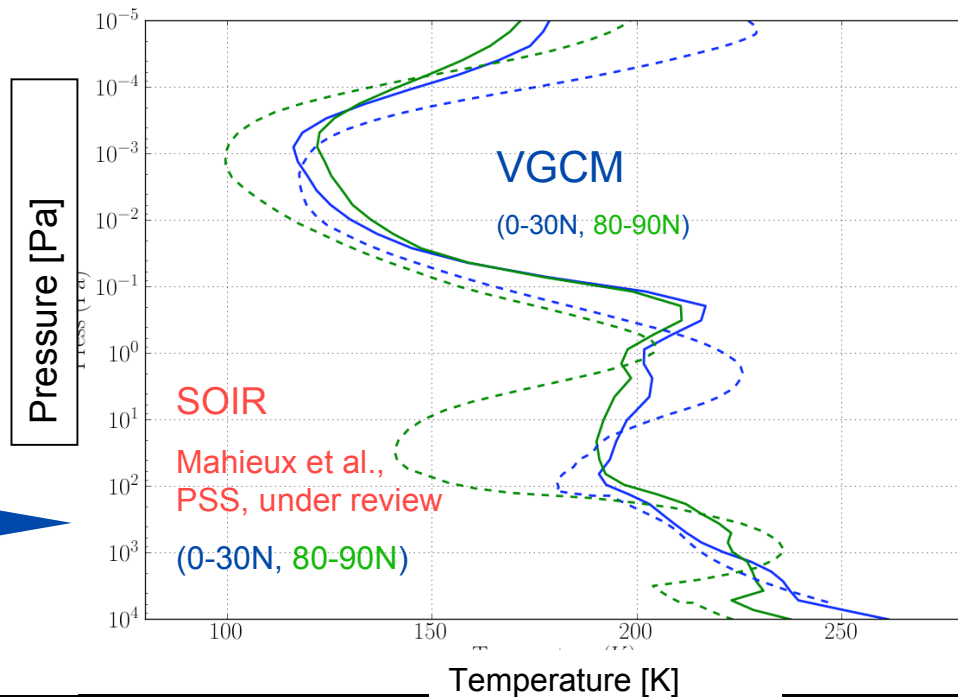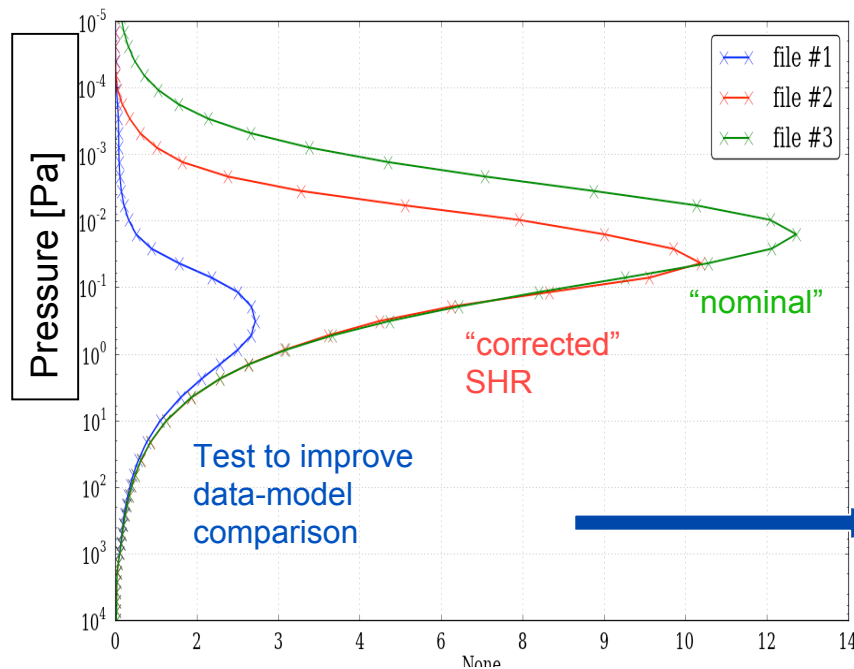
- winds fields

- High-Resolution runs (96x96x78)

THANKS!

VGCM-data comparison

Tests performed to improve the comparison data-model: on-going work…

- small changes in the non-LTE param (mimicking SHR by Roldan et al. 2000)

- halving/doubling SHR

- changing initial Oxygen density/CO_2 density

- Changing the intensity (factor 3-4) and the shape of SHR

Better agreement with SOIR above the
peak (1 Pa), but not below (1-1.e2 Pa)