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

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

1. **Model development**
   - Martian “inheritance”
   - LATMOS collaboration

2. **Data analysis**
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
Thermal balance: noon, equatorial regions, after 3 Vdays

CURRENT STATUS:
- NIR (1-5 \(\mu\)m) CO\(_2\) non-LTE heating
- 15 \(\mu\)m 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)
Recent improvements:

Inclusion of *correction factors* to take account of the dependence of SHR to several parameters (i.e. $K_v - v$, 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)**

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Thermal structure (after 2 Venus days of simulations)

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: 30S-30N

Lat: 60N-90N
**VGCM versus observations**

*Terminator:* SOIR/Venus Express

*Nighttime:* SPICAV/Venus Express

*Daytime:* VIRTIS-H/Venus Express

ground-based (IR-heterodyne, THIS)

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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)

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**SOIR**

Mahieux et al., PSS, under review

- (0-30N, 80-90N)

**VGCM**

- (0-30N, 80-90N)

- 125 km
- 100 km
- 90 km

Pressure [Pa] vs. Temperature [K] graph
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

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VGCM-data comparison: VIRTIS-H

Near SS point  

Daytime

Afternoon, equatorial regions

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!)

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Summary

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)

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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/CO₂ 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)