

Introduction to the Venus Planetary Climate Model (Venus PCM formerly the IPSL Venus GCM)

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The Venus PCM

- Three-dimensional: 96x96x
 - [50 (0~95 km) / 78 (0~150 km) / 90 (0~250 km)]
- Vertical coordinates: hybrid (sigma/pressure)
- Dynamical core, transport of tracers
- Specific physics:
 - ◆ Radiative transfer: Infrared Net Exchange Rates matrix
Solar heating rates: tables
 - ◆ Thermosphere: Non-LTE processes
EUV heating
molecular diffusion
ionospheric chemistry
 - ◆ Parameterizations of sub-grid processes:
boundary layer (Mellor&Yamada 1982), convection
non-orographic gravity waves
(orographic gravity waves)
 - ◆ Topography
- Photochemistry implemented (PhD of Aurélien Stolzenbach)
+ simple cloud model

The Venus PCM

◆ Reference initial papers :

- ◆ Lebonnois et al (2010) JGR 115
- ◆ Lebonnois et al (2016) Icarus 278

◆ Photochemistry : Stolzenbach et al (2023) Icarus 395

◆ Cloud region and cold collar :

- ◆ Garate & Lebonnois (2018) Icarus 314
- ◆ Scarica et al (2019) Atmosphere 10
- ◆ Lai et al (2024) In revision

◆ Near Surface :

- ◆ Lebonnois et al (2018) Icarus 314
- ◆ Navarro et al (2018) Nature Geoscience 11

◆ Upper atmosphere :

- ◆ Gilli et al (2017) Icarus 281
- ◆ Navarro et al (2021) Icarus 366
- ◆ Gilli et al (2021) Icarus 366
- ◆ Martinez et al (2023) Icarus 389
- ◆ Martinez et al (2024) Icarus

◆ LES and mesoscale :

- ◆ Lefèvre et al (2017) JGR 122
- ◆ Lefèvre et al (2018) JGR 123
- ◆ Lefèvre et al (2020) Icarus 335

(Aurelien)'s talk, tuesday

Nicolas' talk, friday

Franck's talk, friday

Dexin's talk, wednesday

Peng's talk, thursday

Antoine's talk, tuesday

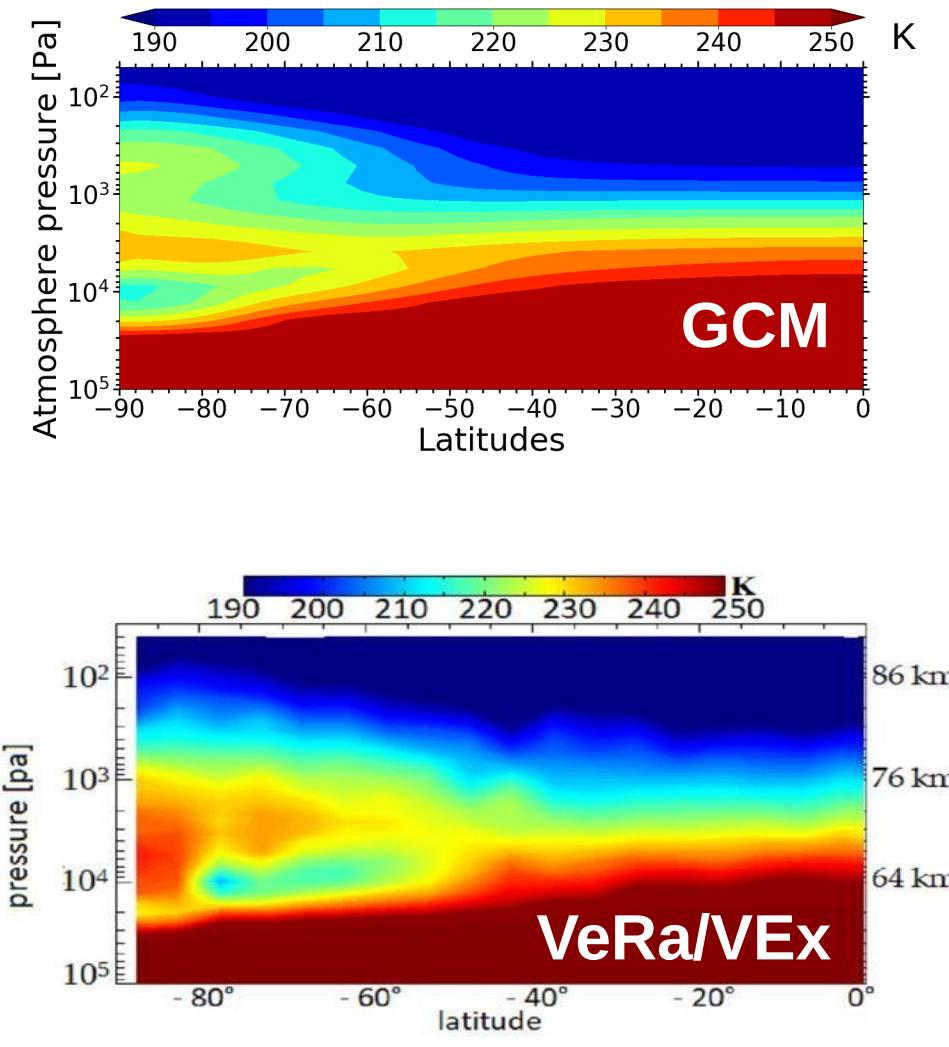
Maxence's talk, thursday

Main features

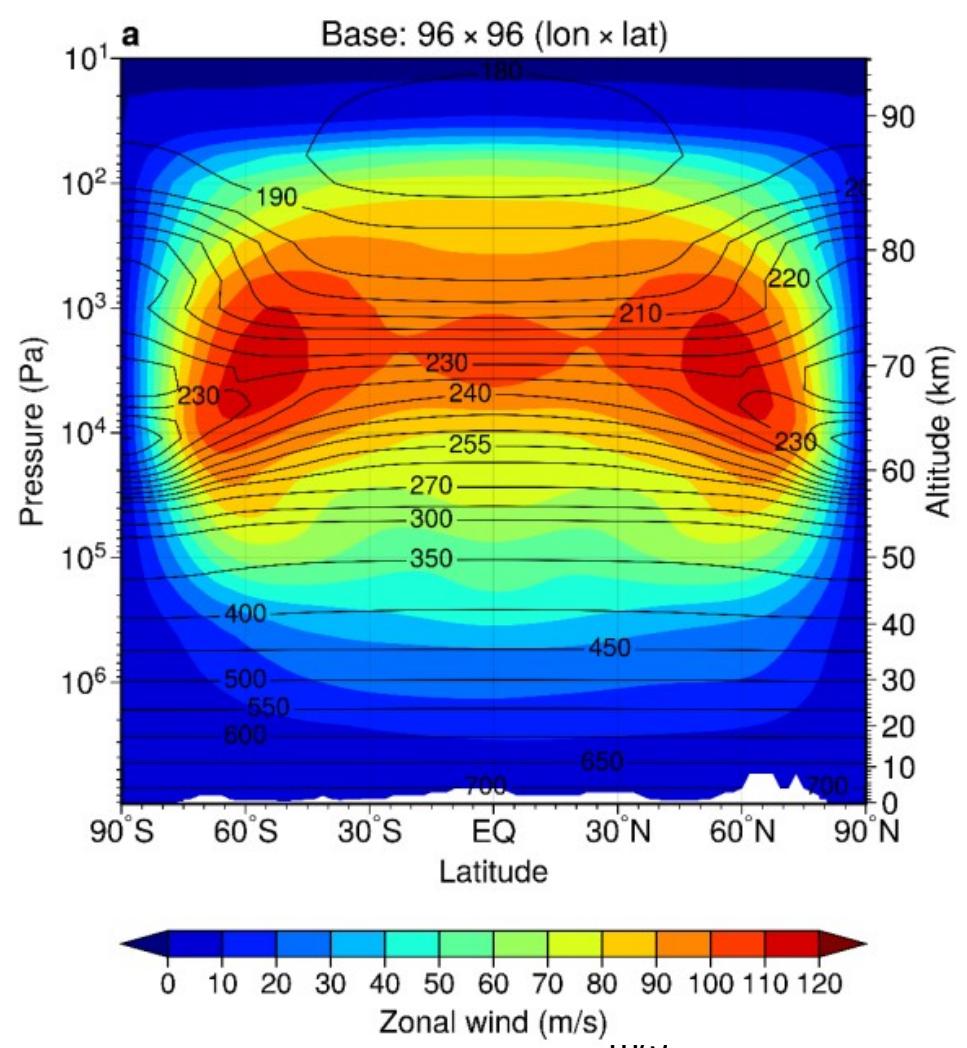
Main features

Latest tuning : done in the context of the **Venus Climate Database** (ESA-funded project, v2.3, <http://www-venus.lmd.jussieu.fr/>)

Temperature structure

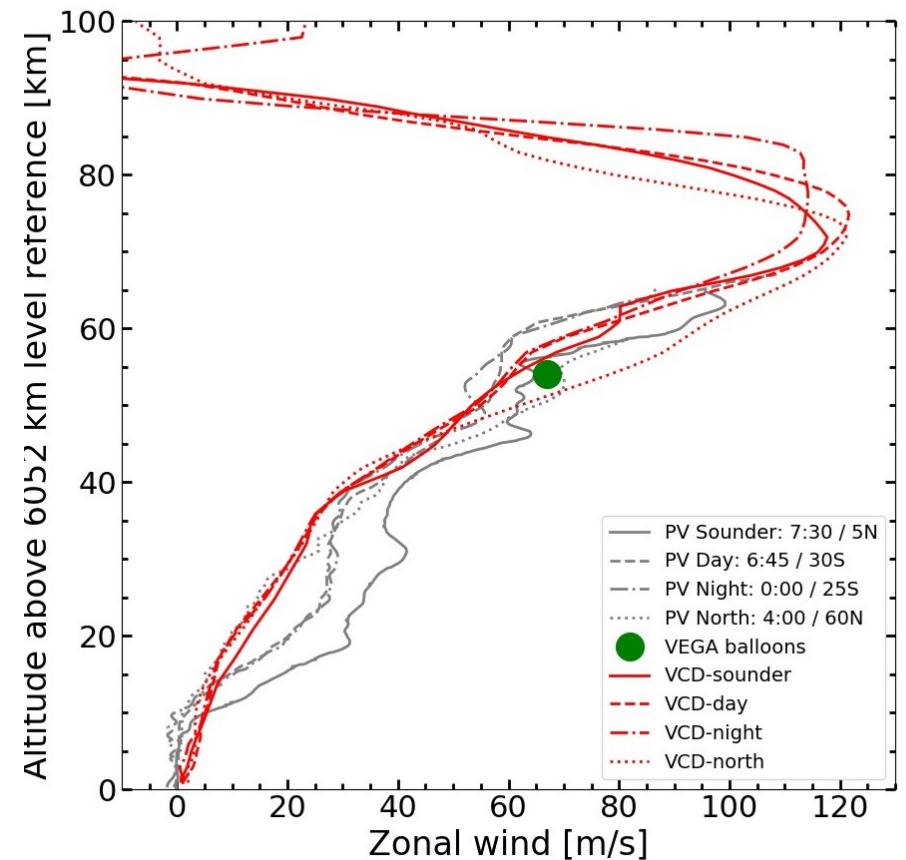
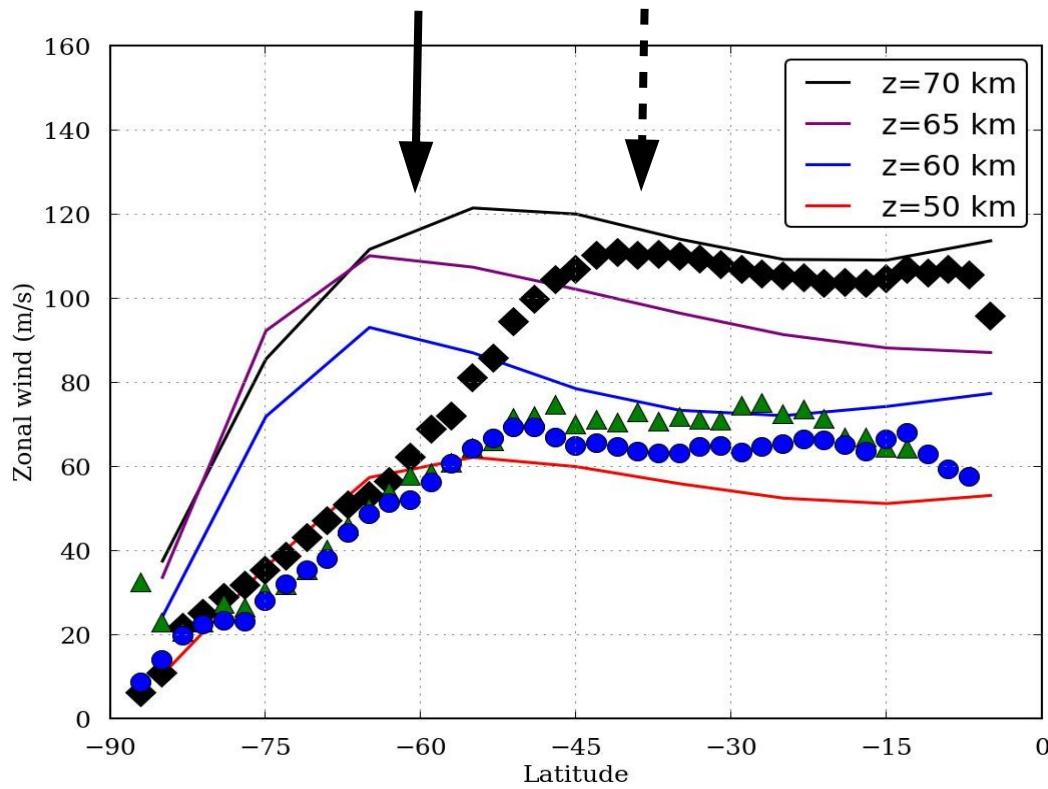


Zonal wind structure



Main features

Latitudinal position of the jet is a major problem



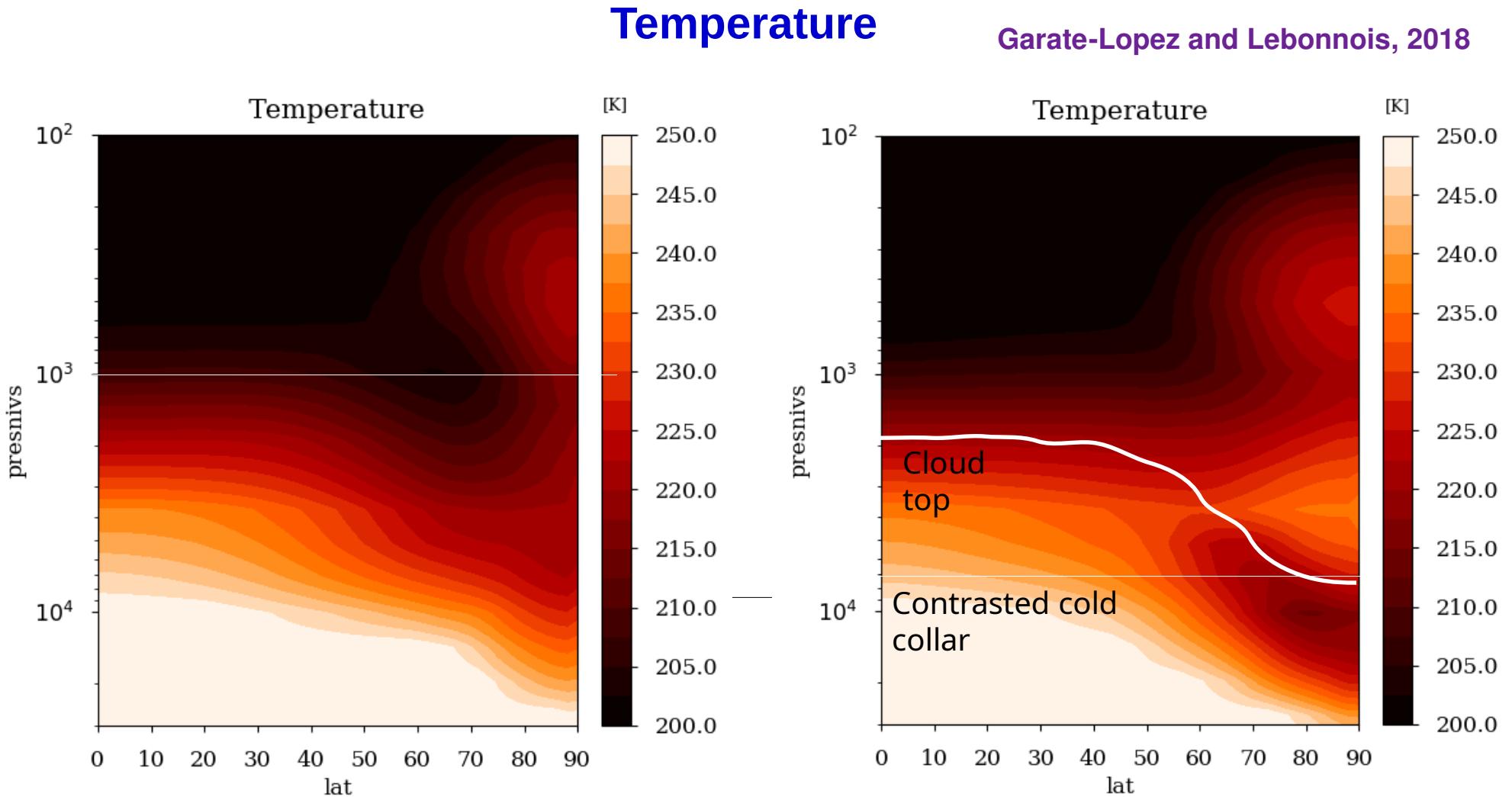
Compared to VIRTIS cloud tracking

Compared to PV probes

Cloud region

Cold Collar

Including the latitudinal structure of the clouds has a critical impact :



Uniform clouds

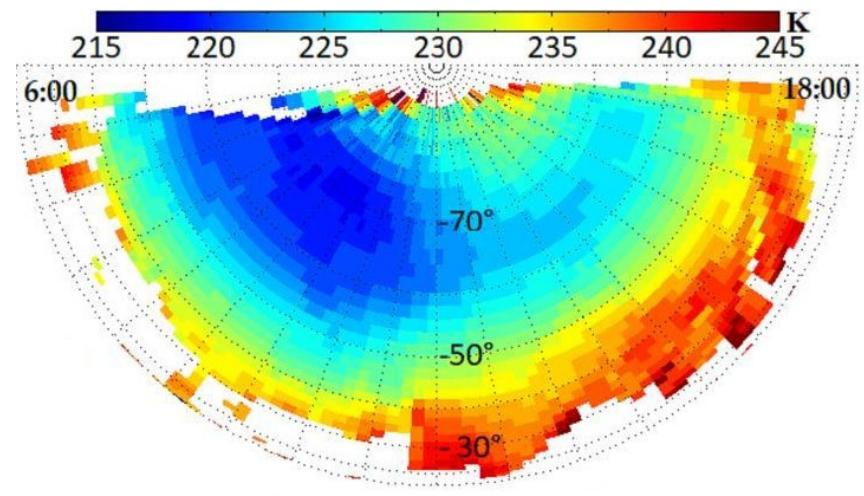
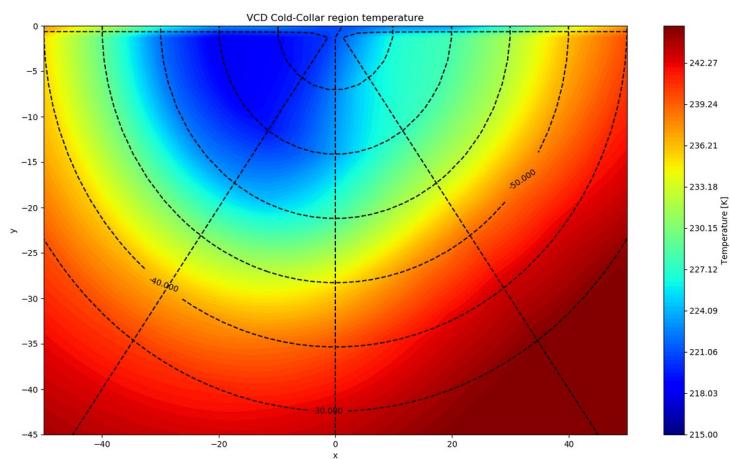
in IR (for solar, latitudinal structure taken into account in both simulations)

Latitudinally variable cloud

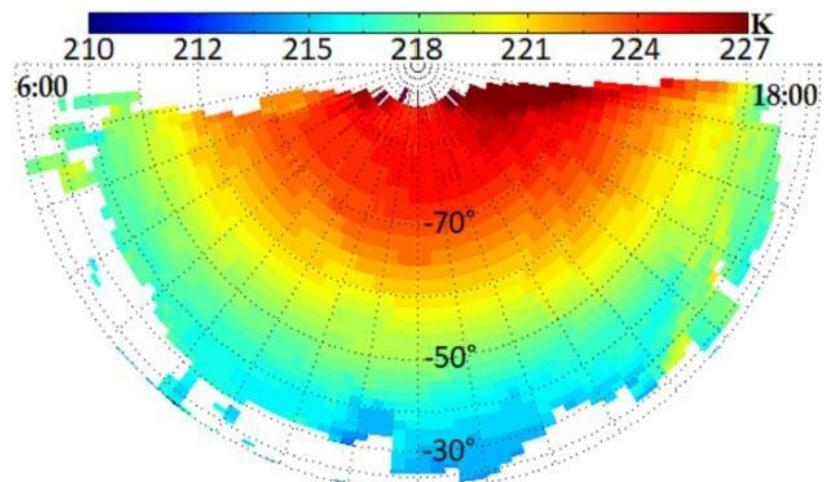
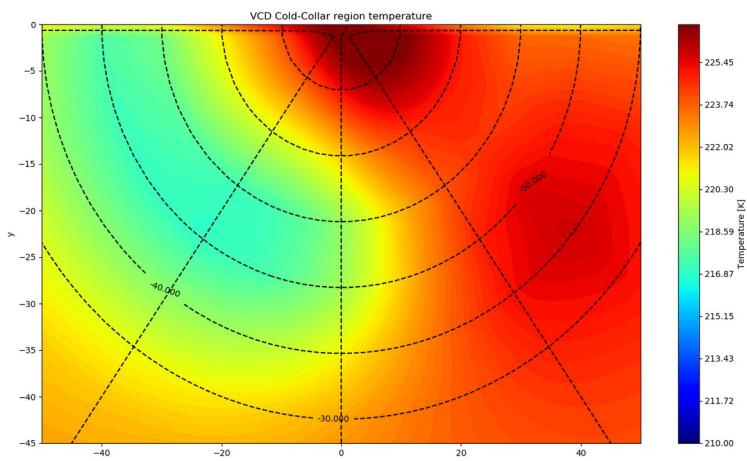
Cold Collar

Impact of thermal tide

Collar ($7 \cdot 10^3$ Pa)



Cloud top ($2 \cdot 10^3$ Pa)

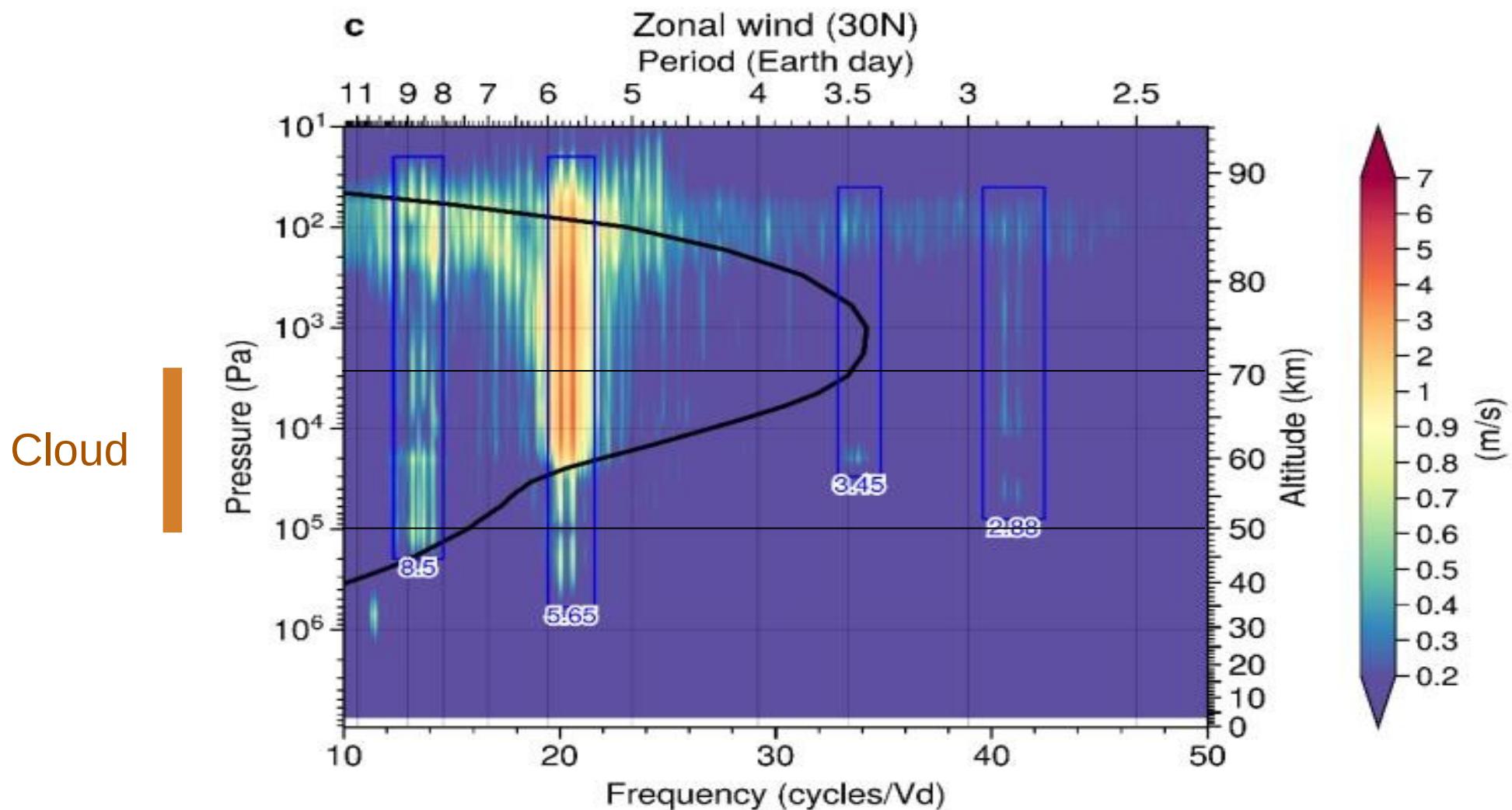


Venus PCM

VIRTIS/Venus Express

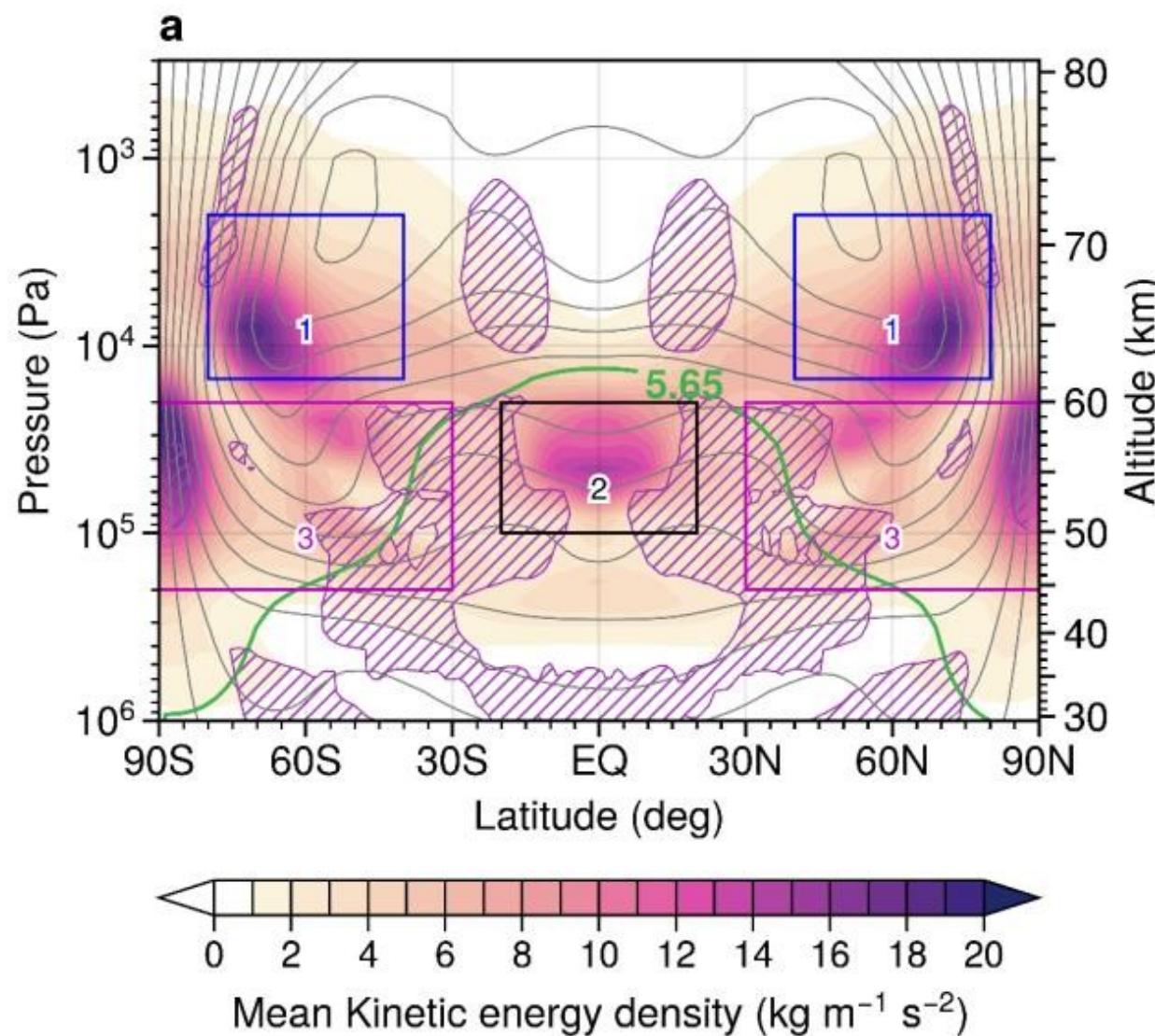
Cloud wave activity

FFT analysis of 15-Vd time series (zonal wind)
High-resolution run (288x144)



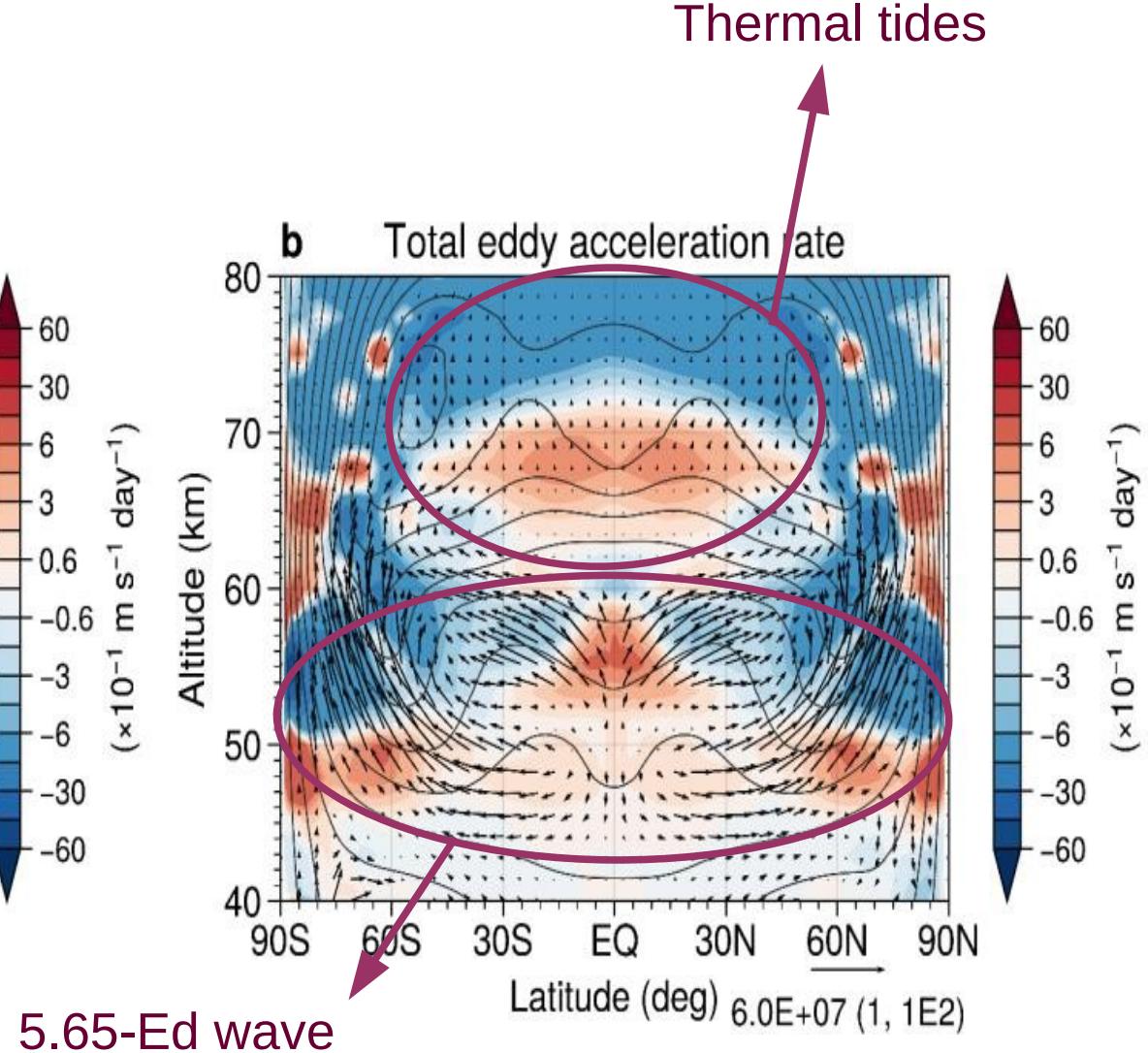
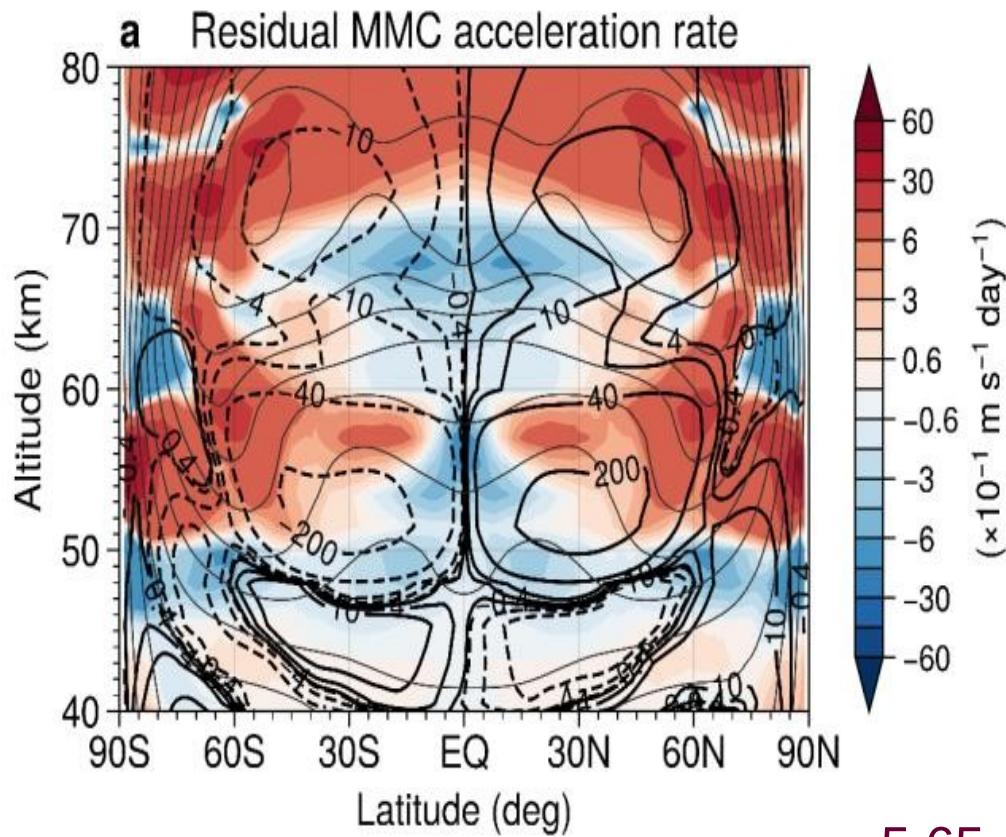
Cloud wave activity

5.65-Ed wave : kinetic energy distribution
High-resolution run (288x144)



Cloud wave activity

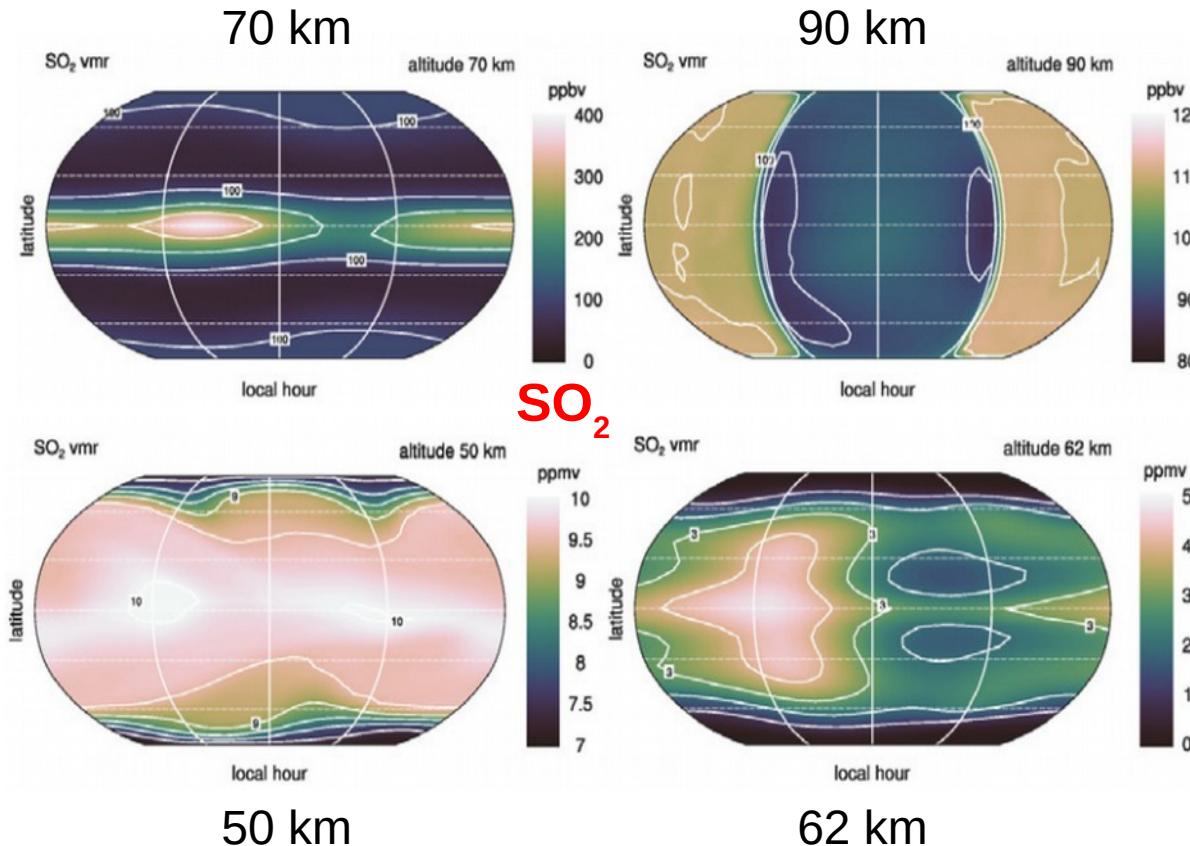
Angular momentum balance
High-resolution run (288x144)



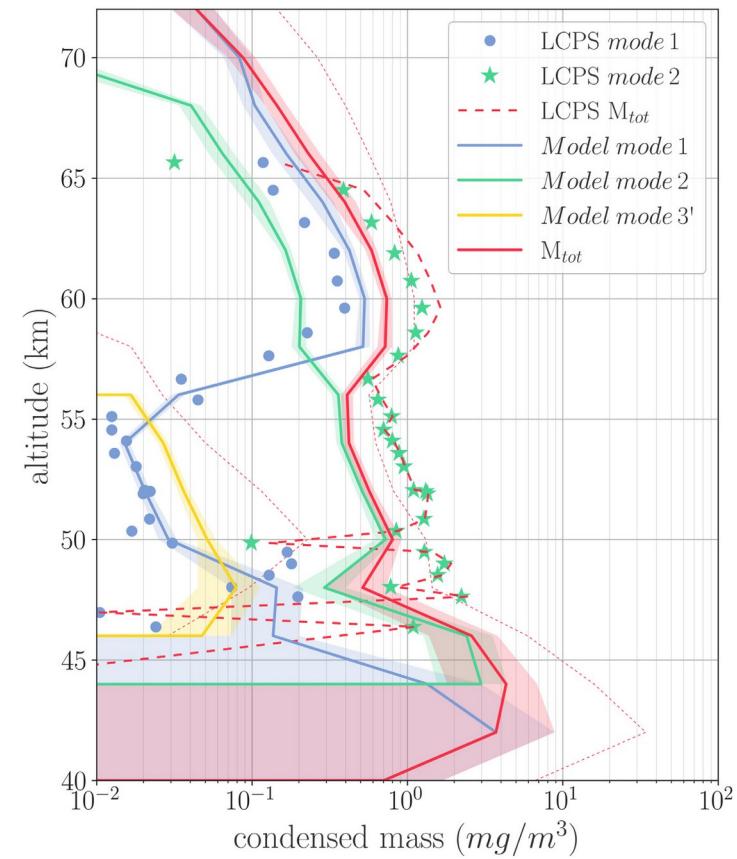
+ long-period oscillations (190 +/- 30 Ed)

Clouds and sulfur cycle

Photochemistry fully implemented



For the moment, simple cloud model



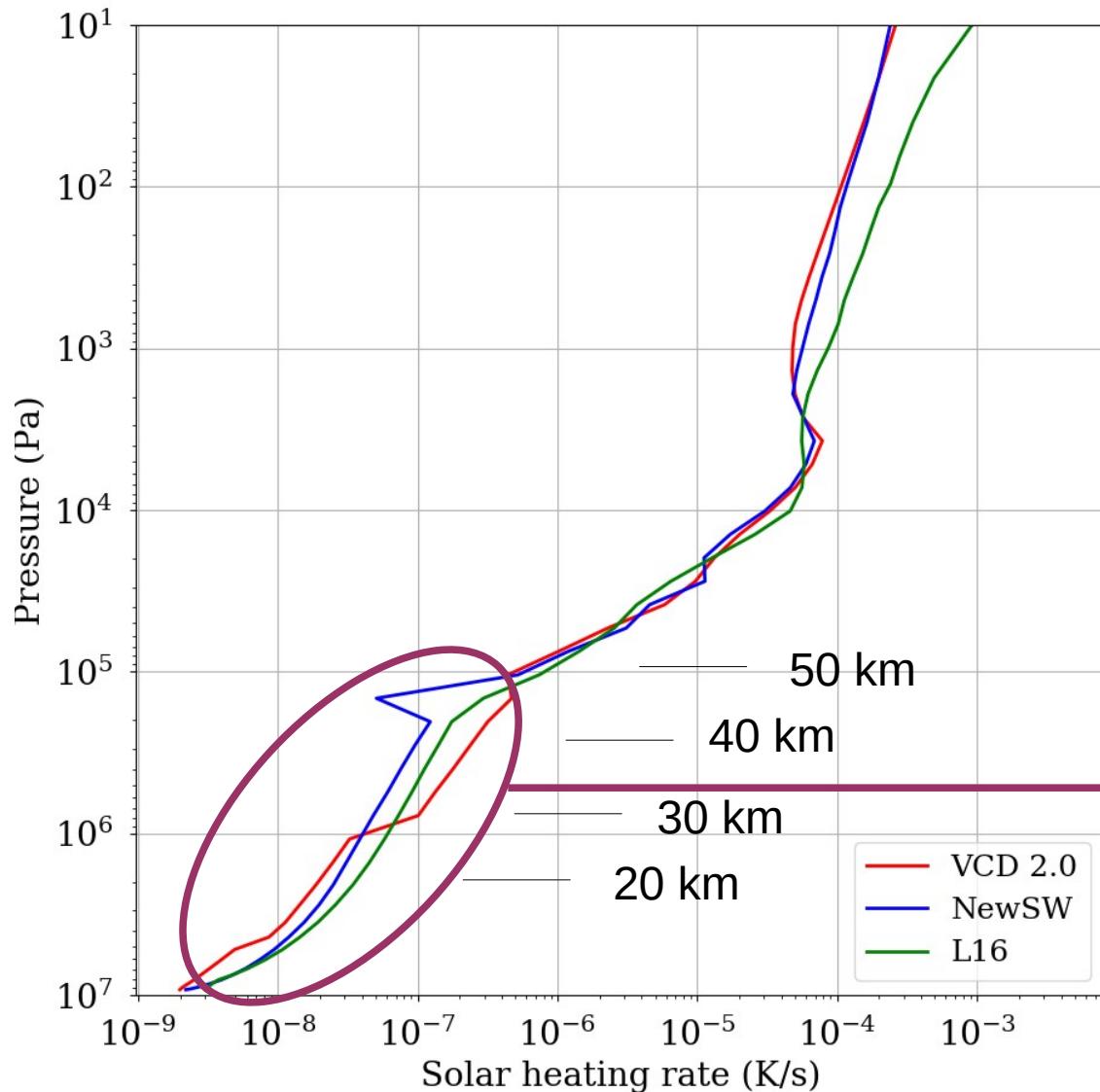
Stolzenbach et al., 2023

Full microphysical cloud model in development

Deep atmosphere

Radiative transfer sensitivity

Tuning solar heating in the deep atmosphere...



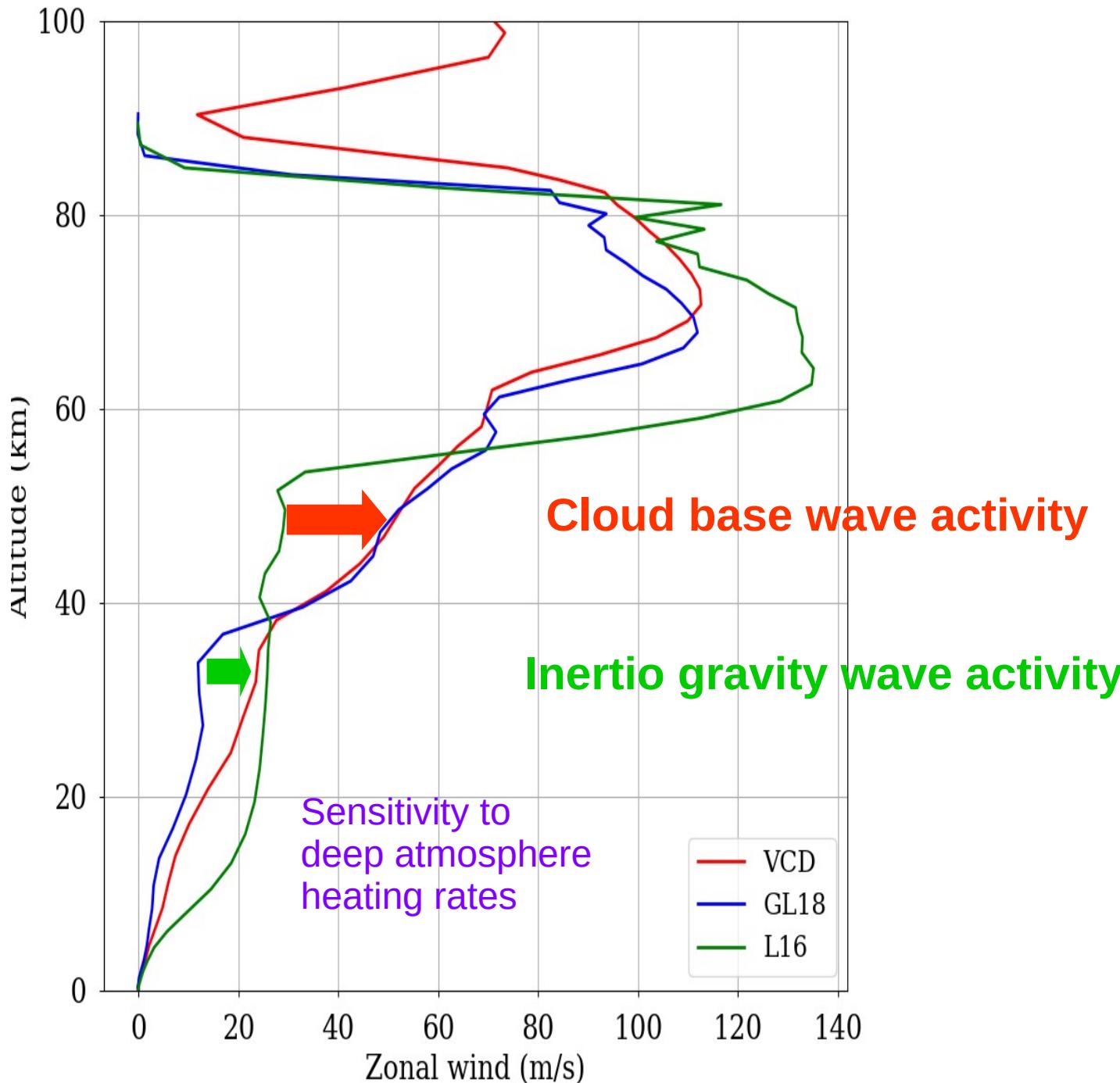
Red : Tuning (VCD 2.0)

Green : Crisp, 1986 (used in L16)

Blue : New full SW RT
(missing haze below clouds)

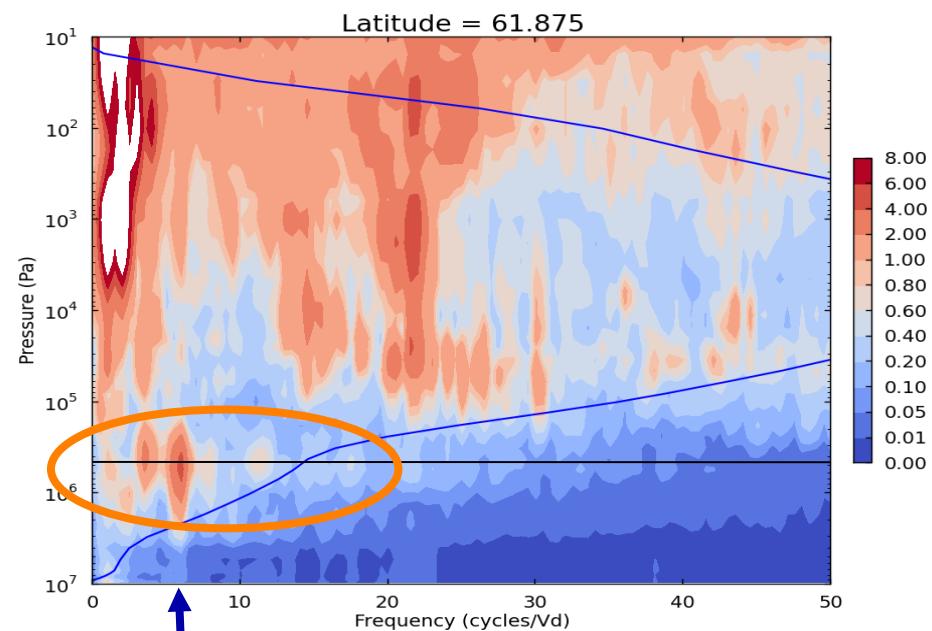
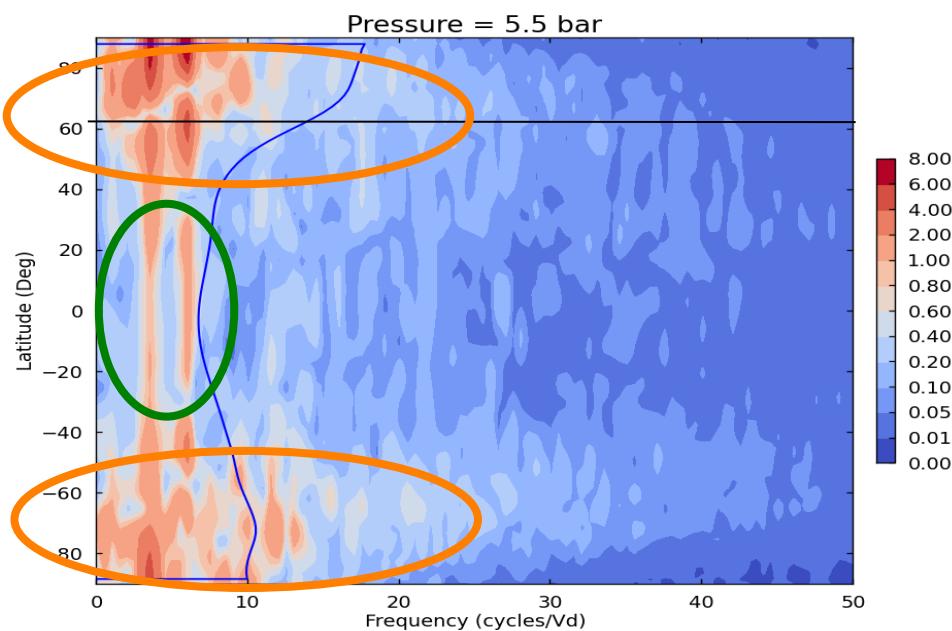
Need for additional modeling
and confirmation

Wave activity in and below clouds



Wave activity in deep atmosphere

Standard-resolution run (96x96)



Freq = 5.8 cy/Vd i.e. period = 20 d



In Lebonnois et al (2016) : Large-scale inertio-gravity waves...
Here ? Less clear... Needs further analysis



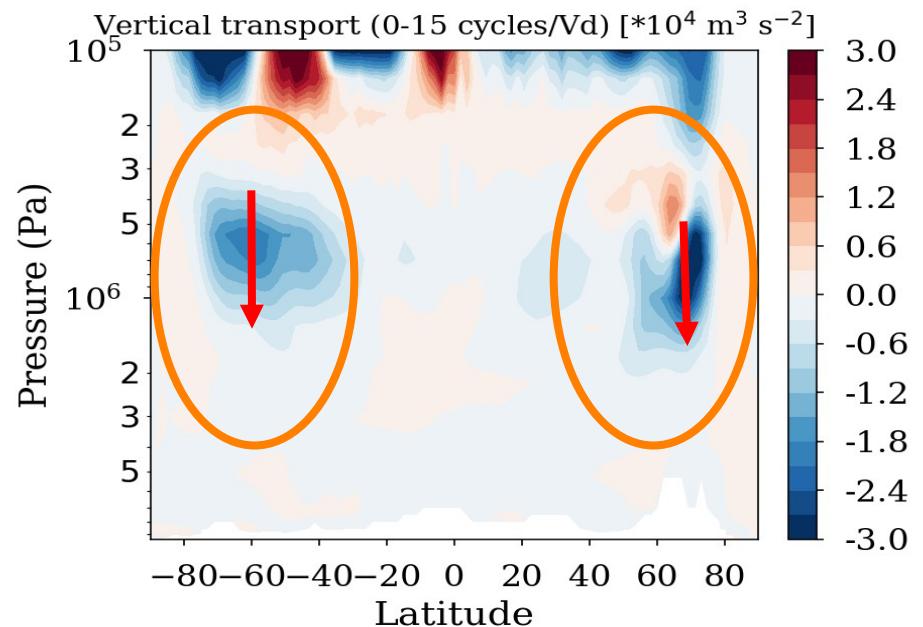
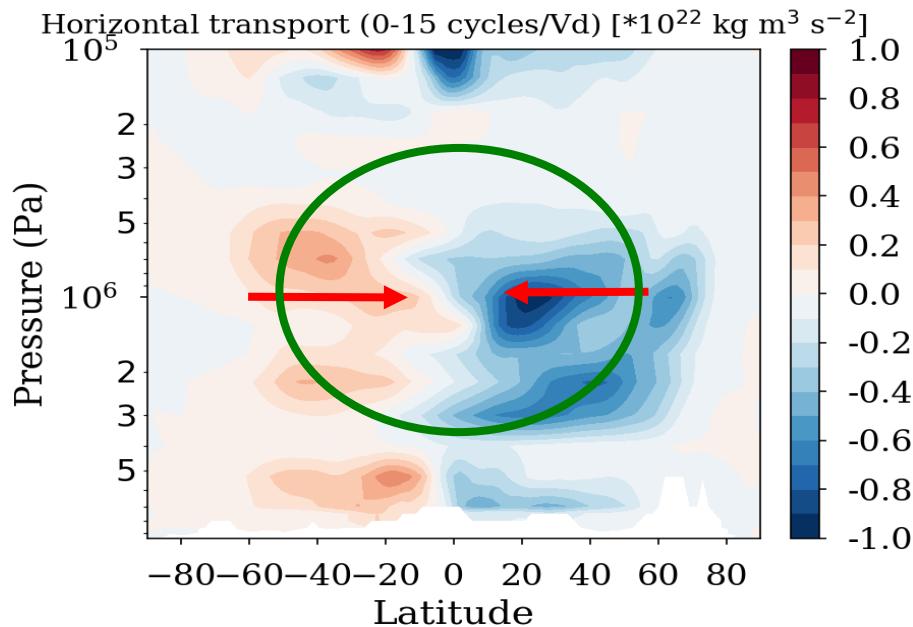
For these ? Needs further analysis

Wave activity in deep atmosphere

Standard-resolution run (96x96)

Role in angular momentum transport in the deep atmosphere

(filtered 0-15 cycles/Vd => dominant wave is 20-d period)

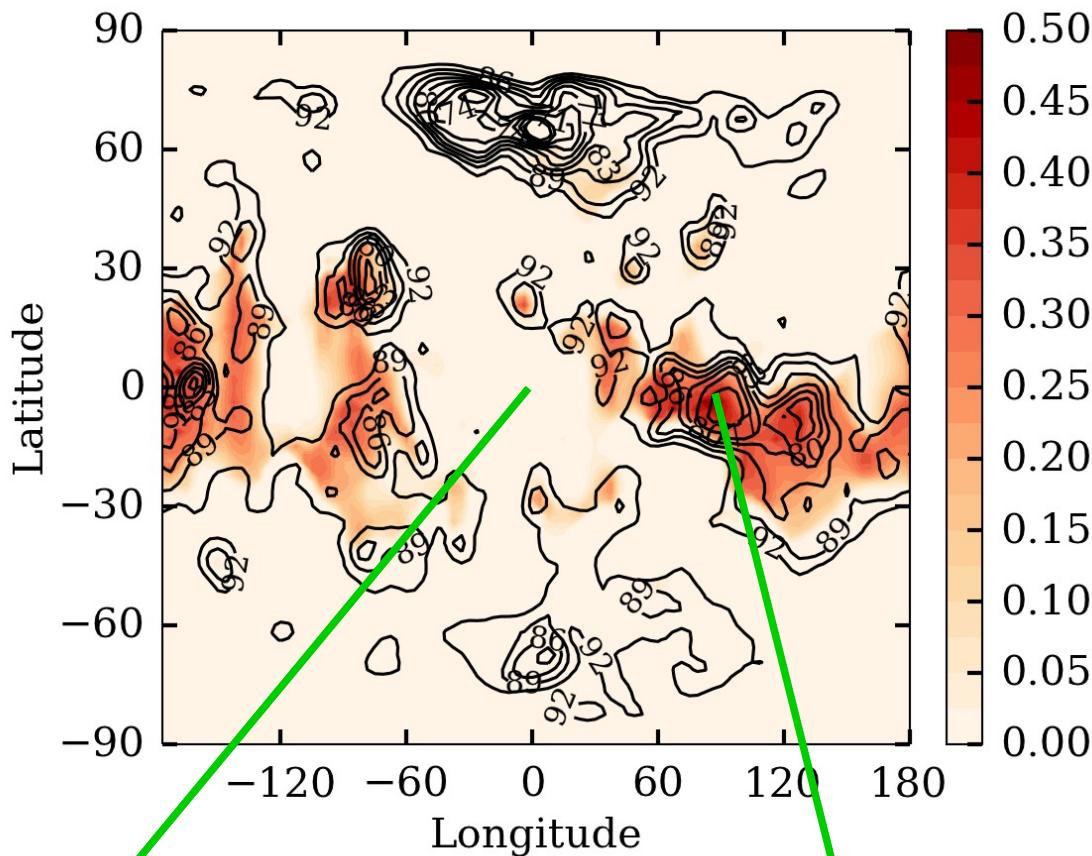


Strong sensitivity to solar heating rate profile

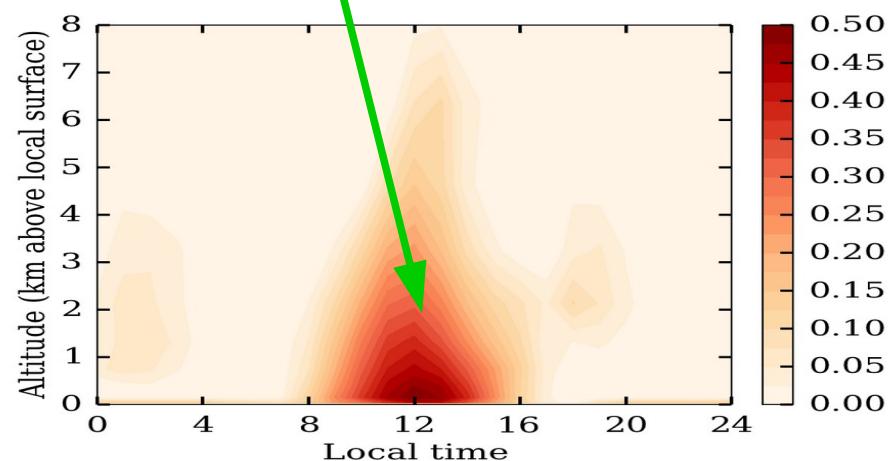
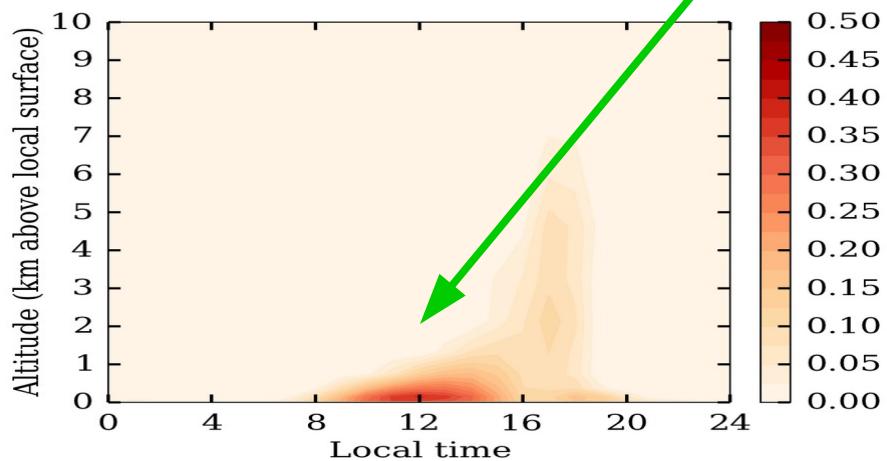
Near surface

PBL structure

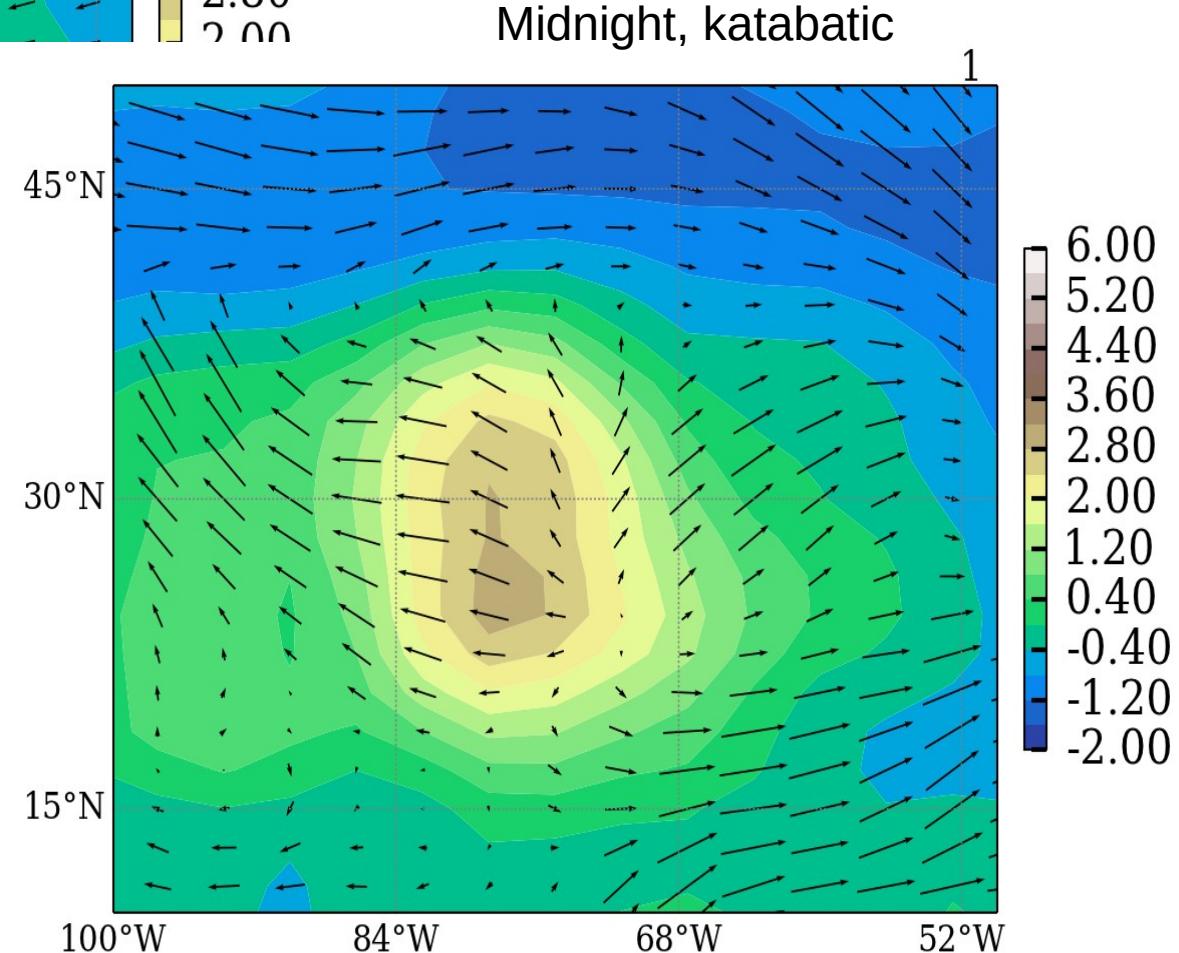
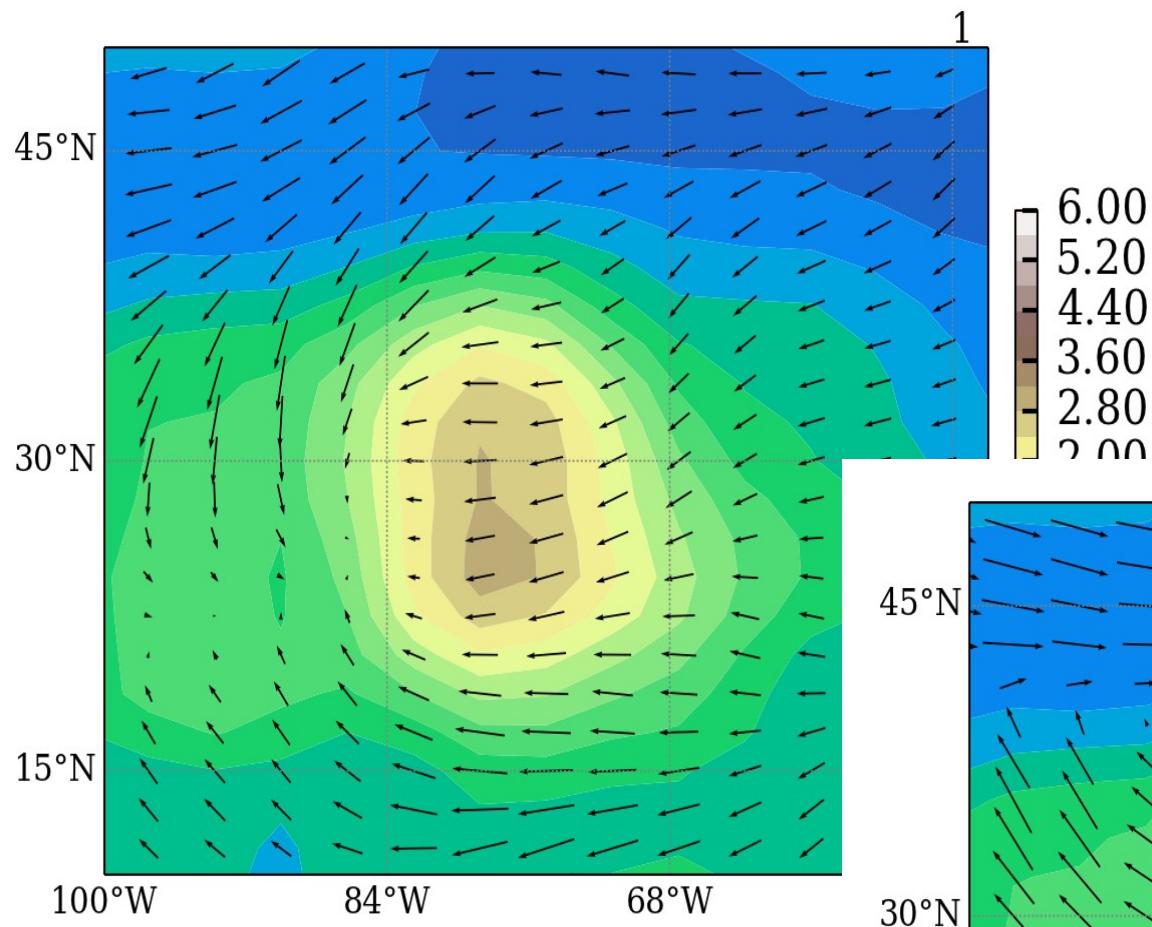
Diurnal convection :
Mixing coefficient
2 km above surface
(noon everywhere)



Lebonnois et al., 2018



Role of slope winds



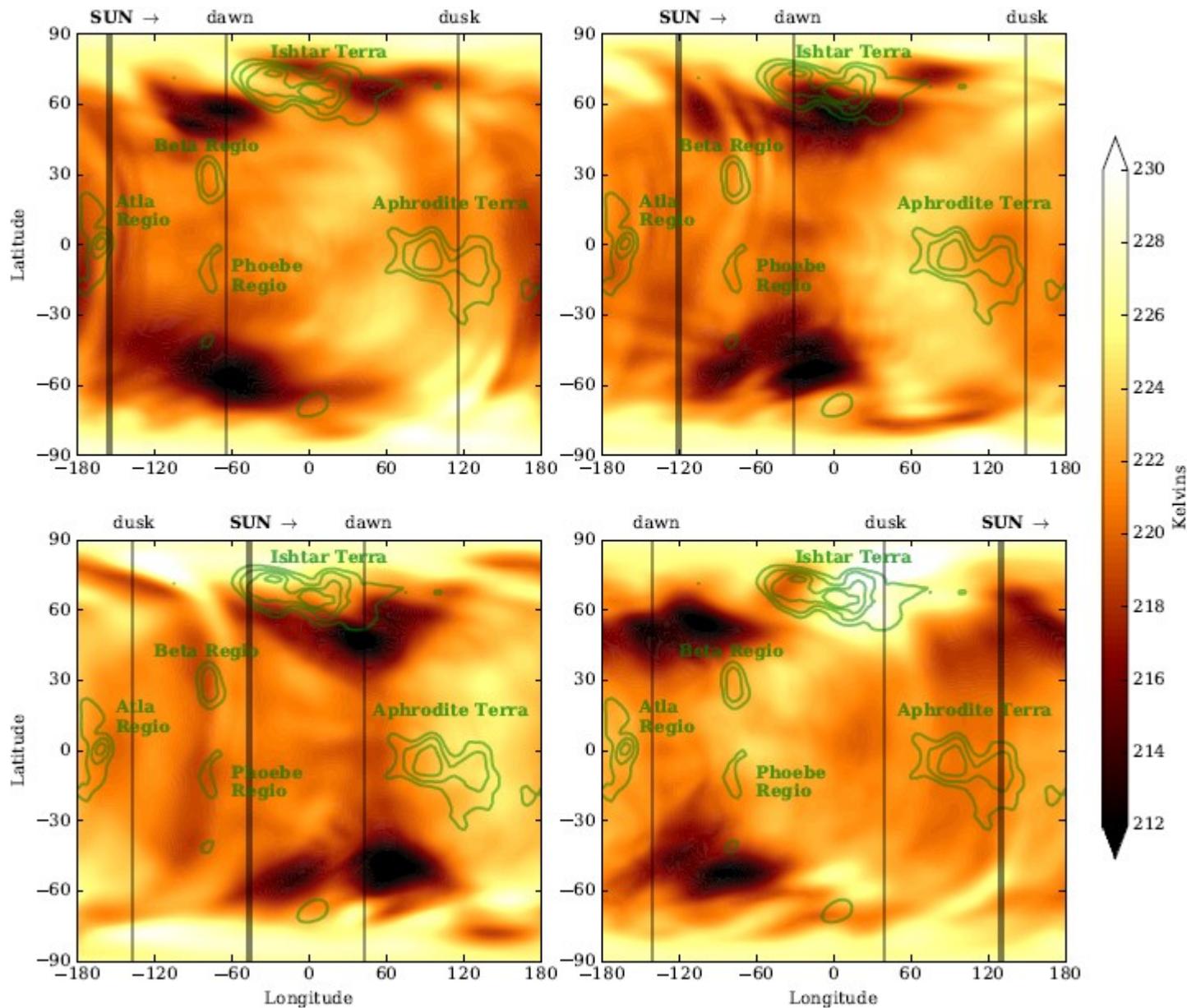
Lebonnois et al., 2018

Mountain waves

Physical parameterization tested in the GCM

GCM

T at 70km
(~cloud-top)



Upper atmosphere

Upper atmosphere

Extension to 10^{-8} Pa (~ 250 km)

Martinez et al., 2023

Comparison to datasets

Tuning of EUV + non-LTE near-IR CO₂ heating parameters

Tuning of non-orographic gravity waves

Implementation of **ionospheric processes**

Martinez et al., 2024

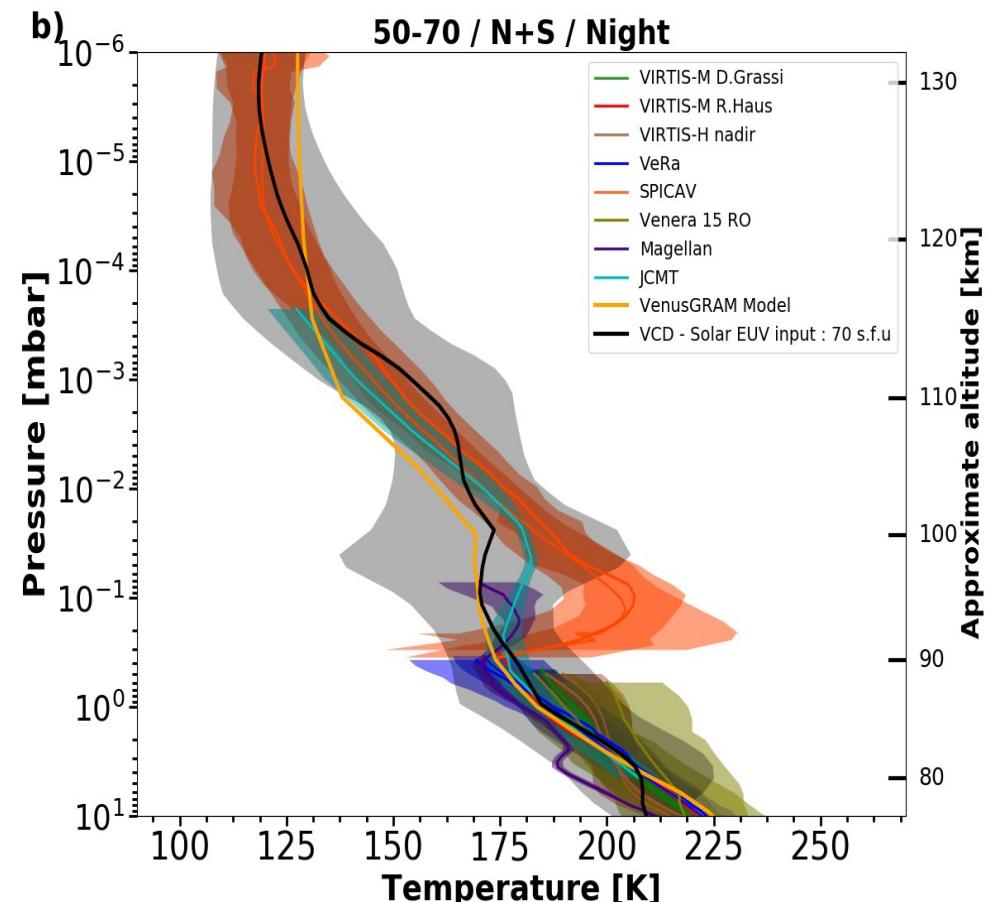
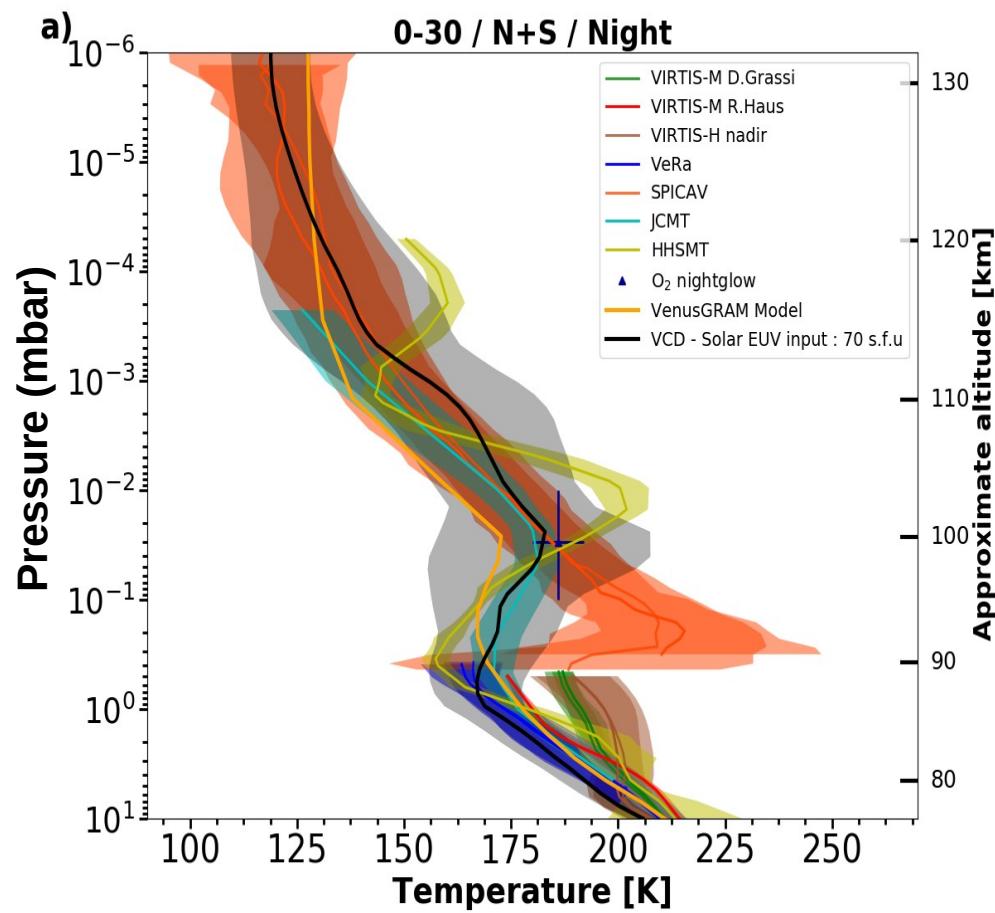
Problem of composition under investigation :

need for large increase of CO₂ → CO + O

Lower thermosphere Temperatures compared to observations

Near IR CO₂ Non-LTE tuning

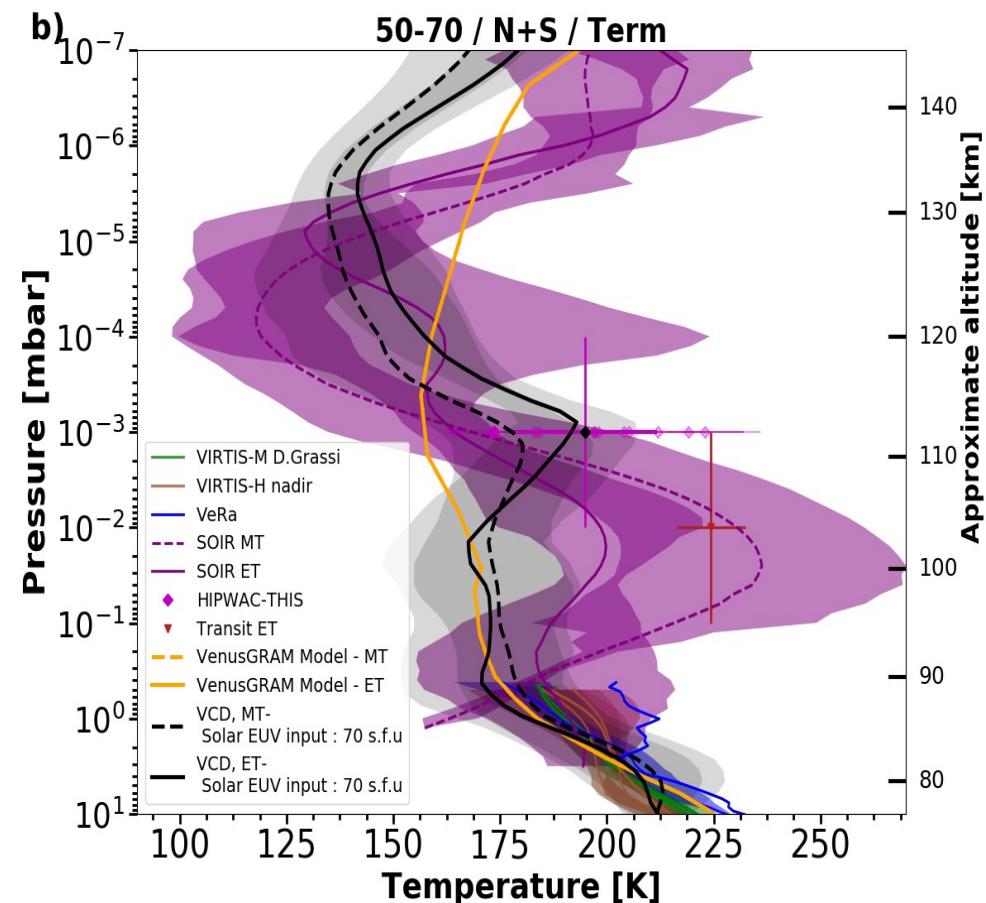
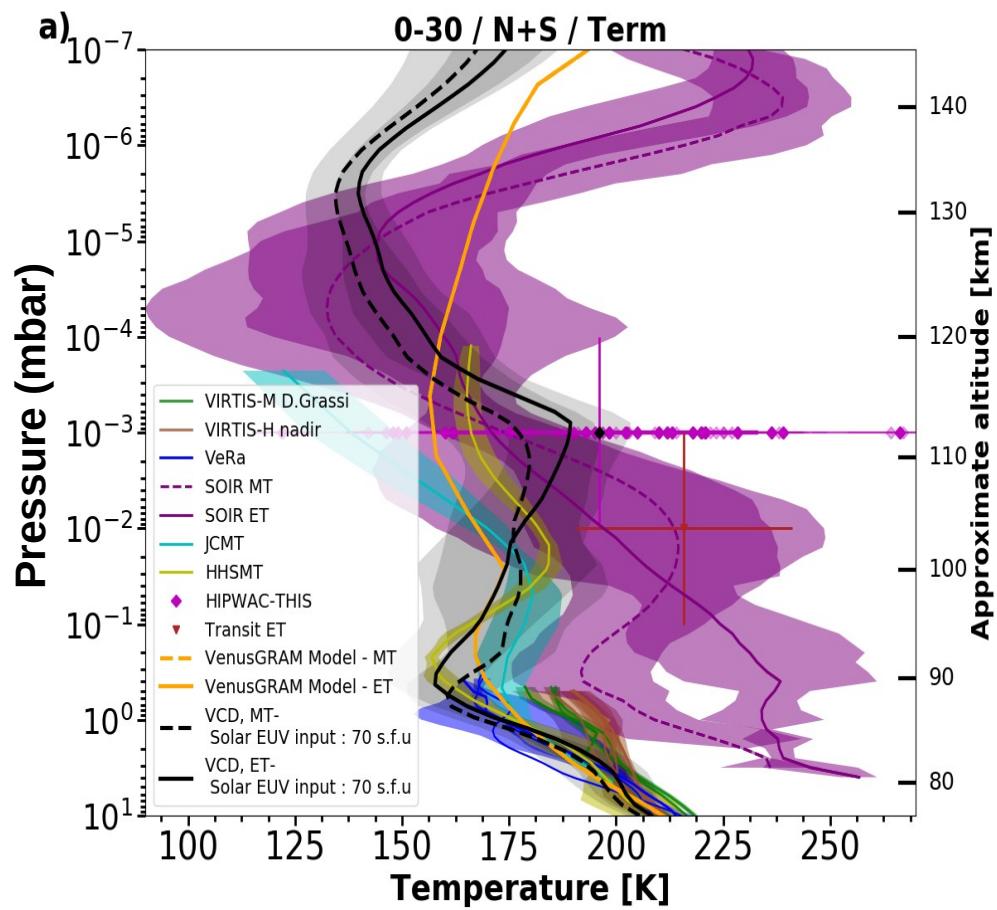
NIGHT



Lower thermosphere Temperatures compared to observations

Near IR CO₂ Non-LTE tuning

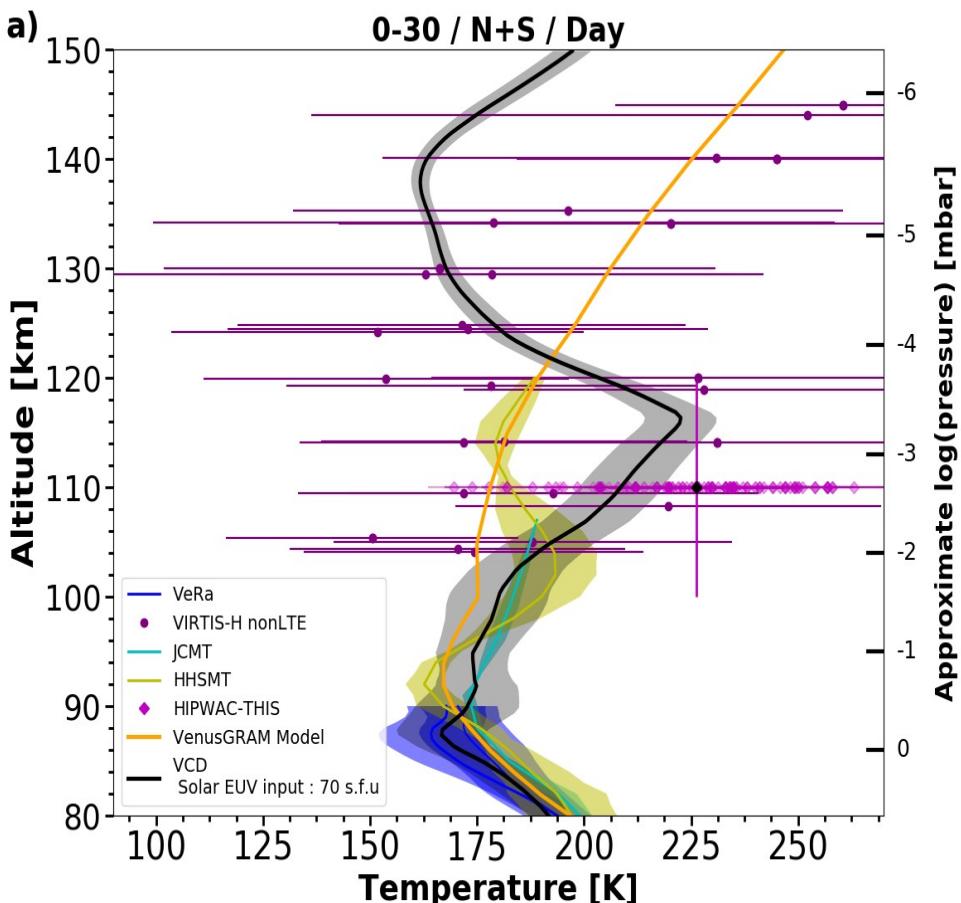
TERMINATORS



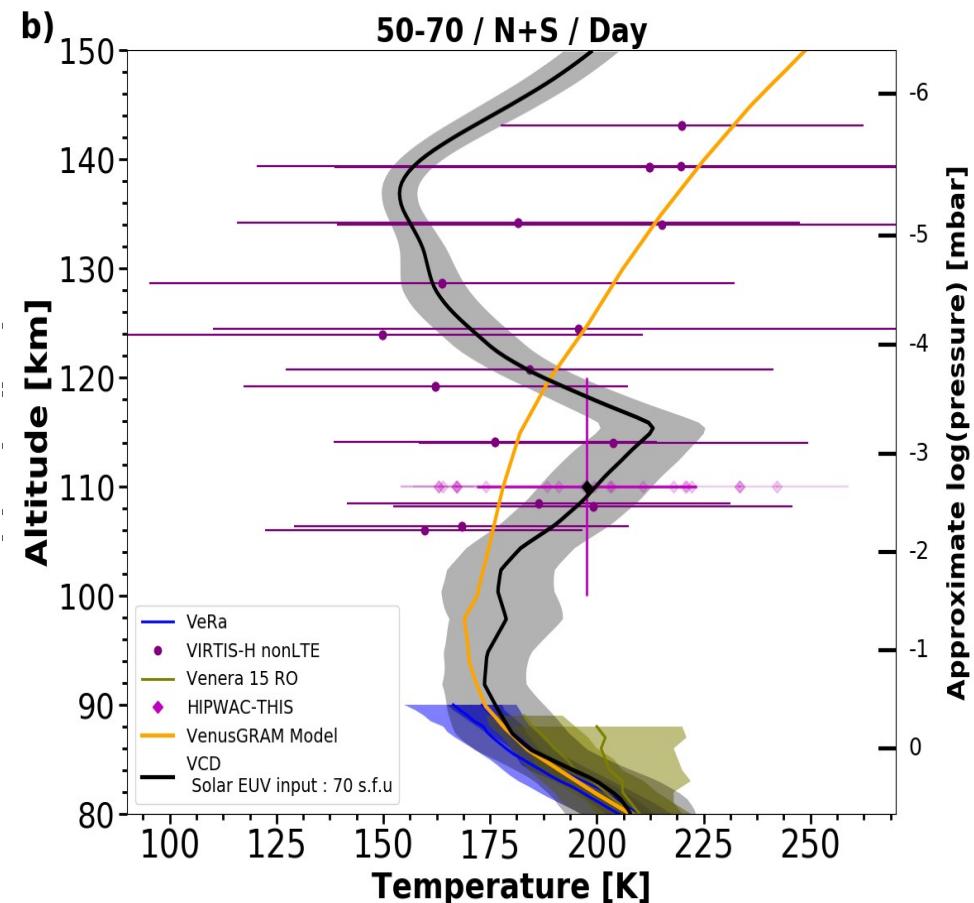
Lower thermosphere

Temperatures compared to observations

Near IR CO₂ Non-LTE tuning



DAY



Above 150 km

Based on datasets from

- Pioneer Venus (OAD, ONMS),
- Magellan (aerobraking, POD)
- Venus-Express (VeXADE),

we can investigate temperature, density and composition above 150 km.

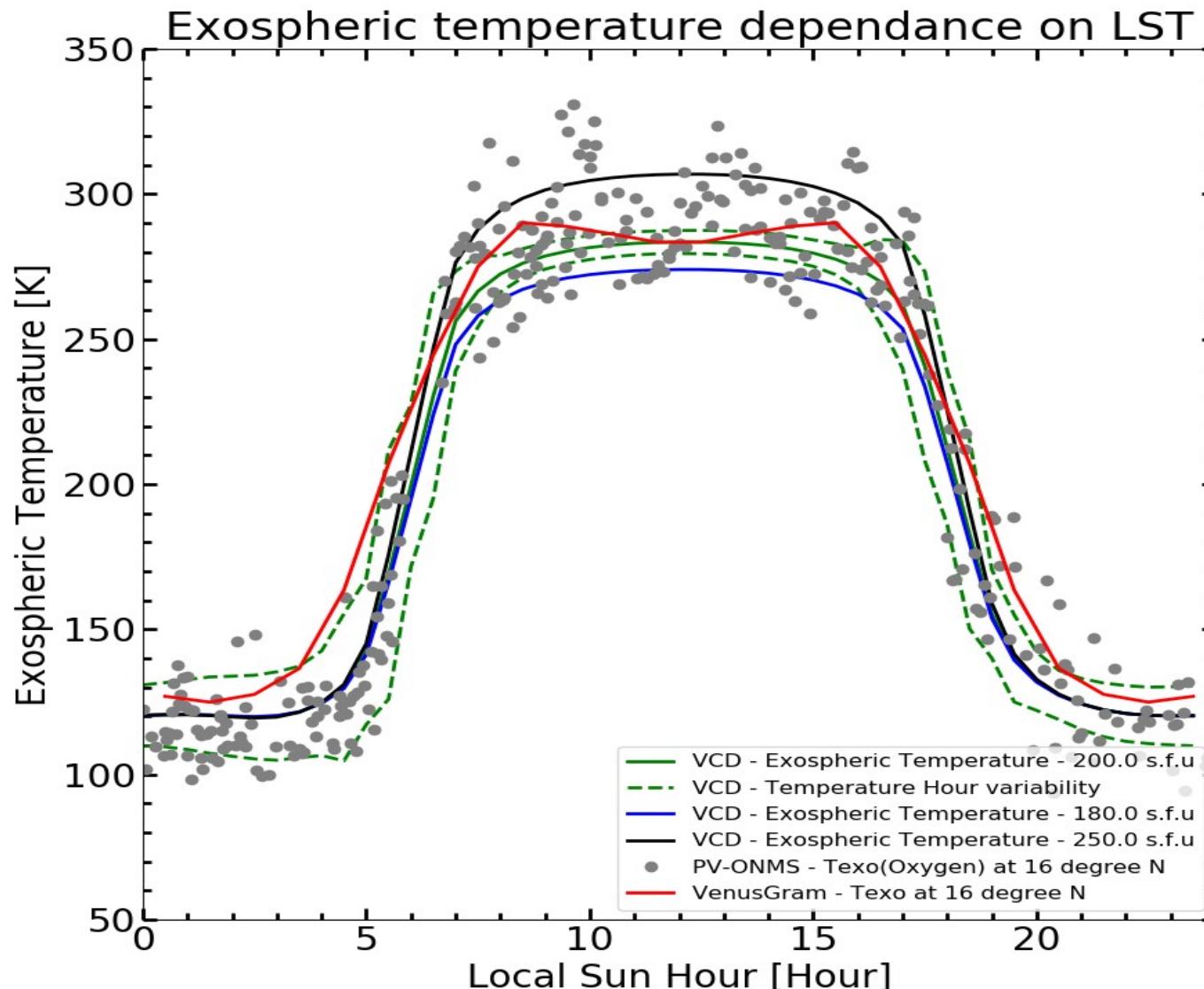
Tuning includes :

- EUV efficiency and CO₂-O quenching coefficient
- CO₂ dissociation => major question
- small-scale gravity wave parameterisation

Parameter to be taken into account : E10.7

Temperature vs observations above 150 km

Exospheric temperature retrieved from O profiles in PV-ONMS datasets

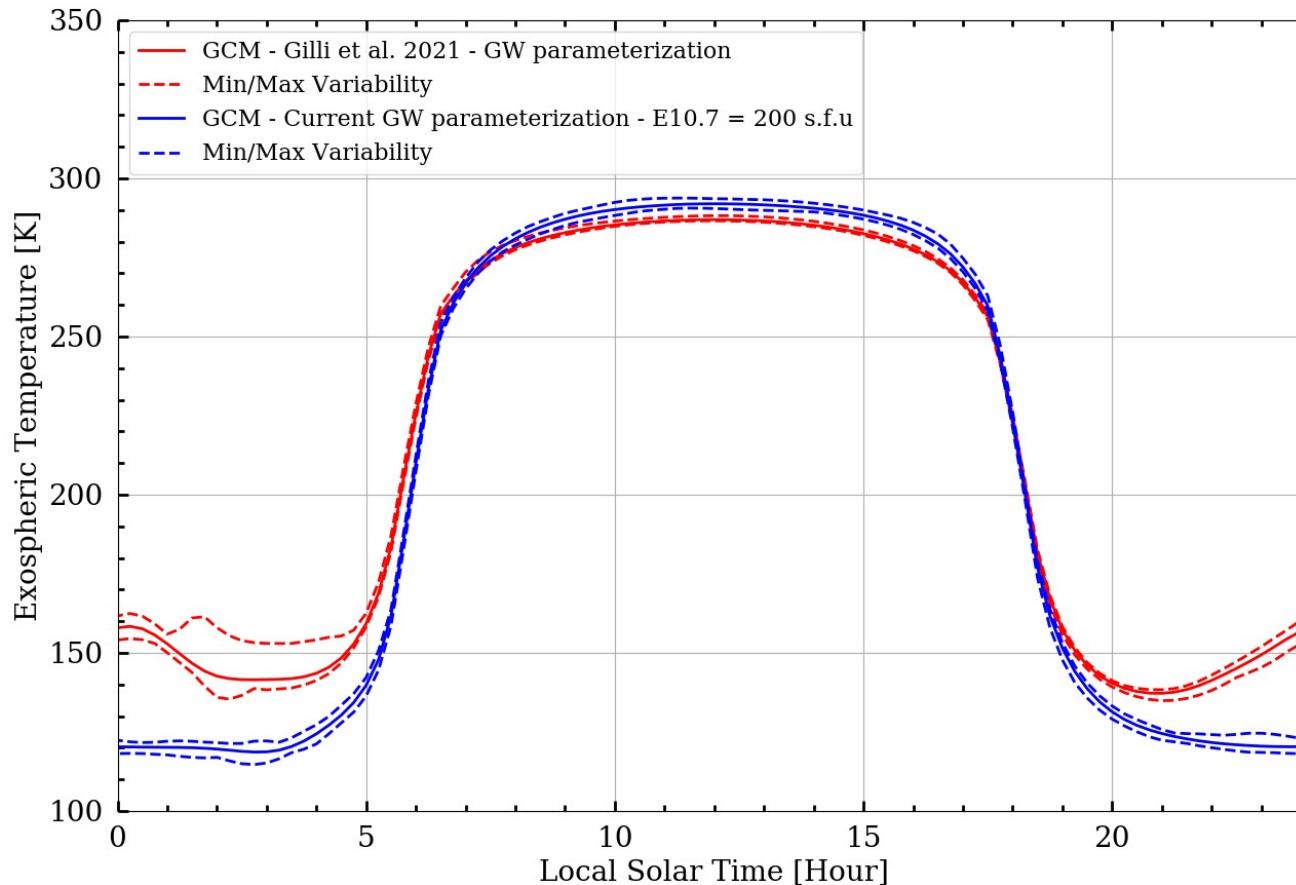


Temperature vs observations above 150 km

Role of gravity wave tuning

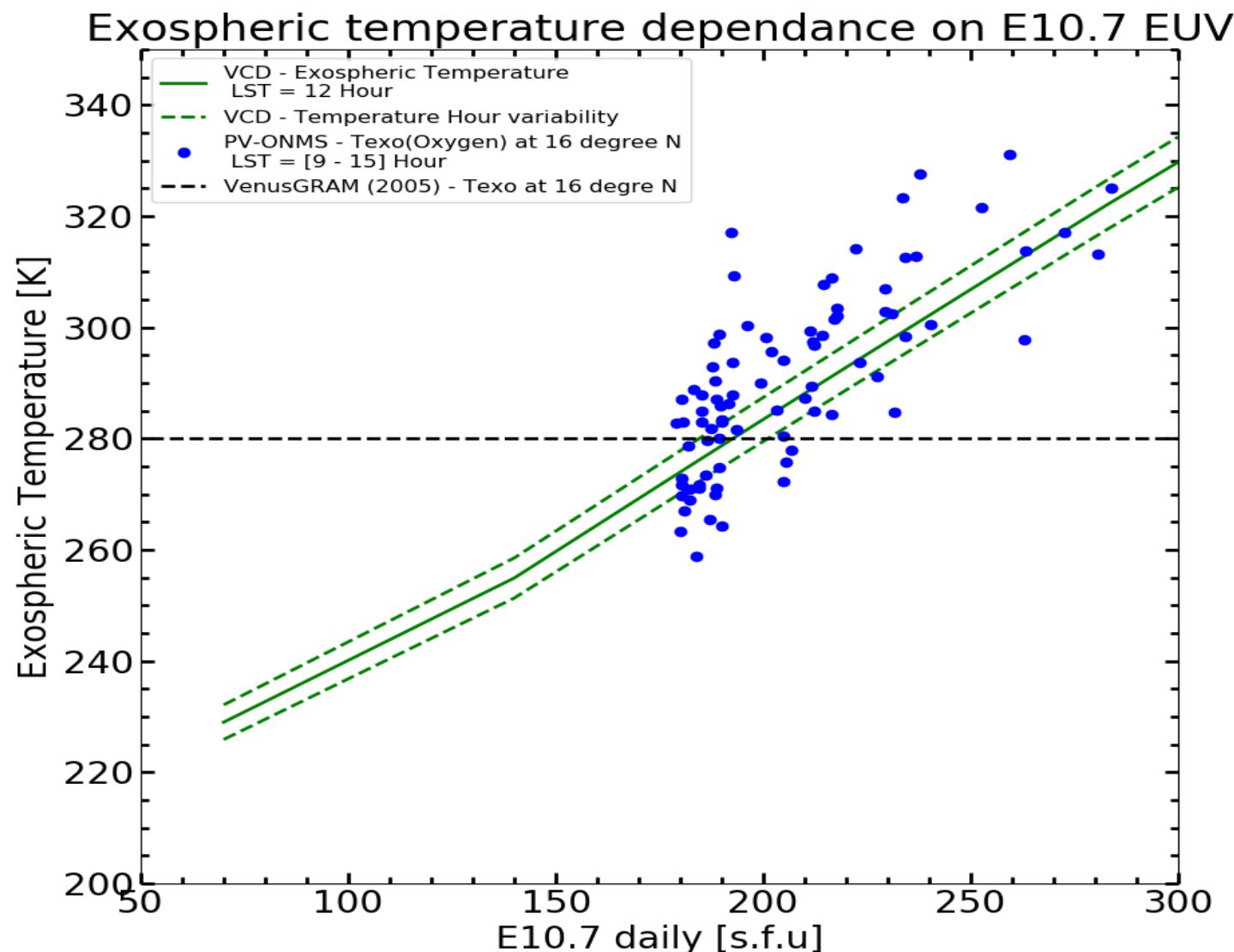
=> strong impact on circulation

=> strong impact on night exospheric temperature



Sensitivity to E10.7

Exospheric temperature as a function of E10.7



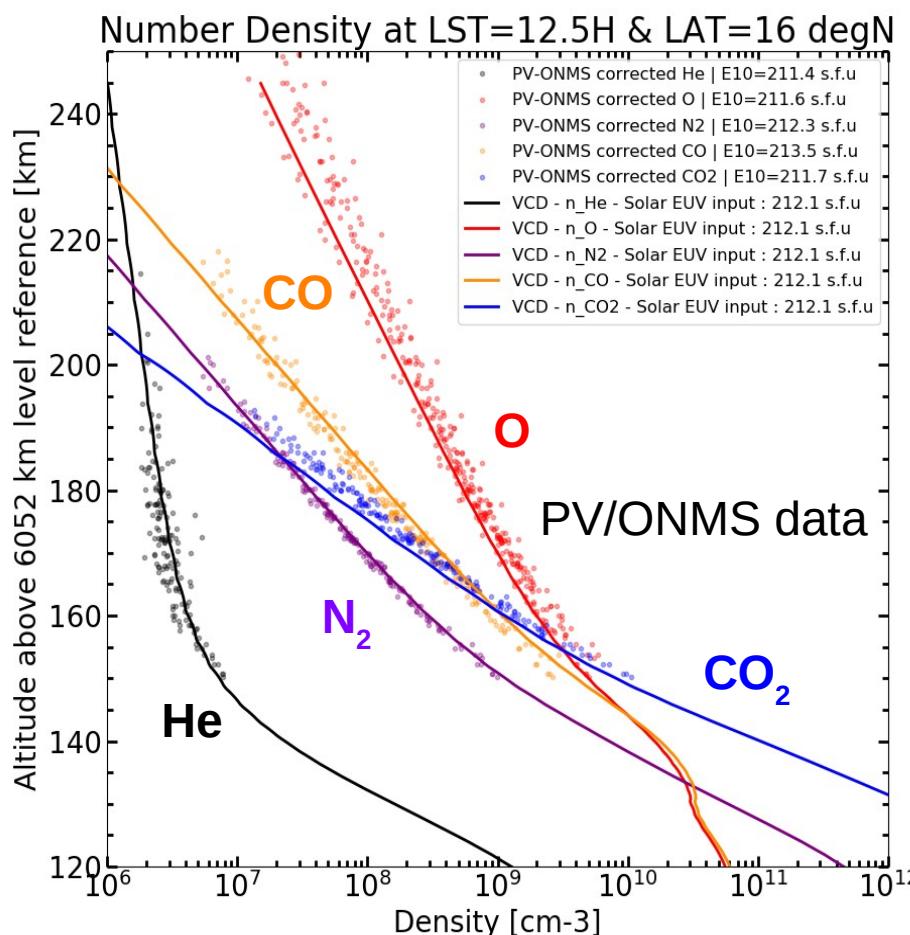
Composition : O and CO

O plays a significant role on temperature !

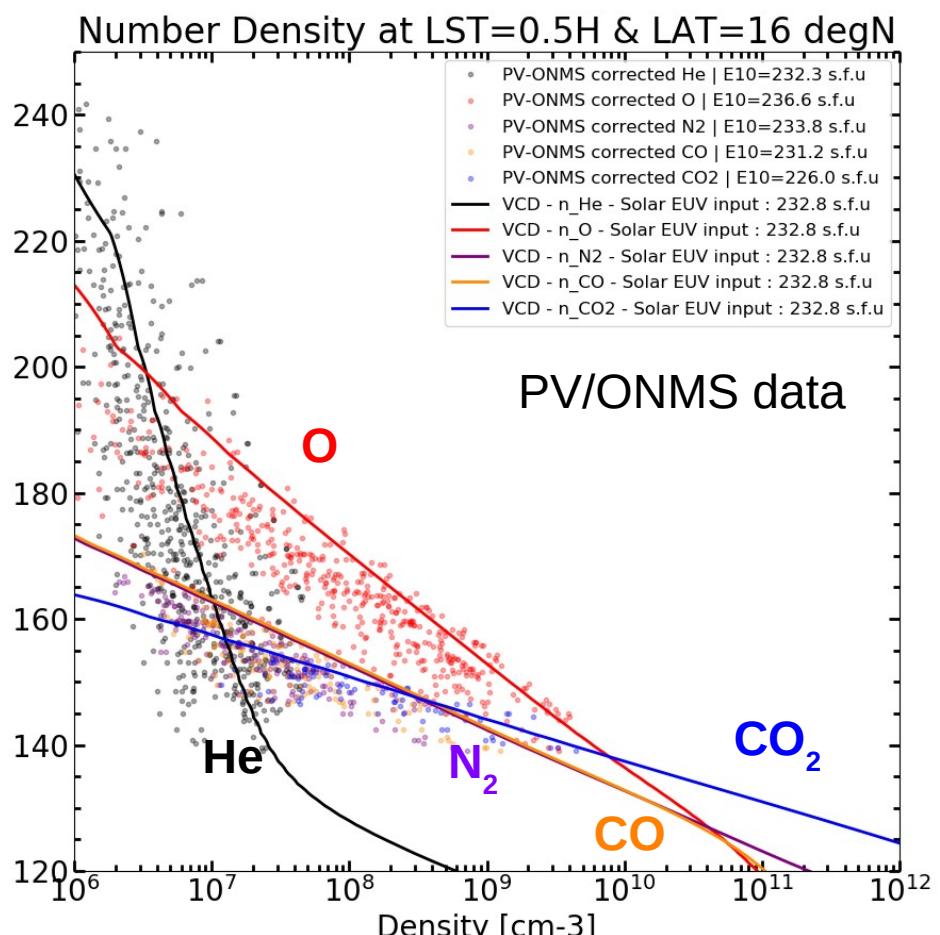
Increasing CO₂ photodissociation improves O and CO...

Investigations ongoing

Noon



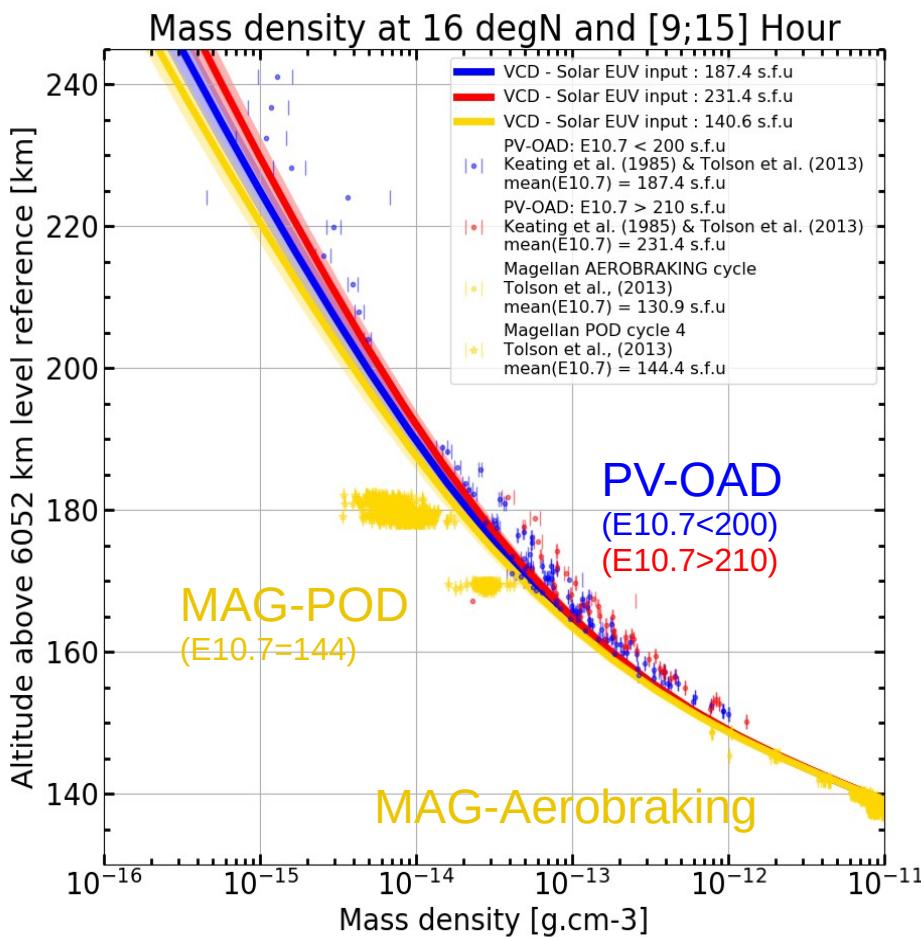
Midnight



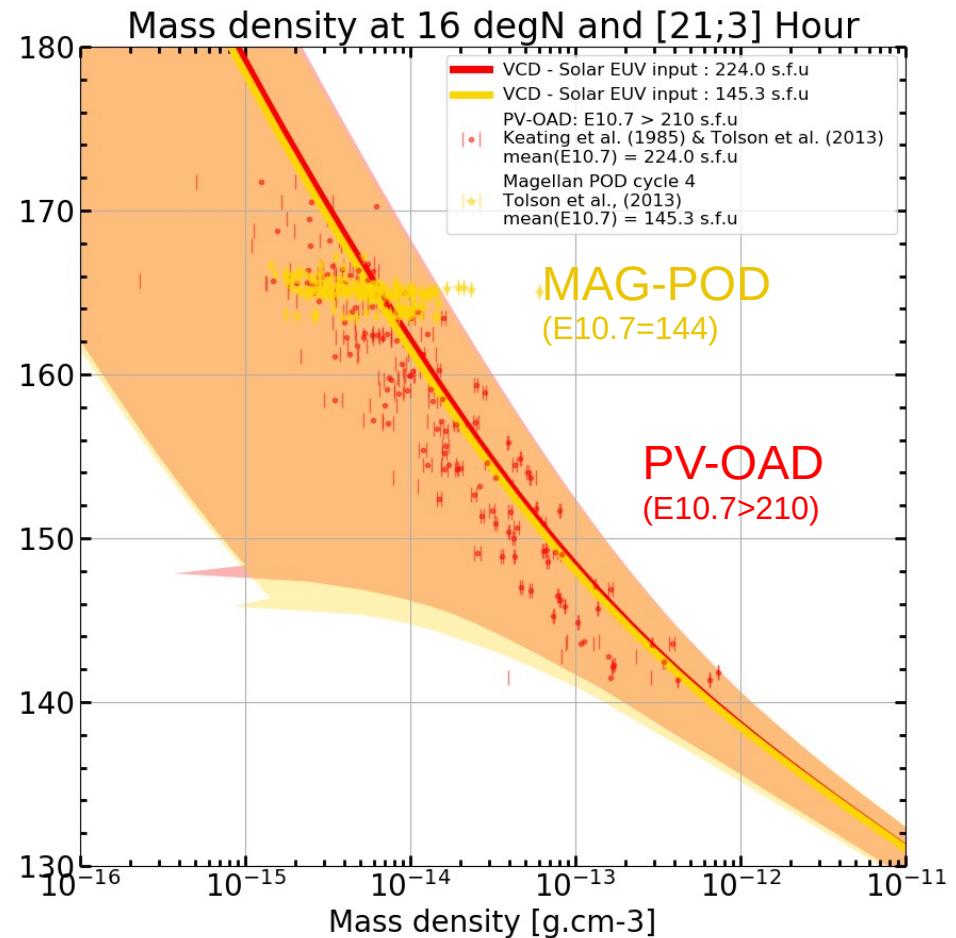
Mass density

Magellan and Pioneer-Venus data : low latitude

Noon

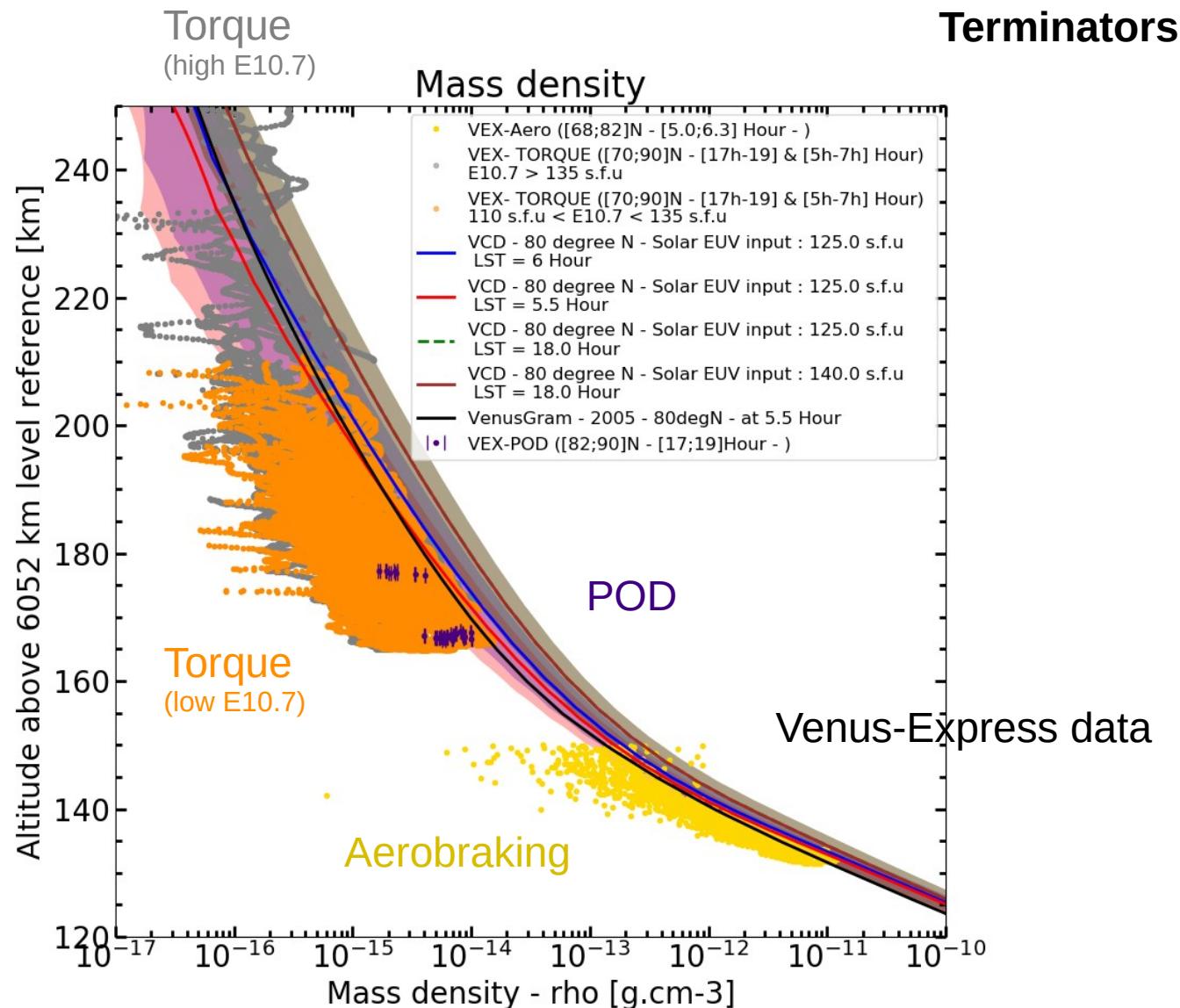


Midnight



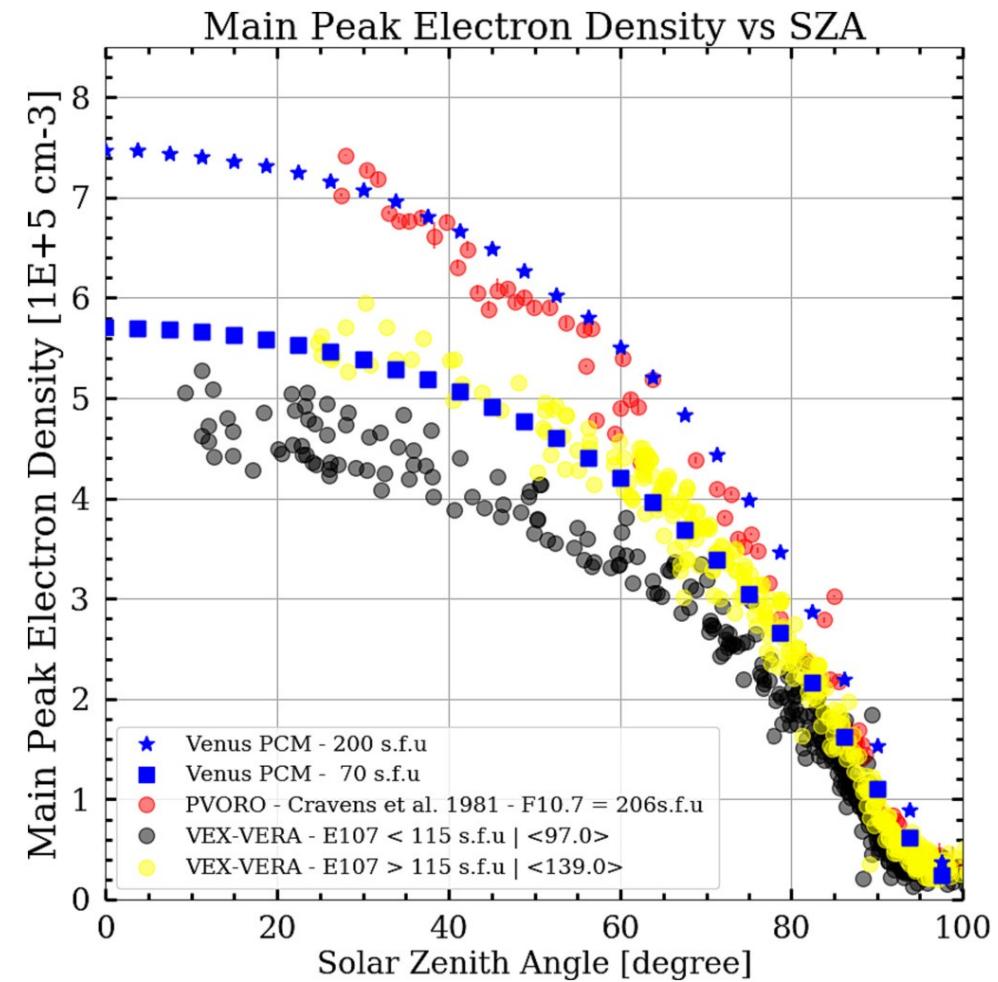
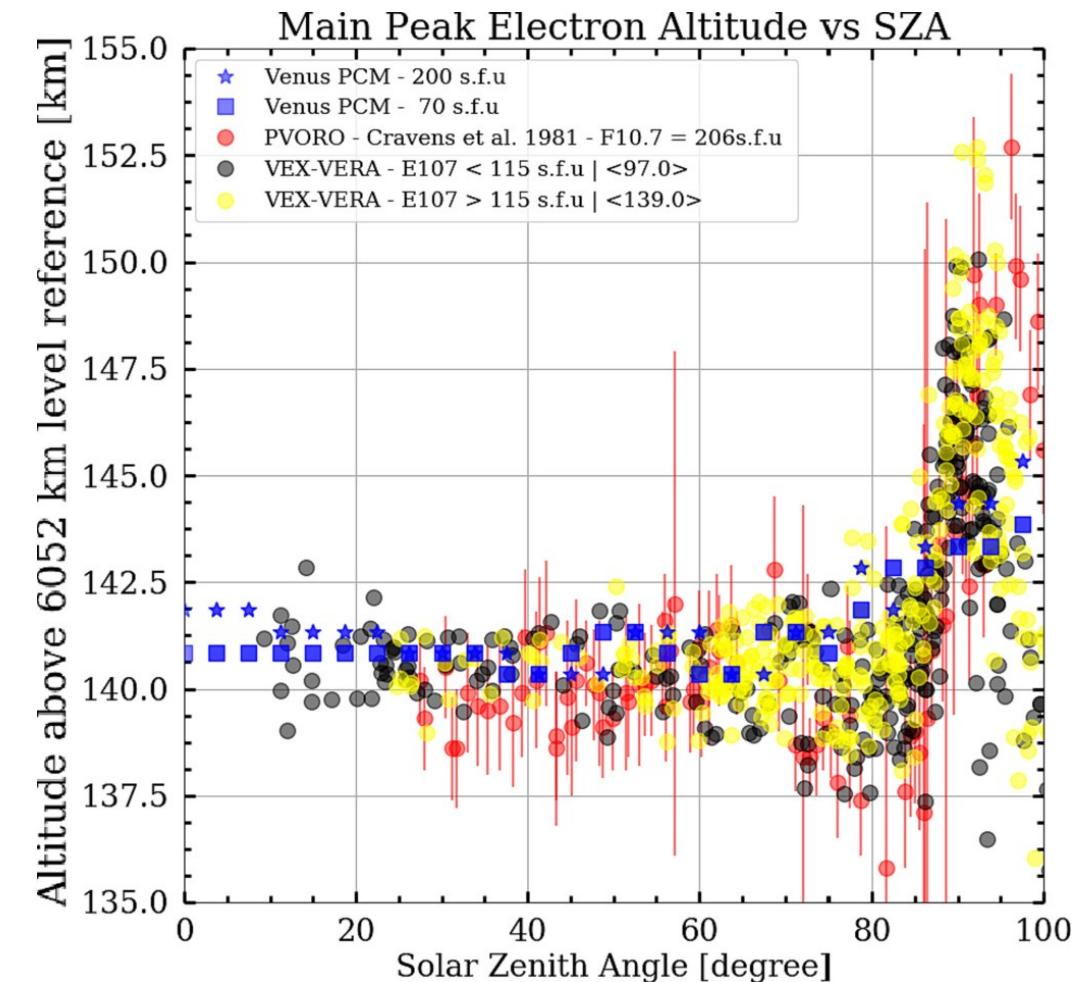
Mass density

Venus-Express data : polar latitude



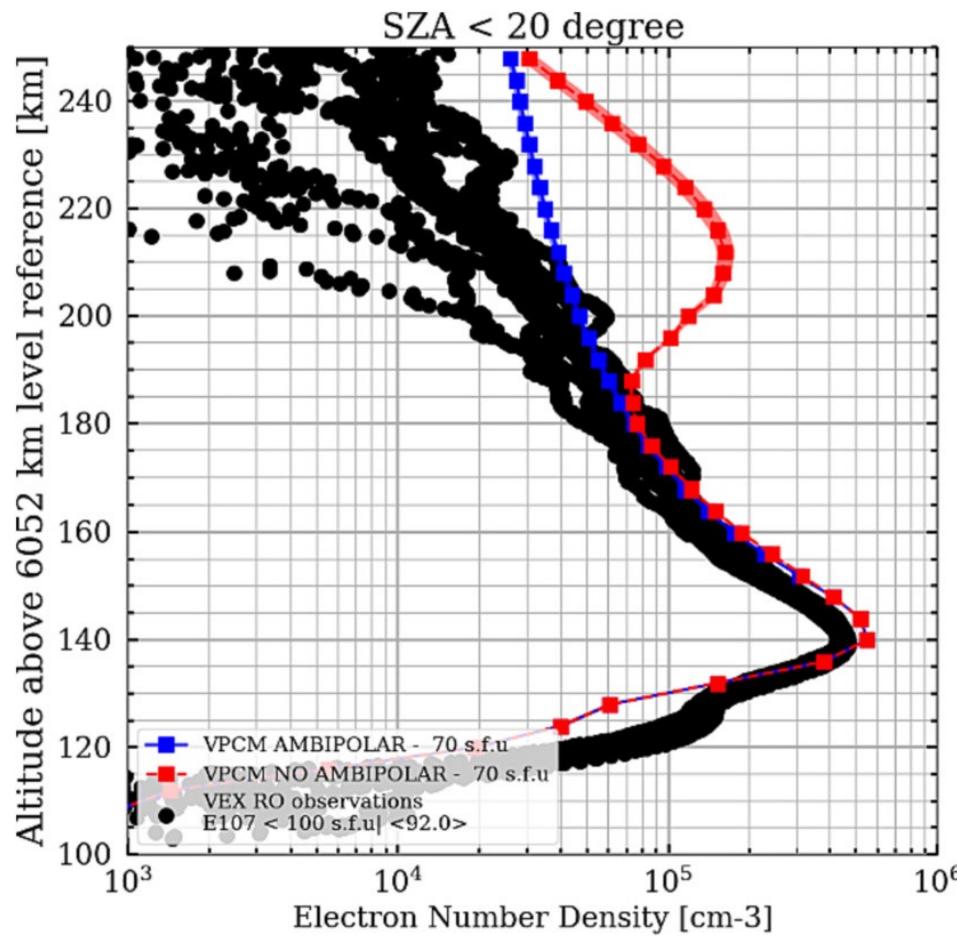
Ionosphere

Electron peak density vs observations

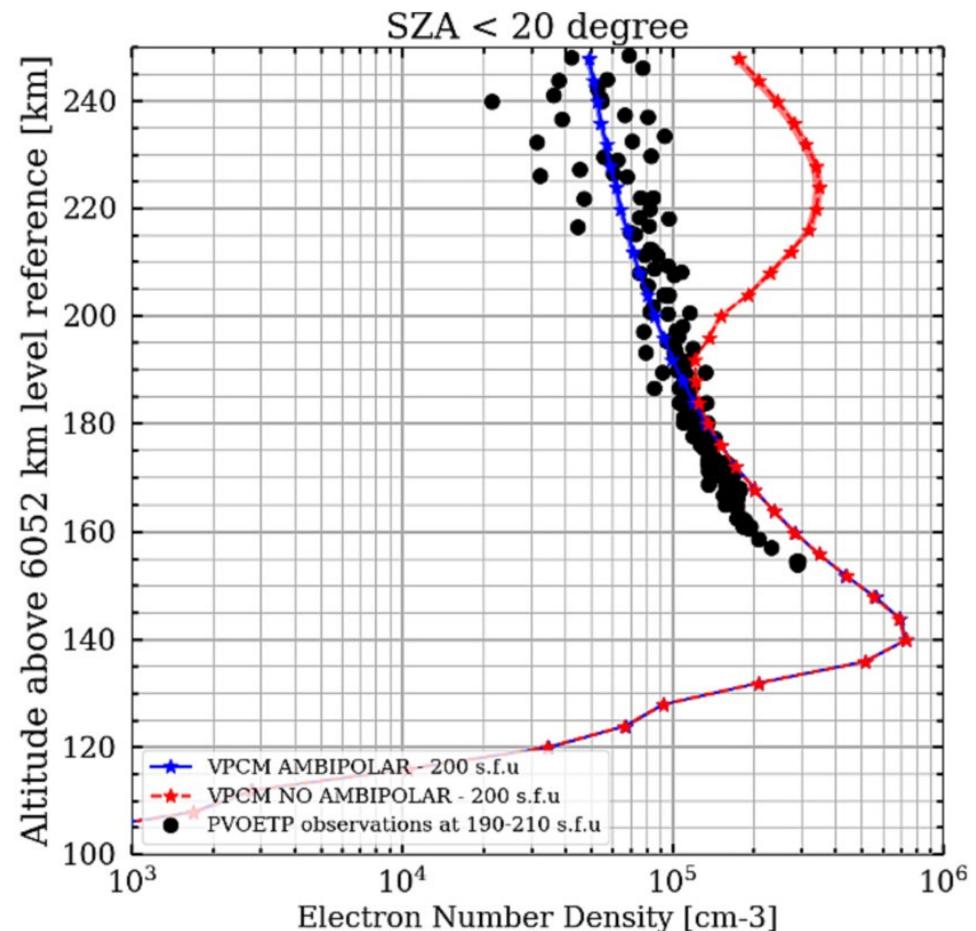


Ionosphere

Electron density profiles vs observations, with / without ambipolar diffusion
Daytime (not so good on nighttime...)



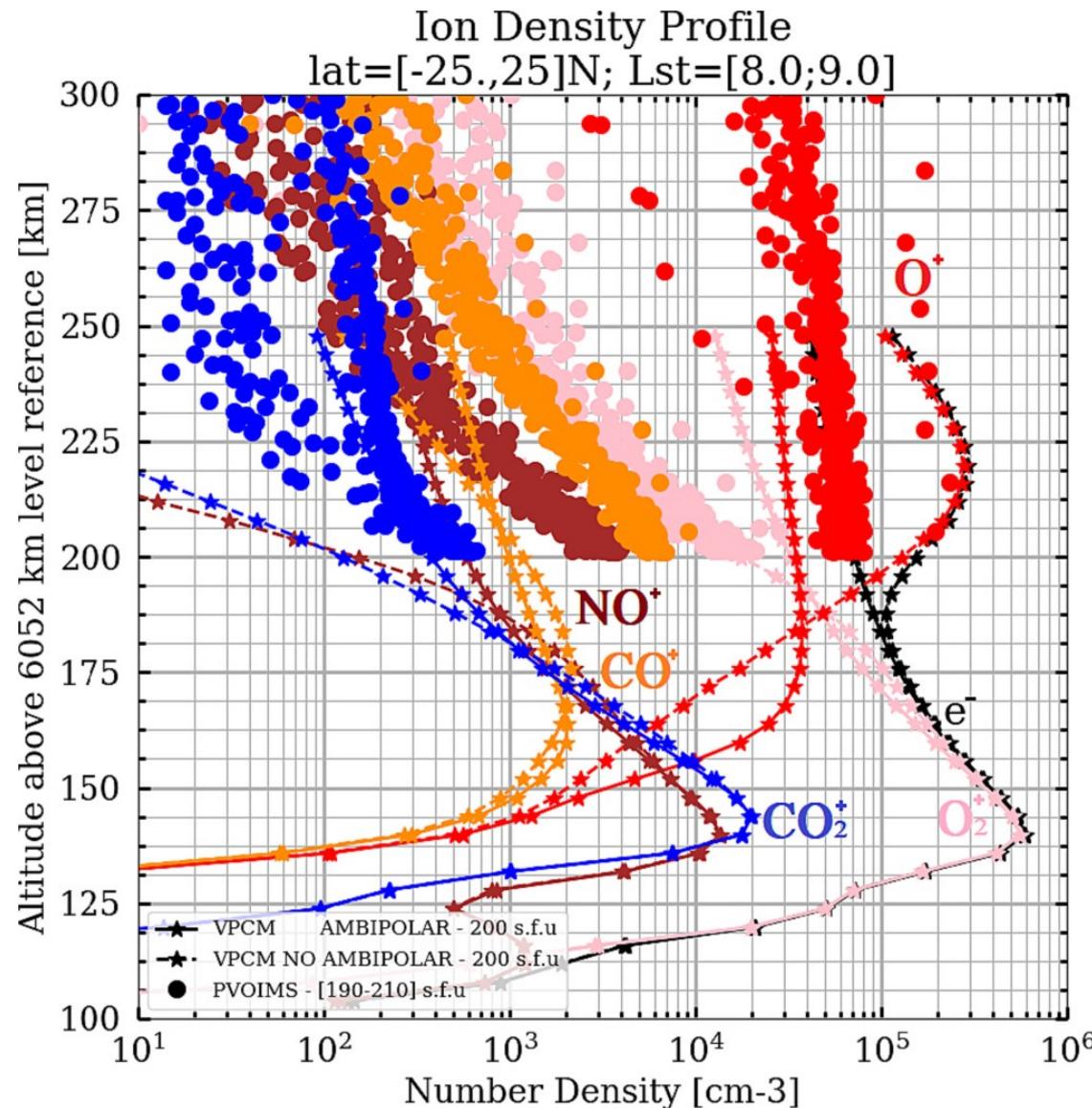
High latitudes / Venus Express



Low latitudes / Pioneer Venus

Ionosphere

Ion profiles vs observations



VCD

The Venus Climate Database

Ehouarn's talk, tuesday

The IPSL Venus GCM is a mature tool to study the upper atmosphere of Venus and its variability
=> interest for the EnVision project and aerobraking

ESA is funding our Venus Climate Database

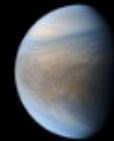
- Engineer and scientific purposes
- Reference simulations for different scenarios (E10.7 / cloud UV albedo)
- Plug-in tools, but also web interface

Vertical extension of GCM simulations up to 250 km
+ analytical exosphere

Sensitivity of temperature and circulation to model parameters and to horizontal resolution still to be fully assessed.

VCD 2.3 released in september 2023

VCD web interface



Venus Climate Database v2.3 : The Web Interface

[Information] [Gallery] [Report issue] [Credit] [How to cite the VCD]

VARIABLE(S) TO DISPLAY OR DOWNLOAD

Variable 1 Temperature (K)

Variable 2 (None)

Variable 3 (None)

Variable 4 (None)

TIME COORDINATES

- **VENUS date** Local Time Venusian hour
write a value (or) a range 'val1 val2' (or) 'all'

- **EARTH date** YY / MM / DD @ hh:mm:ss UTC

2023 / 10 / 16 @ 13:12:30

[Use Earth date to calculate Venus Ls](#)

Earth Julian Date

Venus Solar Longitude

SPATIAL COORDINATES

write a value (or) a range 'val1 val2' (or) 'all'

Latitude degree North

Longitude degree East

Altitude m above surface

Spacecraft landing site & date (None)

CUSTOMIZE DATA REQUEST

- Same localtime everywhere off on
- Cloud albedo scenario
- Solar EUV scenario
- High-resolution topography off on
- Averaging (only for 2D plots for now!) off zonal diurnal

CUSTOMIZE FIGURES

- Figure format PNG PNG hi-res EPS
- [1D] Log(values) off on
- [2D] Colormap
- [2D] Values range to
- [2D map] View
- [2D map] Transparency (%)
- [2D map] Wind vectors off on
- [2D map] Add marker at lat lon

SUBMIT

RESET

