The IPSL Venus GCM : Status in the context of the development of a Venus Climate Database

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The IPSL Venus GCM

- 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
  - 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)

Gilli et al (2017, 2021) ; Garate & Lebonnois (2018) ; Navarro et al (2018, 2021)

Below the clouds

Below the clouds of Venus

Radiative transfer in deep atmosphere

Strong impact on dynamics

Wave activity

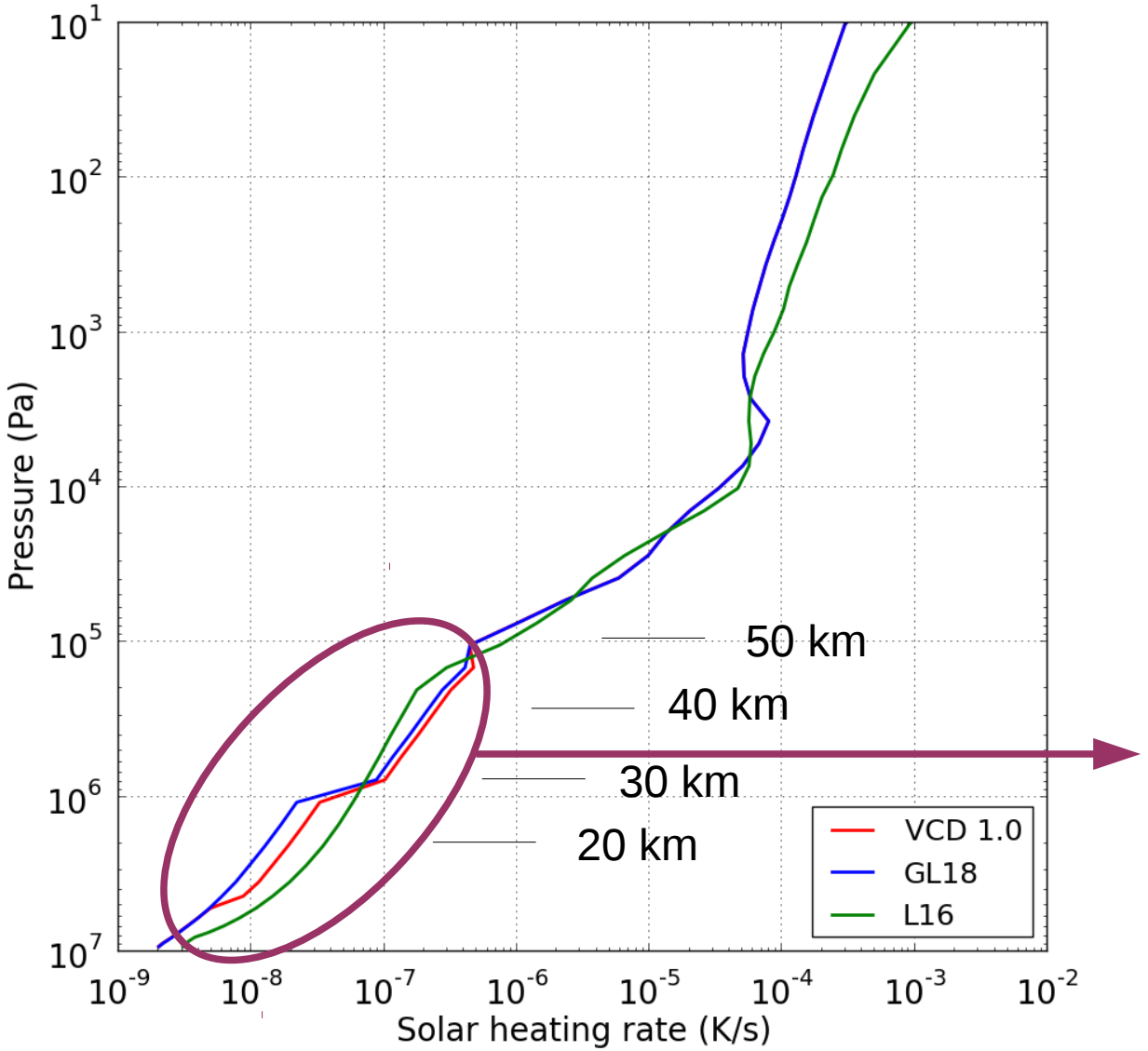
Impact on angular momentum transport and zonal wind profile

Near-surface behavior

Planetary boundary layer (PBL) structure,
slope winds and mountain waves

Radiative transfer sensitivity

Tuning solar heating in the deep atmosphere...



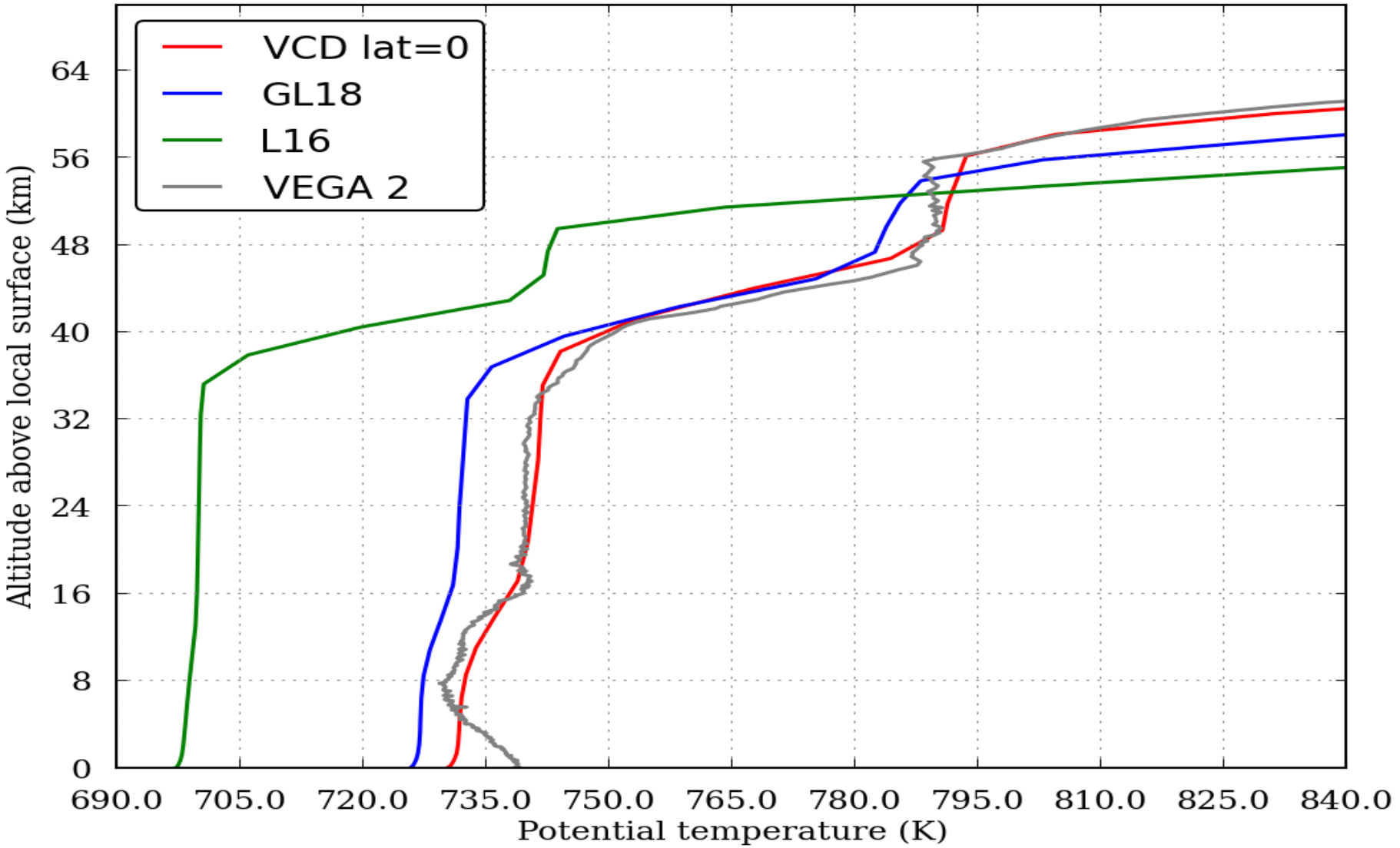
Red : Tuning (VCD)
Green : Crisp, 1986 (used in L16)
Blue : Haus et al, 2015
+ additional heating (30-48 km)
(used in GL18)

Additional heating
below 30 km

Need for additional modeling
and confirmation

Radiative transfer sensitivity

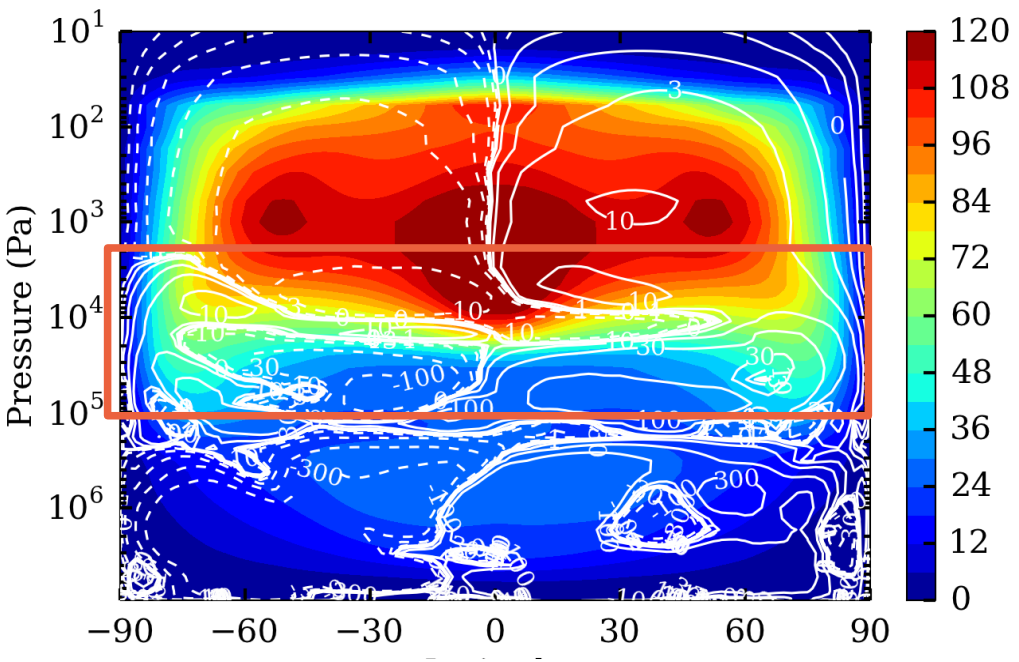
New solar tuning
=> fit of the temperature to Vega 2 profile (stable over 100 Vd)



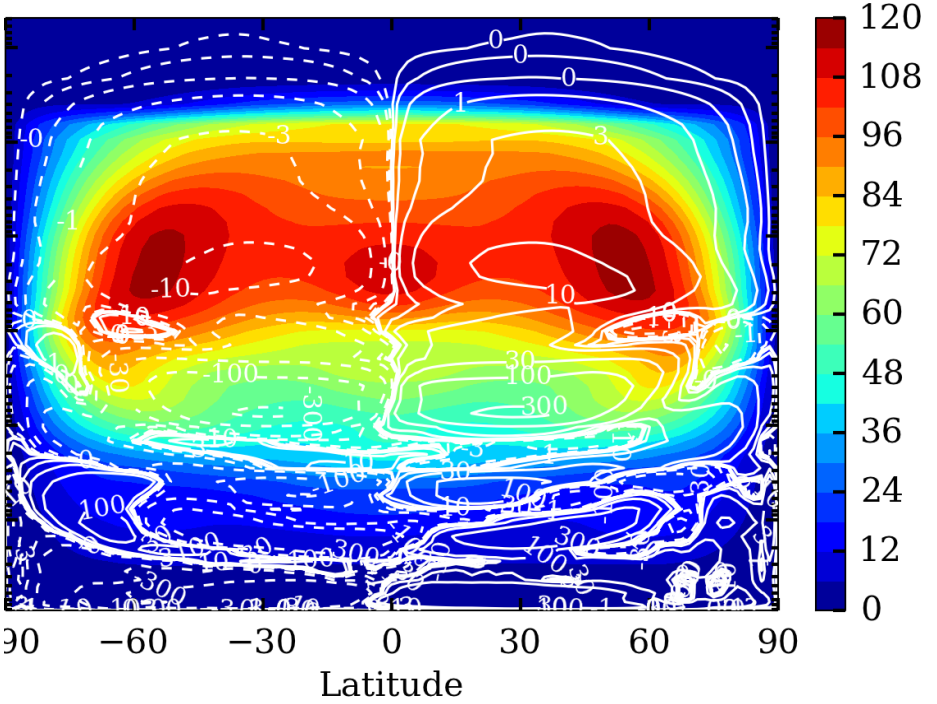
Superrotation

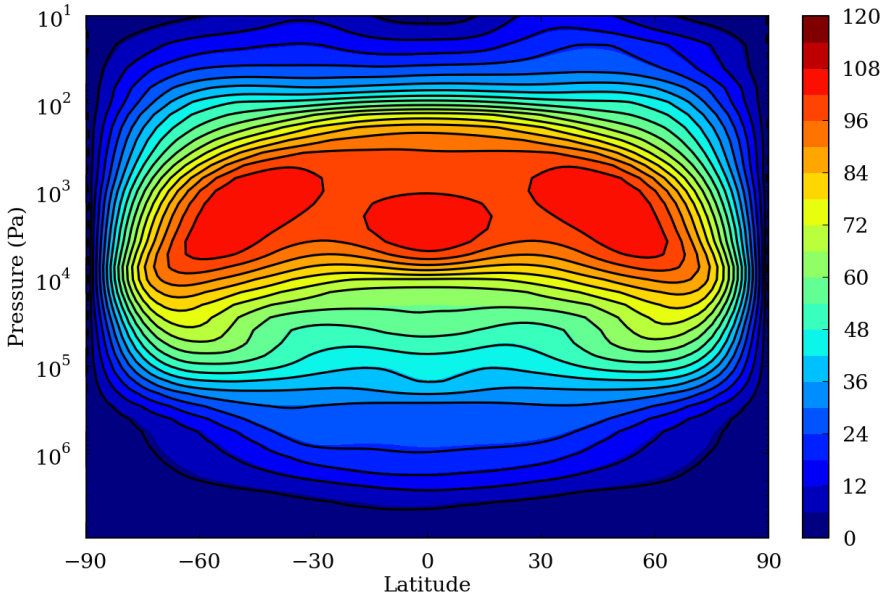
Clouds

Lebonnois et al. (2016)



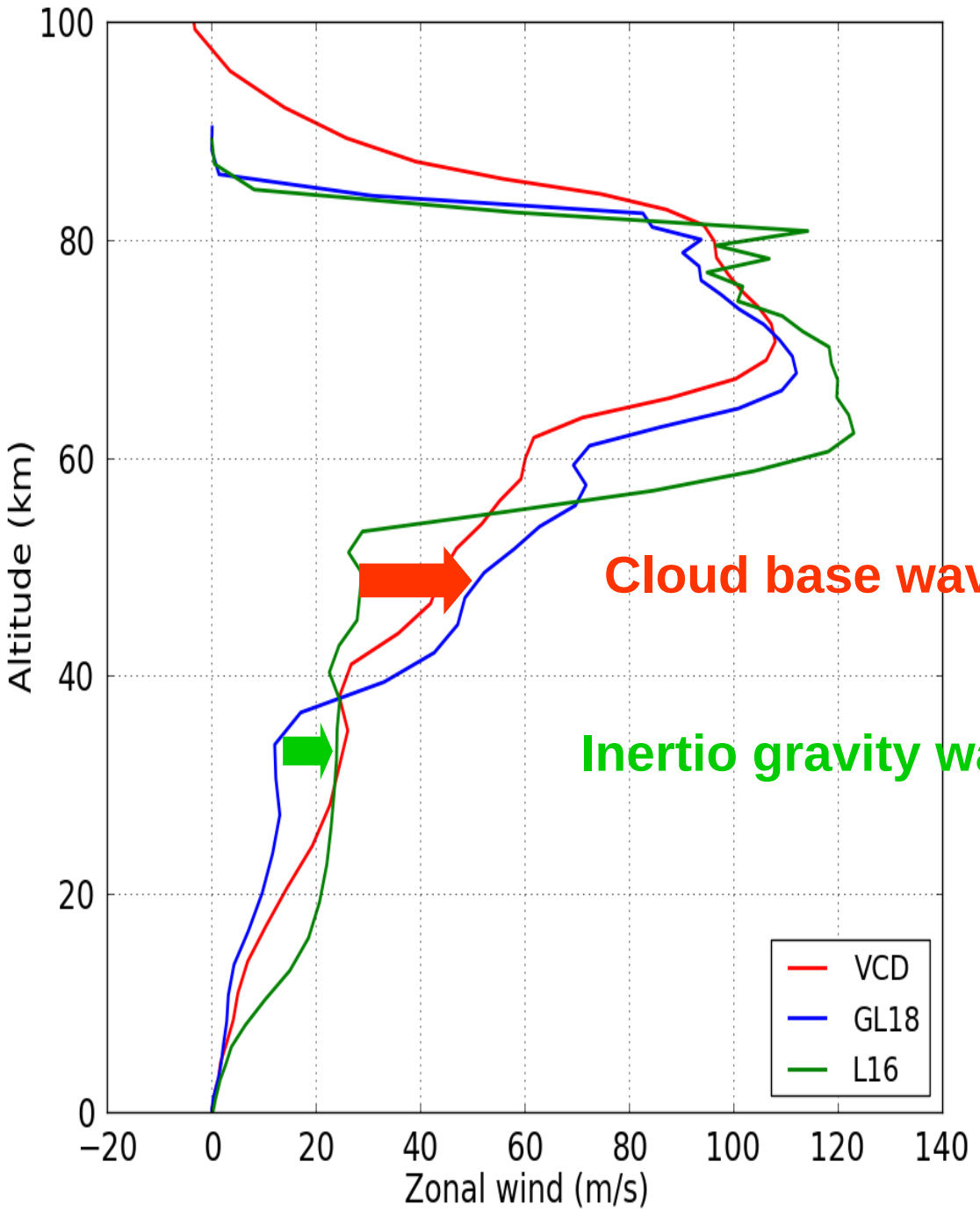
Garate-Lopez & Lebonnois (2018)





VCD tuning
(expands higher,
up to 10^{-8} Pa
on 90 levels)

Wave activity below clouds



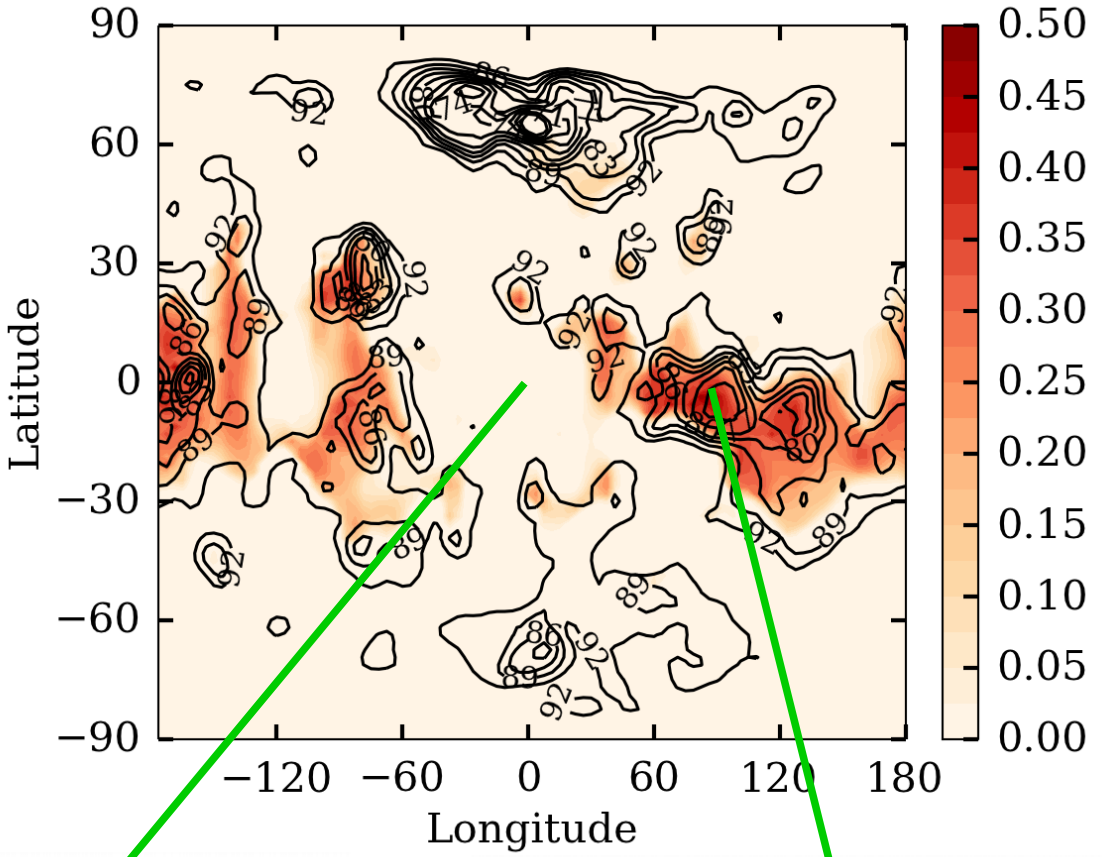
Cloud base wave activity

Inertio gravity wave activity

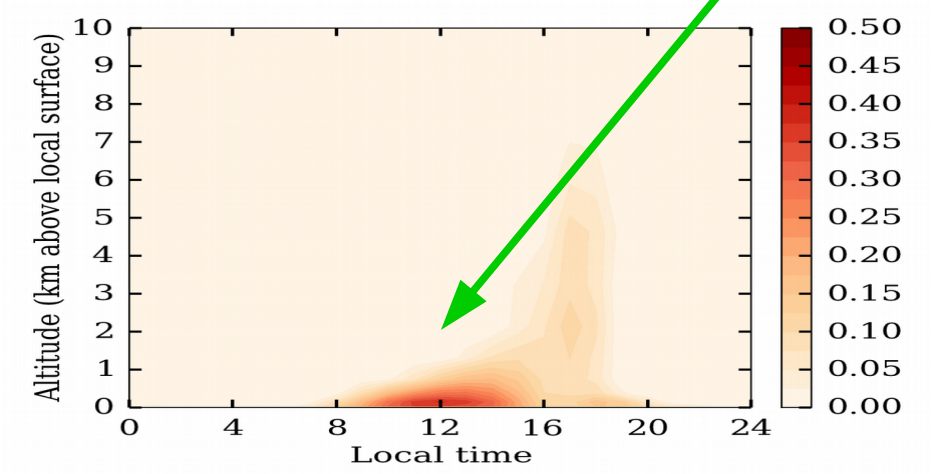
Future analysis of waves to be done soon

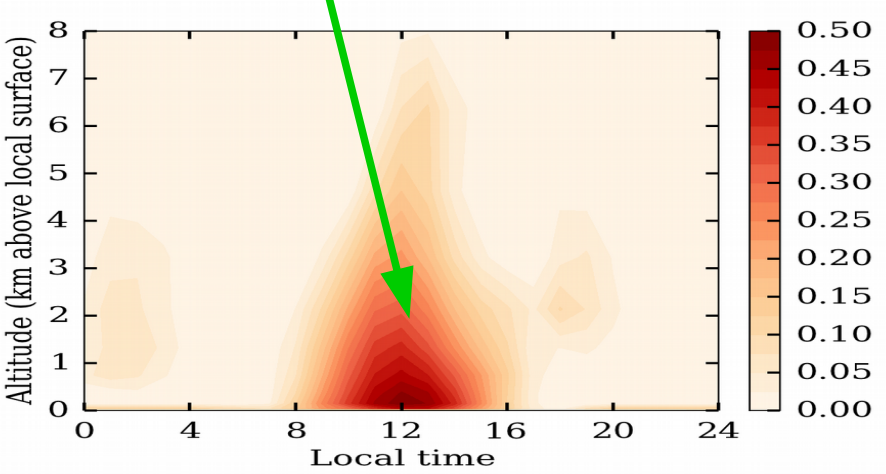
PBL structure

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

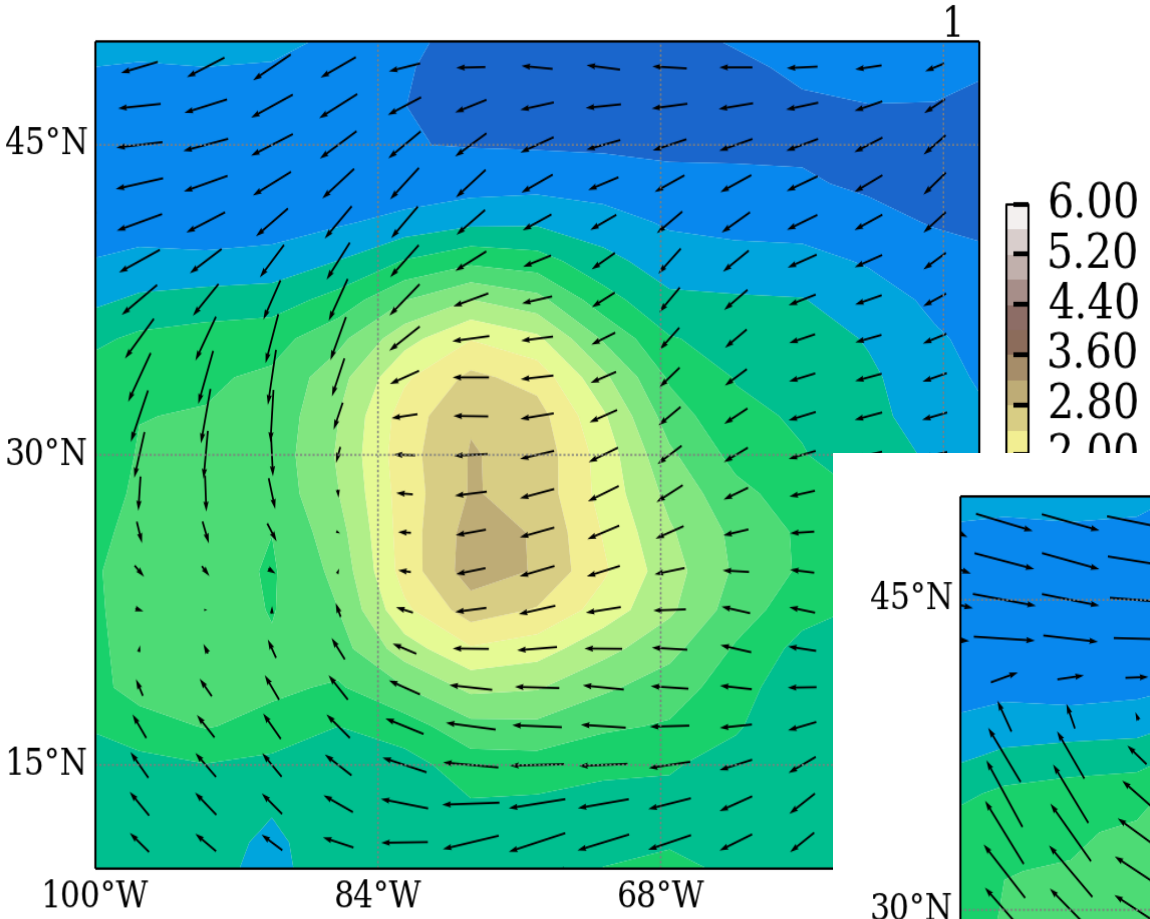


Lebonnois et al., 2018





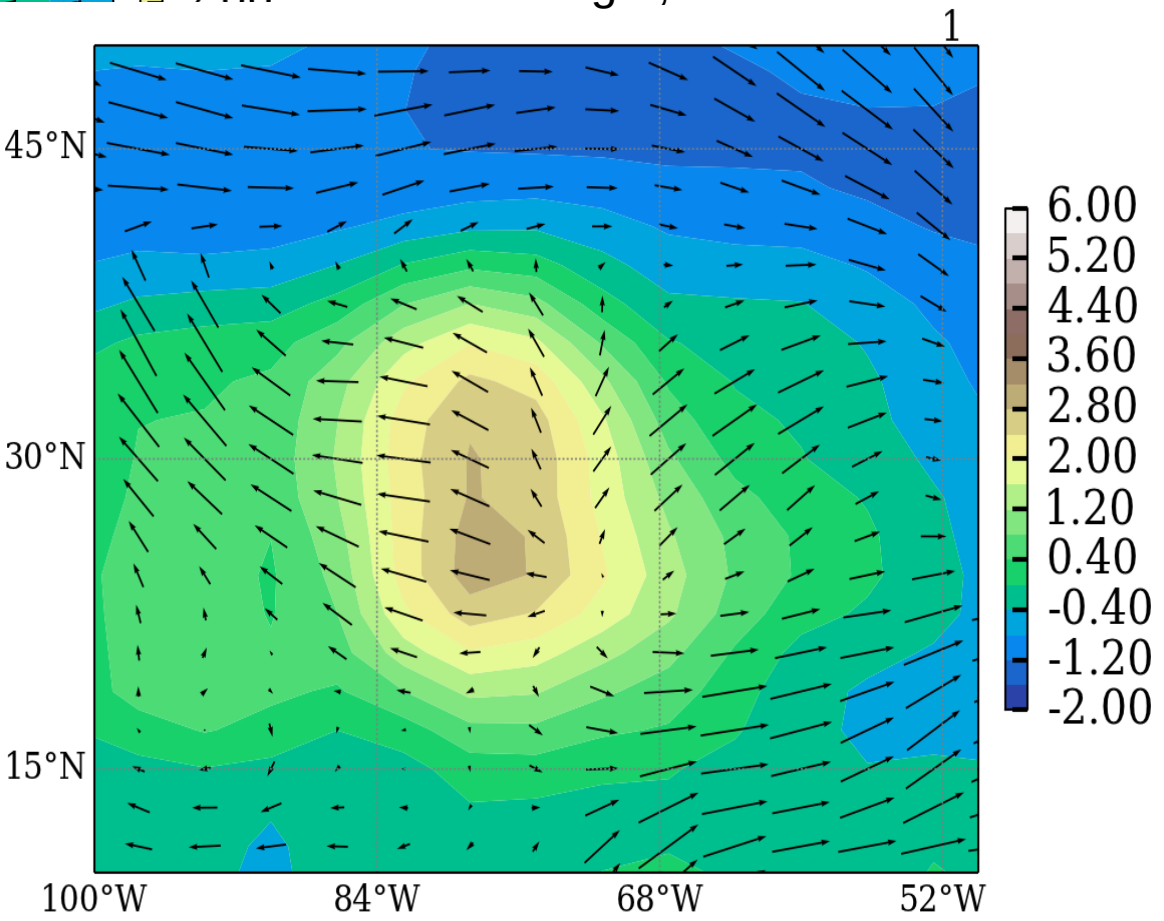
Role of slope winds



Noon, anabatic

winds 150 m above surface
Beta Regio (30N)

Midnight, katabatic



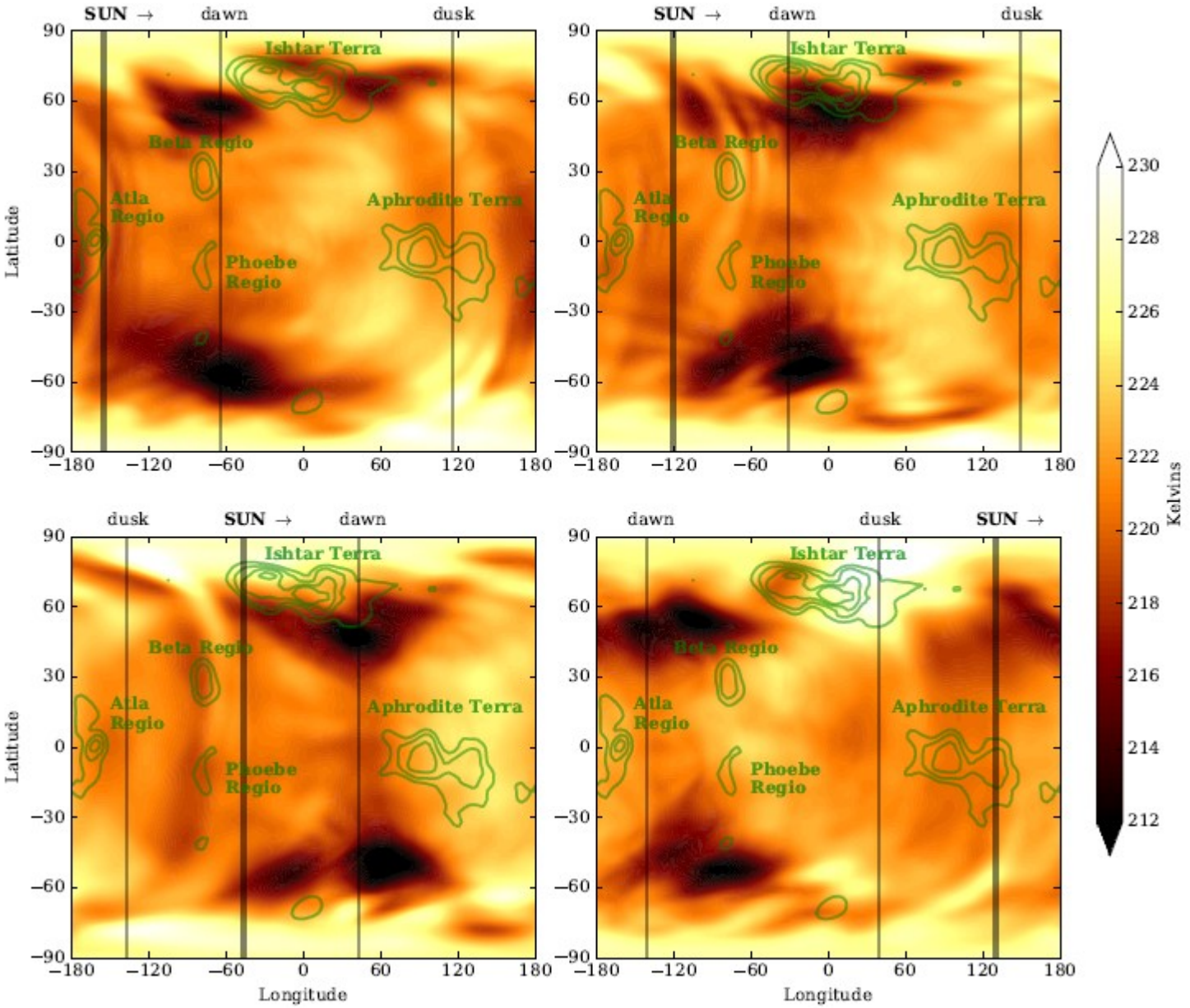
Lebonnois et al., 2018

Mountain waves

Physical parameterization tested in the GCM

GCM

T at 70km
(~cloud-top)



Navarro et al., 2018

The upper atmosphere

The upper atmosphere

Recent tuning of the 80-120 km region

- 78-lev simulations (up to ~150 km)
- Gilli et al 2021 : comparison to T and composition observations
- Navarro et al 2021 : structure and variability of circulation

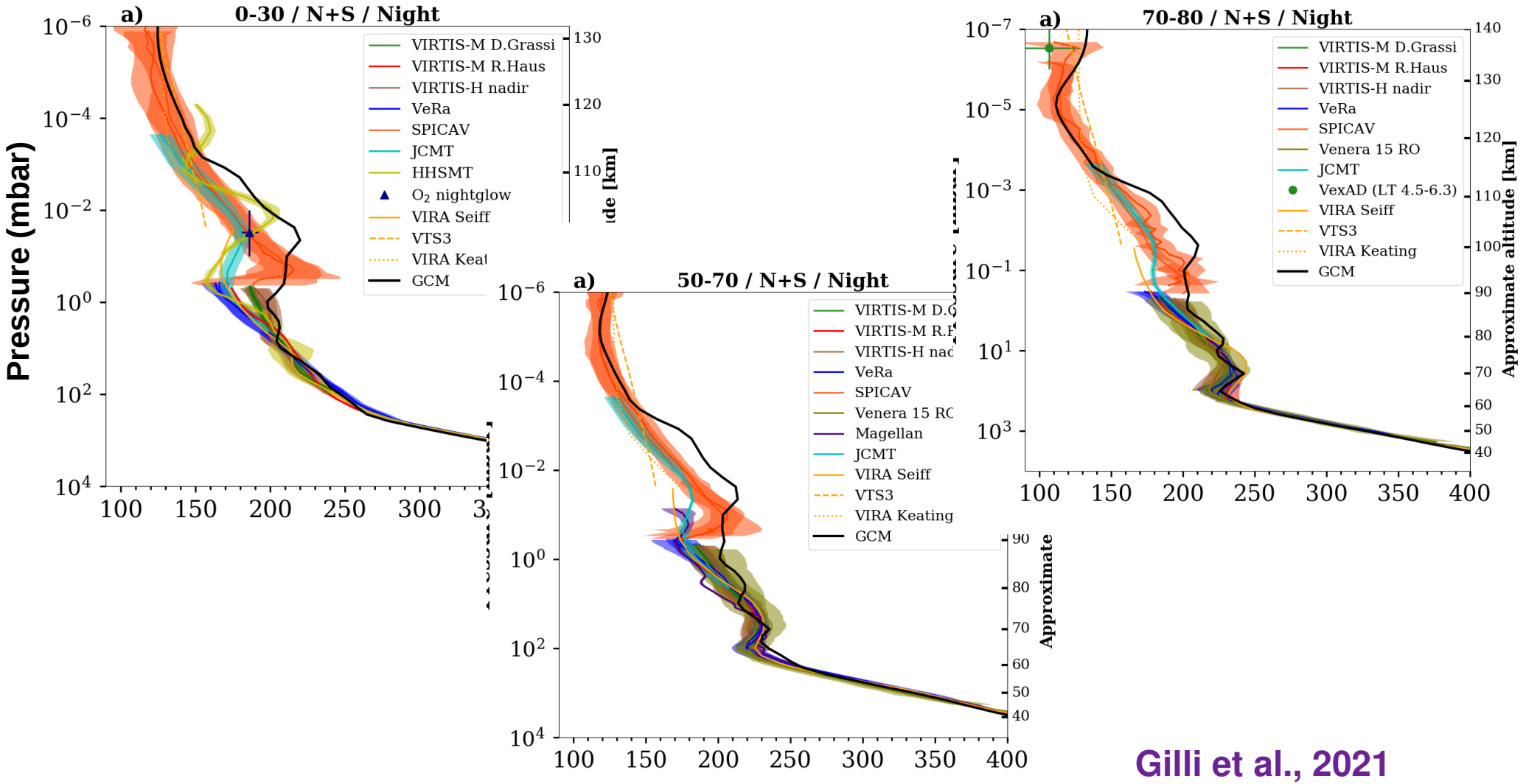
Extension to 10^{-8} Pa (~250 km)

- Comparison to datasets
- Tuning of EUV heating parameters
- Problem of composition...

Lower thermosphere
Temperatures compared to observations

Near IR CO2 Non-LTE tuning => need some additional work...

NIGHT

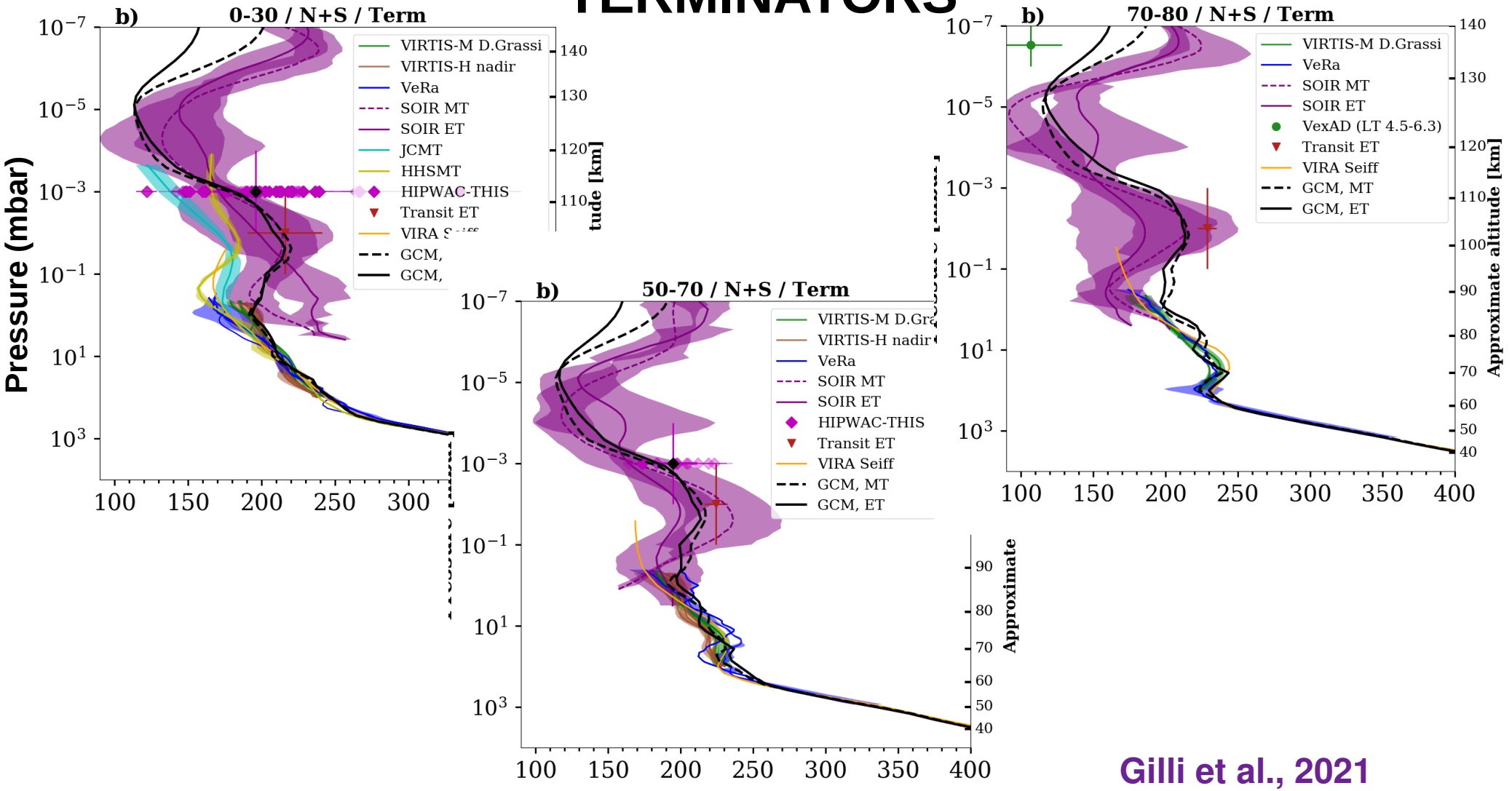


Gilli et al., 2021

Lower thermosphere
Temperatures compared to observations

Near IR CO2 Non-LTE tuning => need some additional work...

TERMINATORS

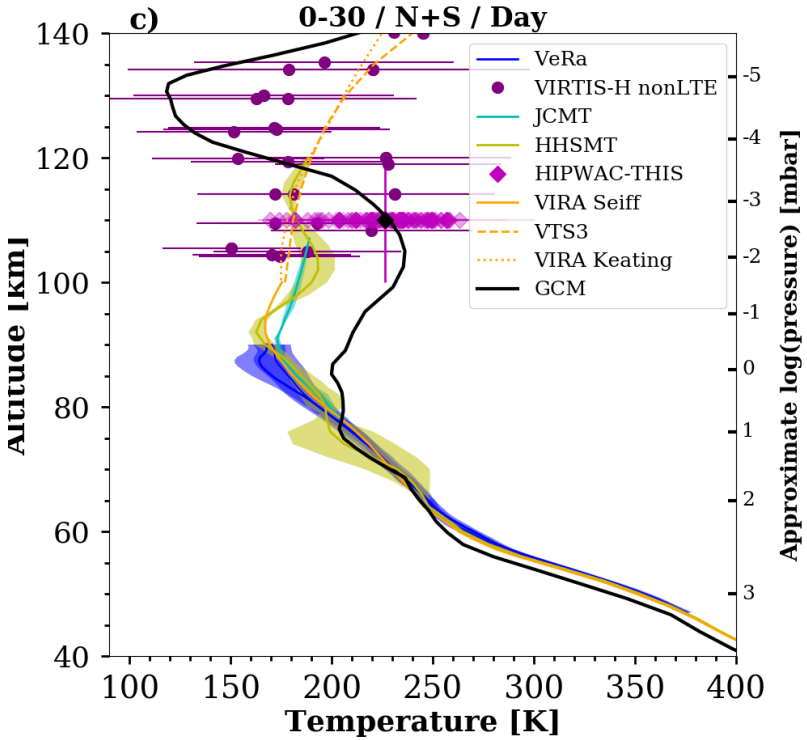


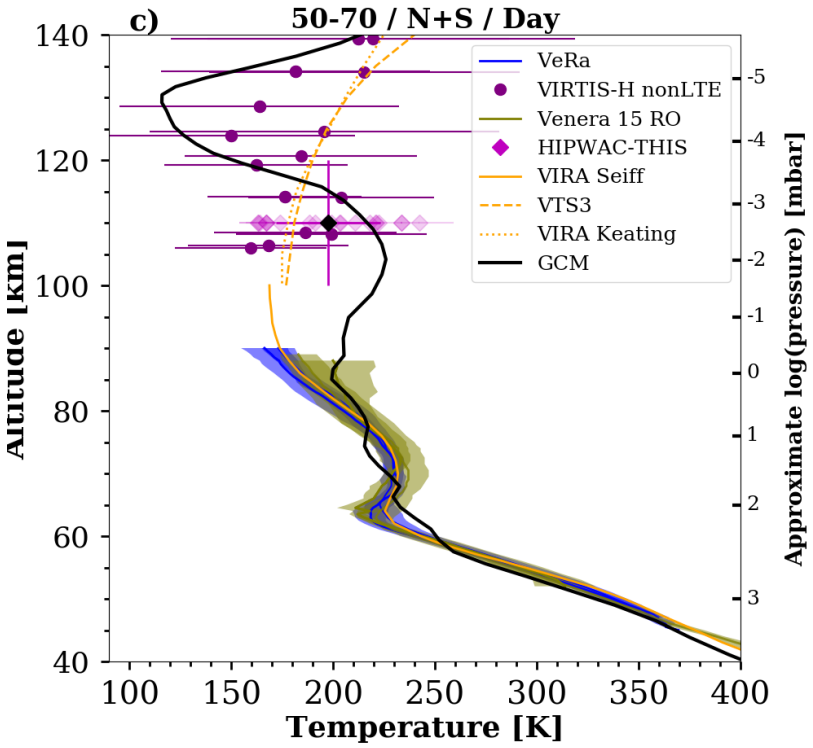
Gilli et al., 2021

Lower thermosphere
Temperatures compared to observations

Near IR CO2 Non-LTE tuning => need some additional work...

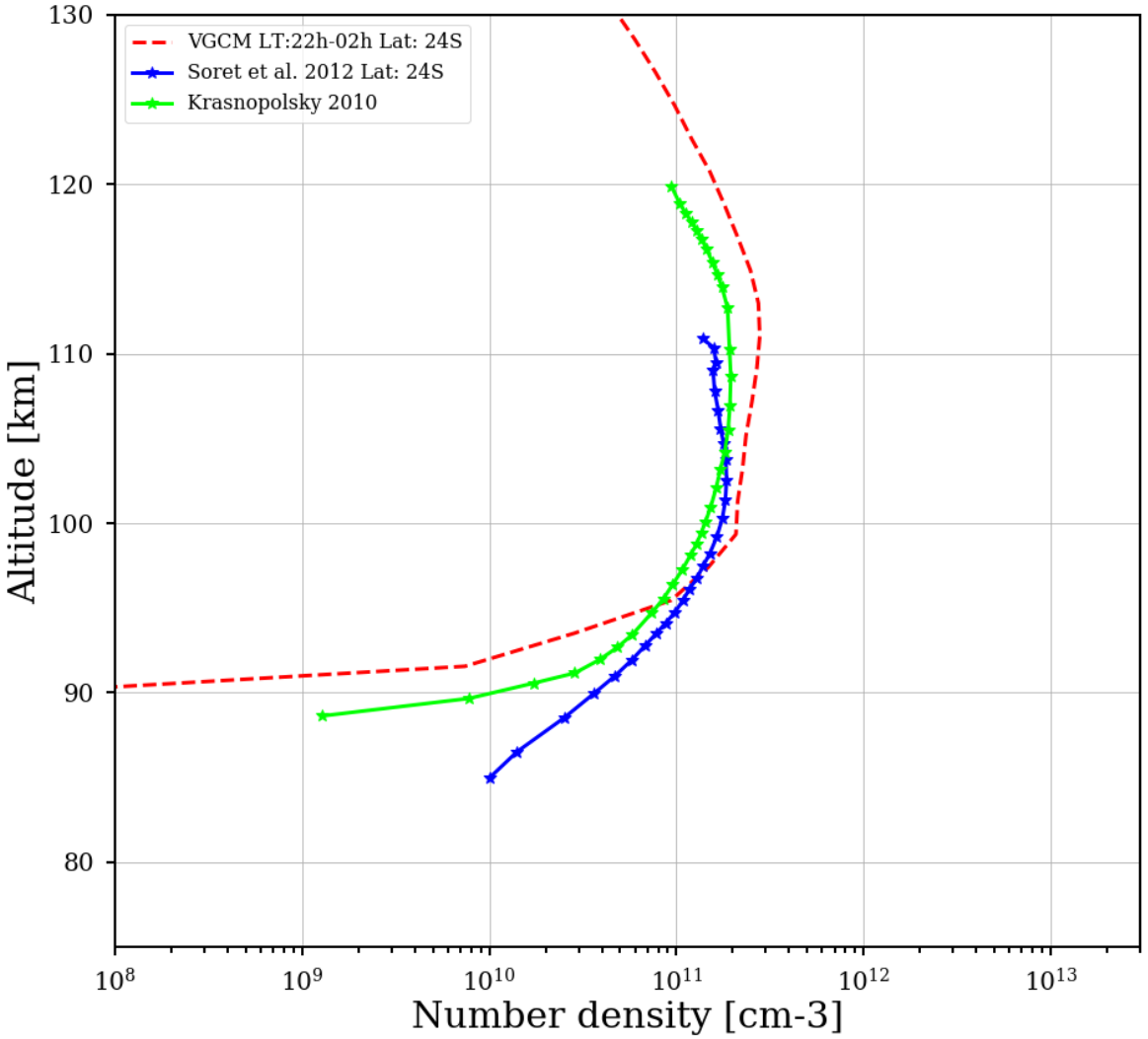
DAY





Gilli et al., 2021

Lower thermosphere
Atomic oxygen peak

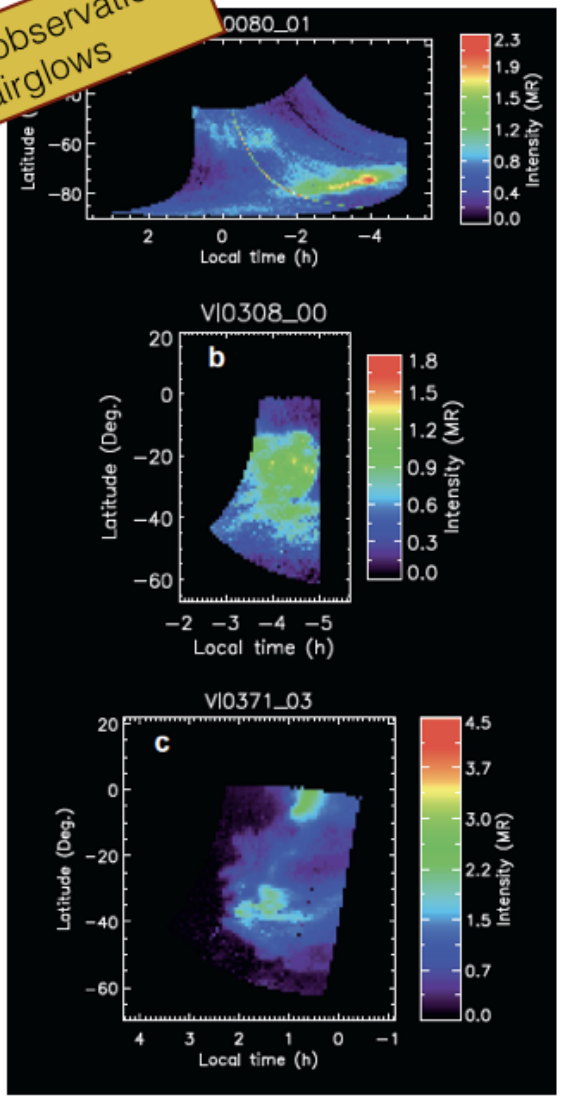


Gilli et al., 2021

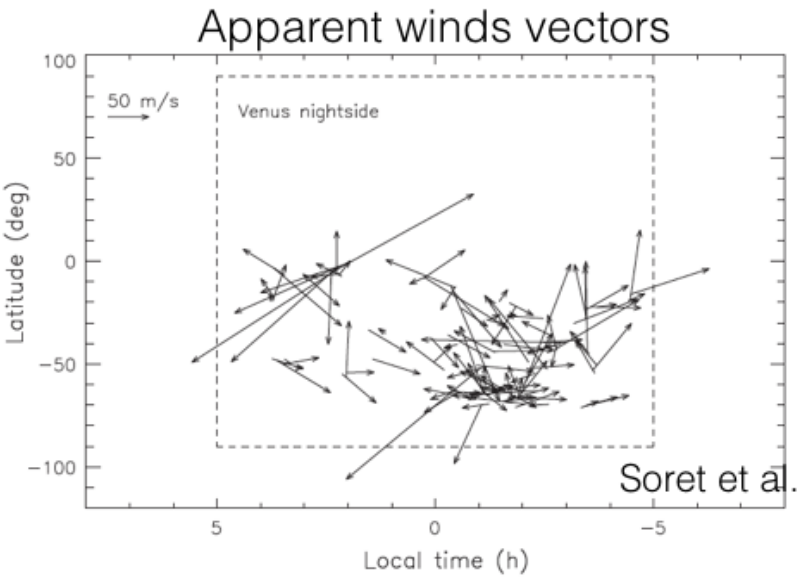
Observed variability above clouds

Distribution of O_2 nightglow brightness observed by VIRTIS/VEx

Individual observations of airglows



Soret et al. 2014



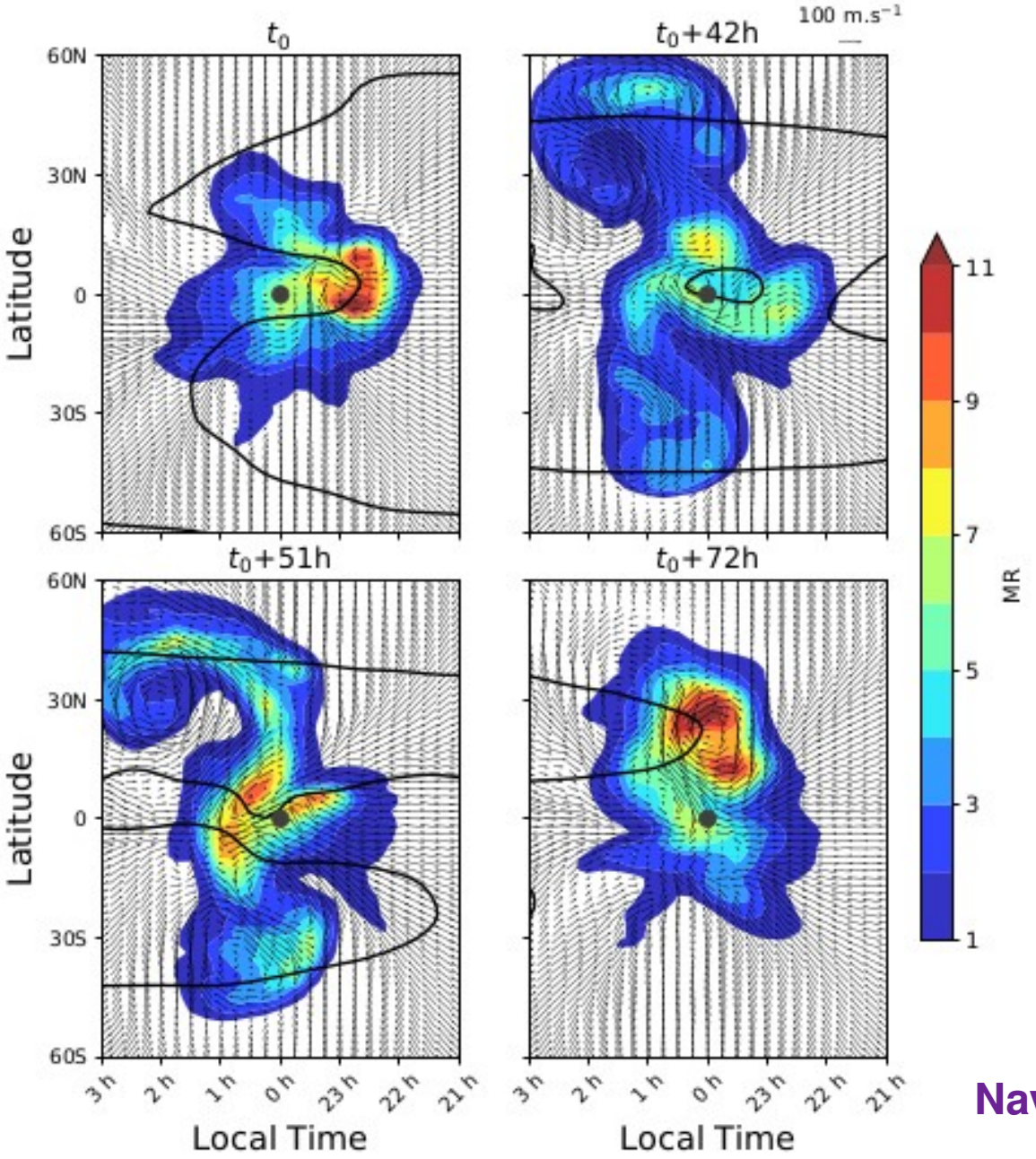
Soret et al. 2014

- Bright emission patches also located far form the AS-point
- Spatial and temporal variation of airglow structure

Current GCMs can not explain this large variation

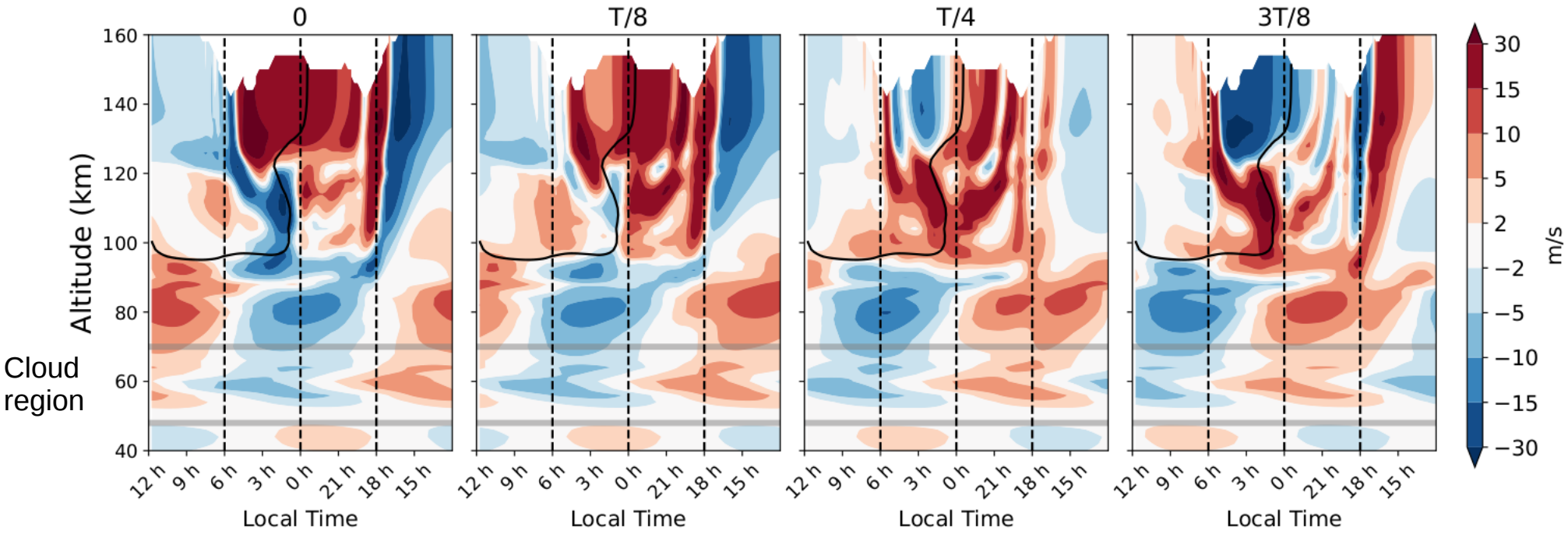
X

O_2 nightglow variability



Navarro et al., 2021

Kelvin-like wave propagation



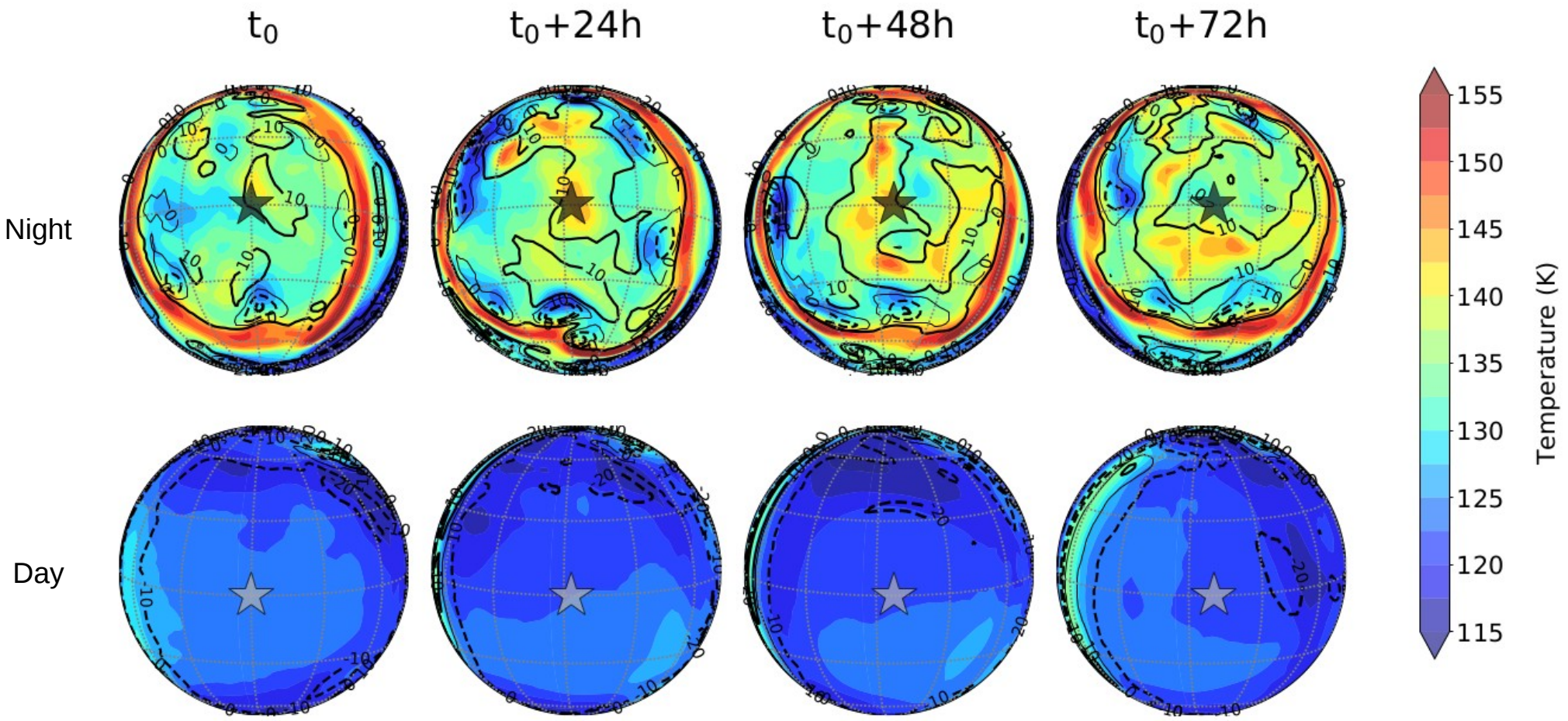
Equatorial zonal wind perturbation for T=5.7 Earth days

Kelvin-like wave, originated in the cloud region

Strongly affects the thermospheric nightside

Navarro et al., 2021

Dynamics in the night side



Temperature and vertical wind at **120 km**

Navarro et al., 2021

Upper thermosphere above 150 km

Above 150 km

Based on datasets from
- Pioneer Venus (OAD, ONMS),
- Magellan (aerobraking, POD)
- Venus-Express (VeXADE),

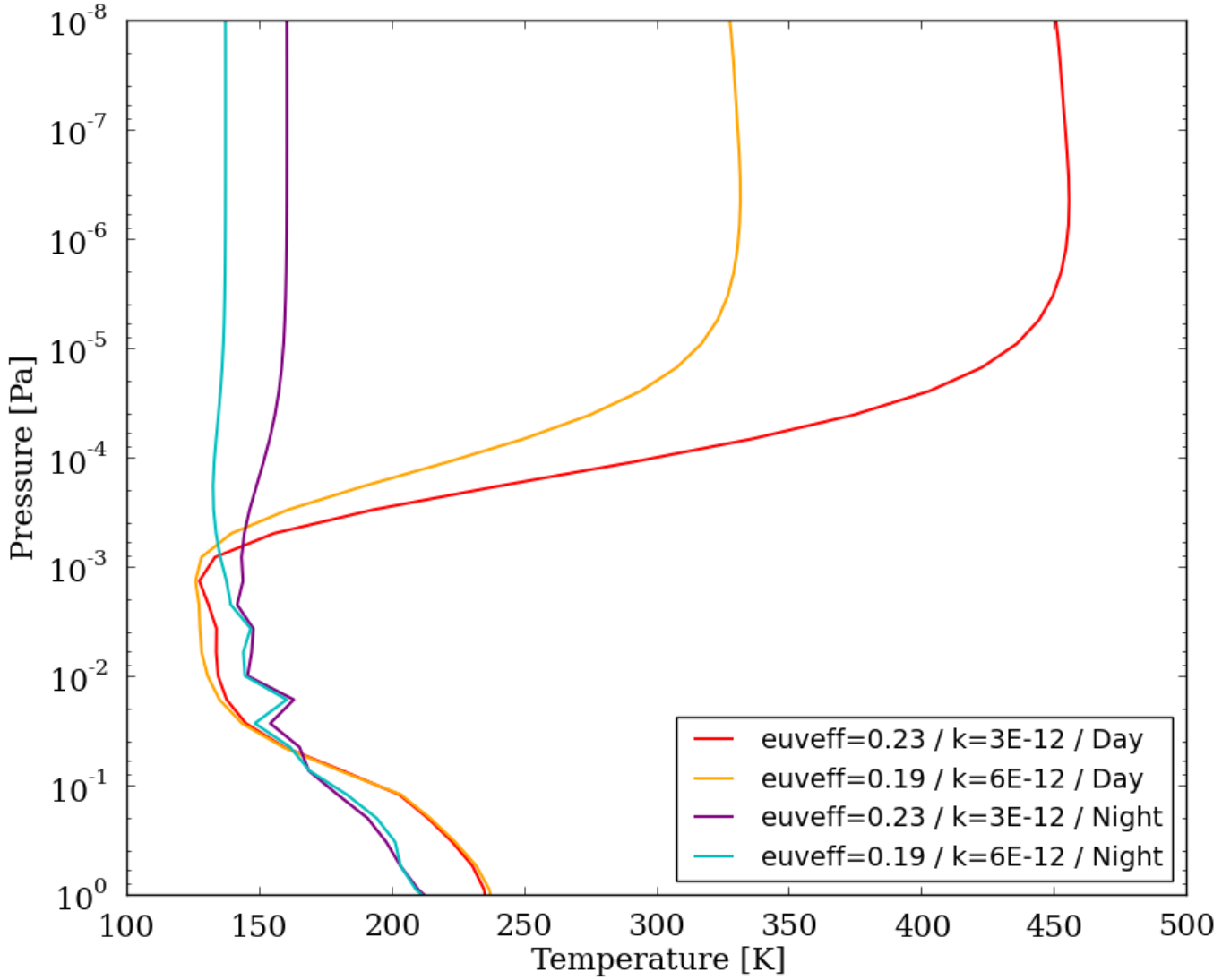
we can investigate temperature, density and composition above 150 km.

Tuning includes :
- EUV efficiency and CO_2-O quenching coefficient
- CO_2 photodissociation ?

Parameter to be taken into account : E10.7

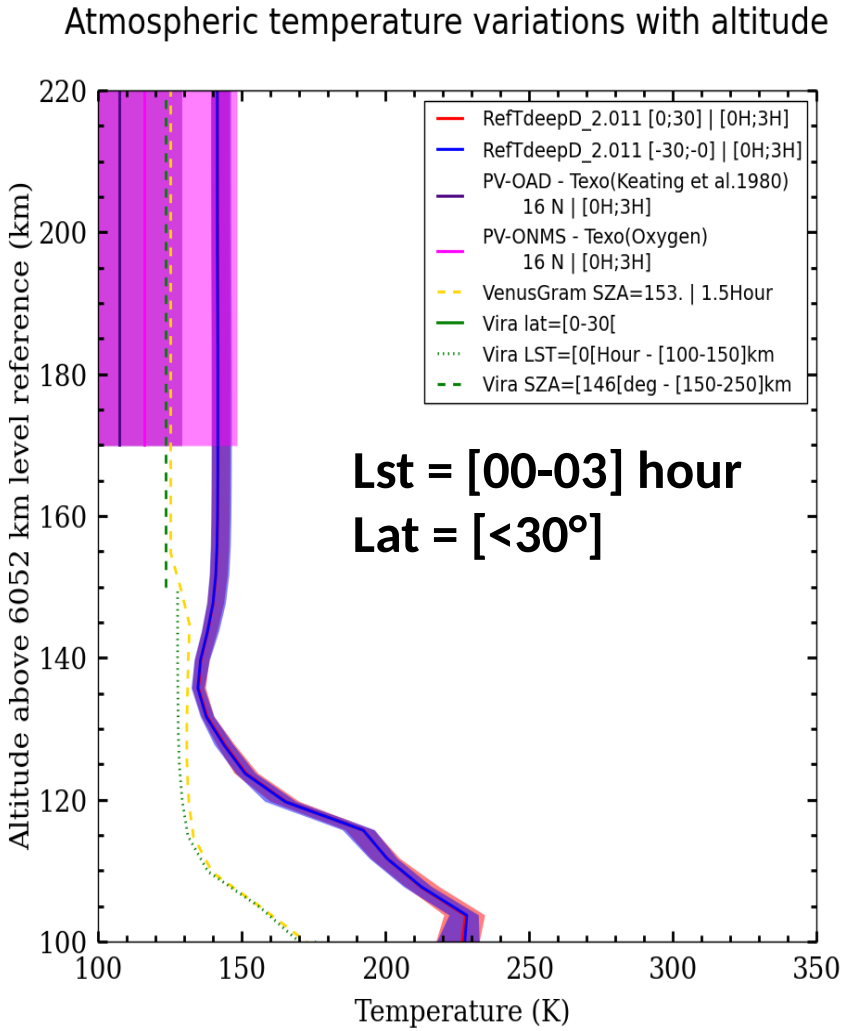
Temperature tuning above 150 km

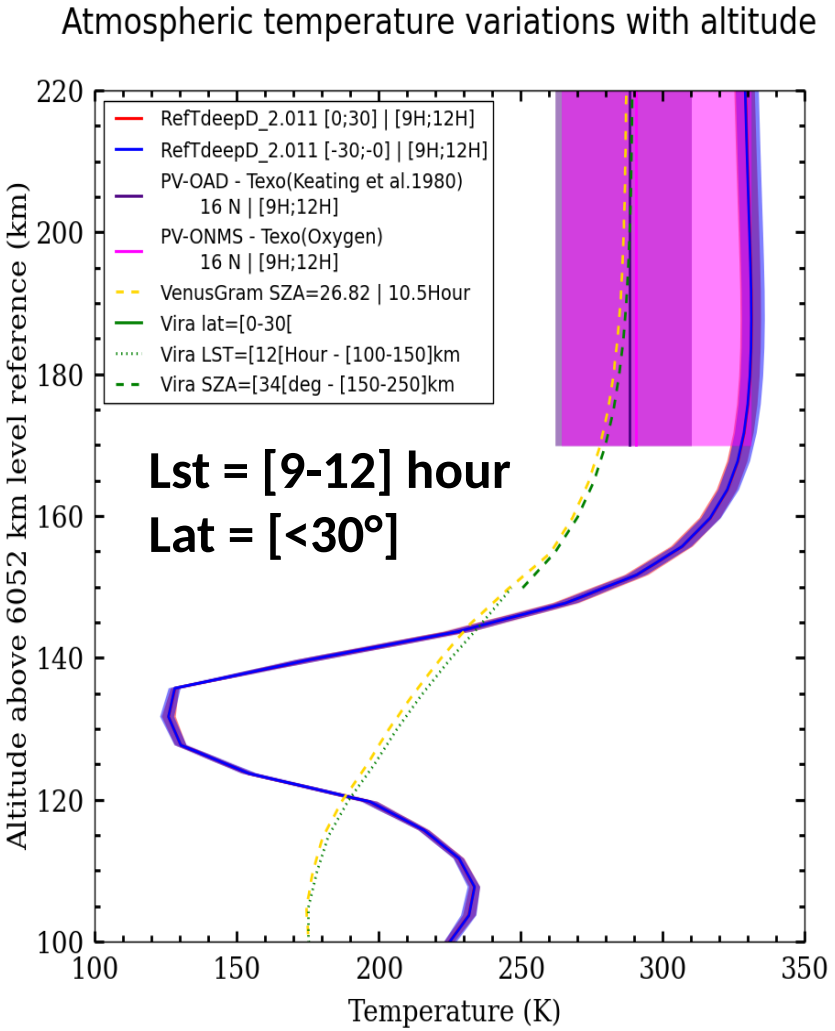
Temperature tuning through EUV efficiency and CO_2-O quenching coefficient



Temperature vs observations above 150 km

Temperature tuning through EUV efficiency and CO_2-O quenching coefficient



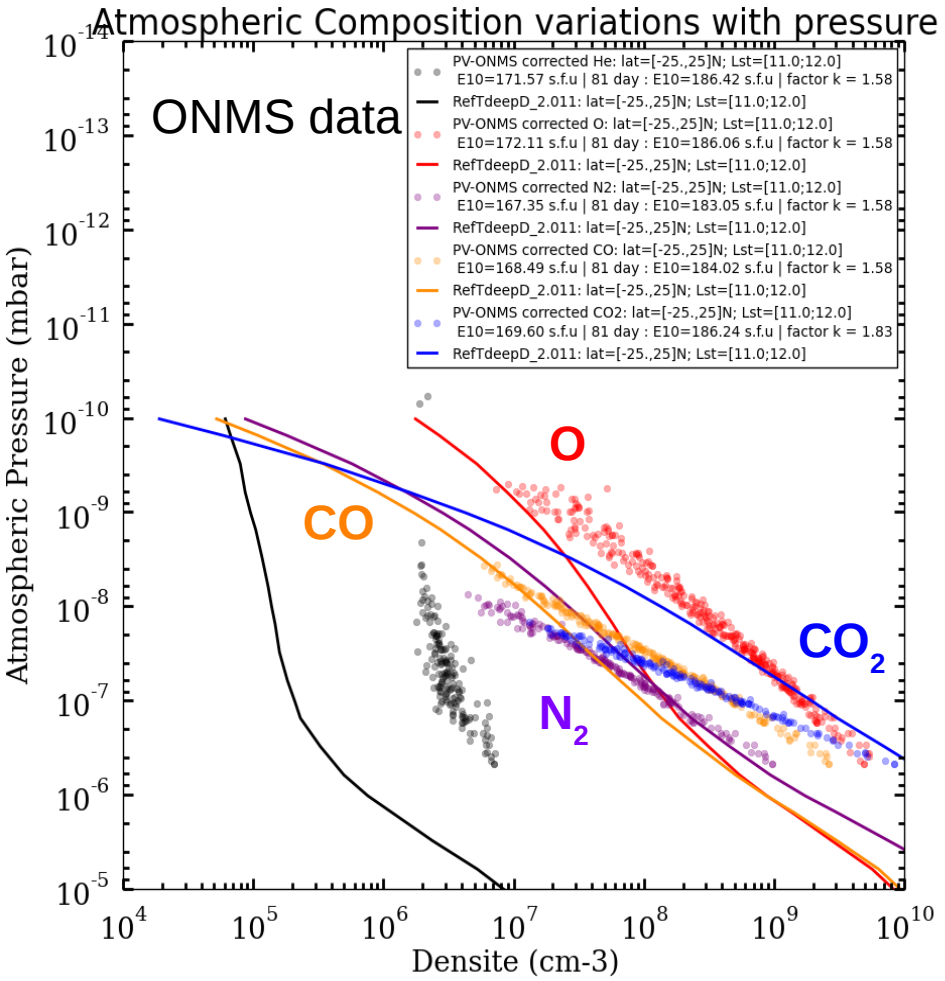


Composition : O and CO

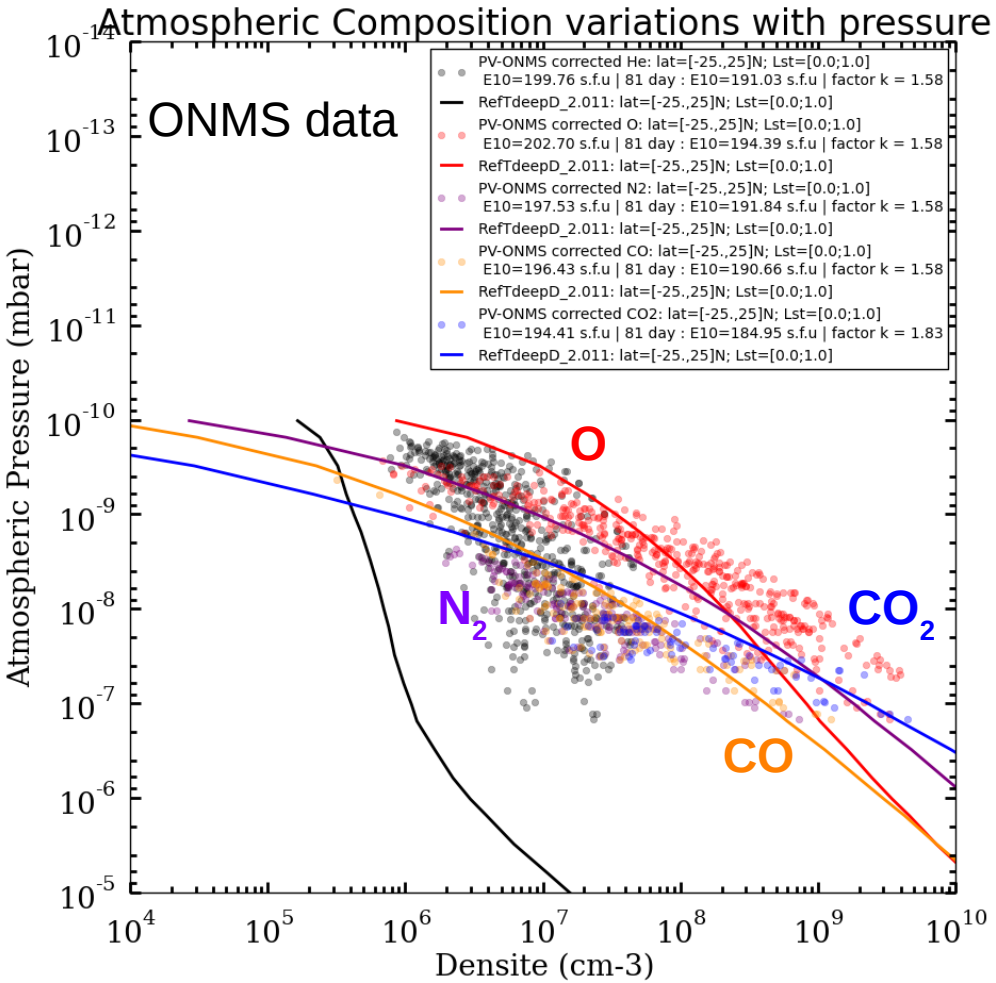
O plays a significant role on temperature !

Problem with the composition : not enough O and CO above 150 km…

Noon



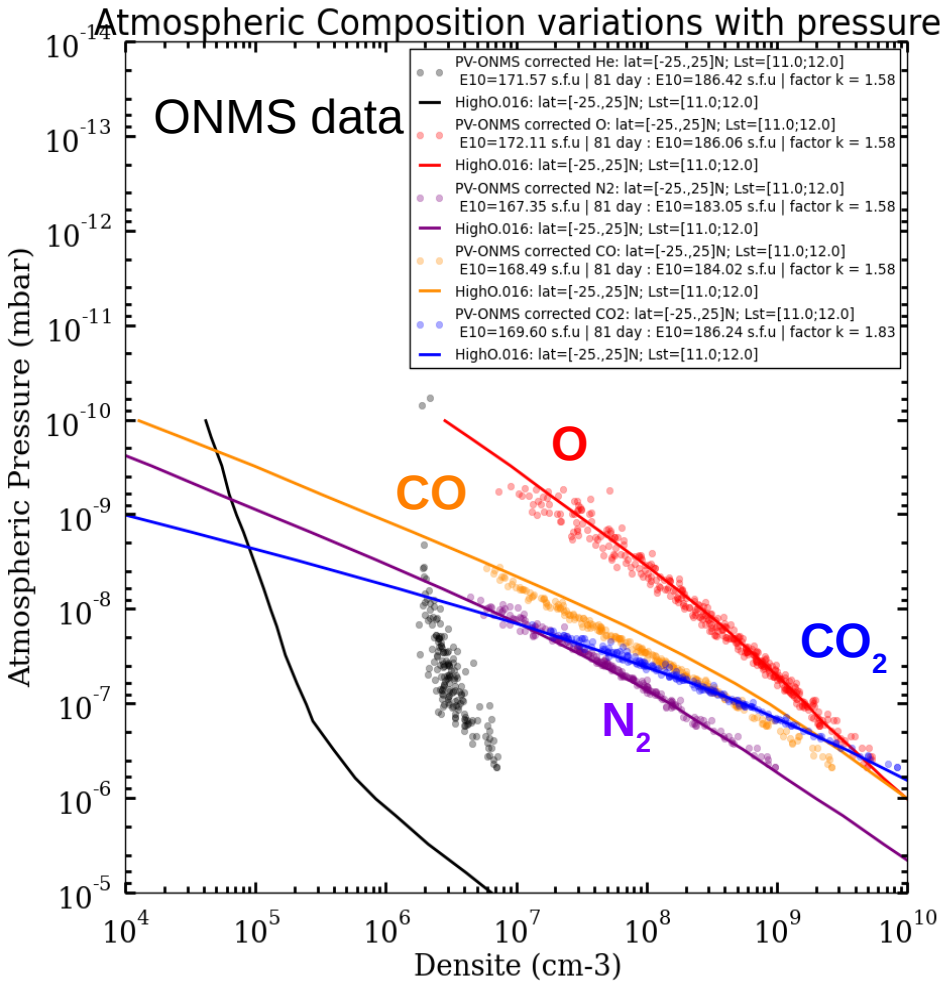
Midnight



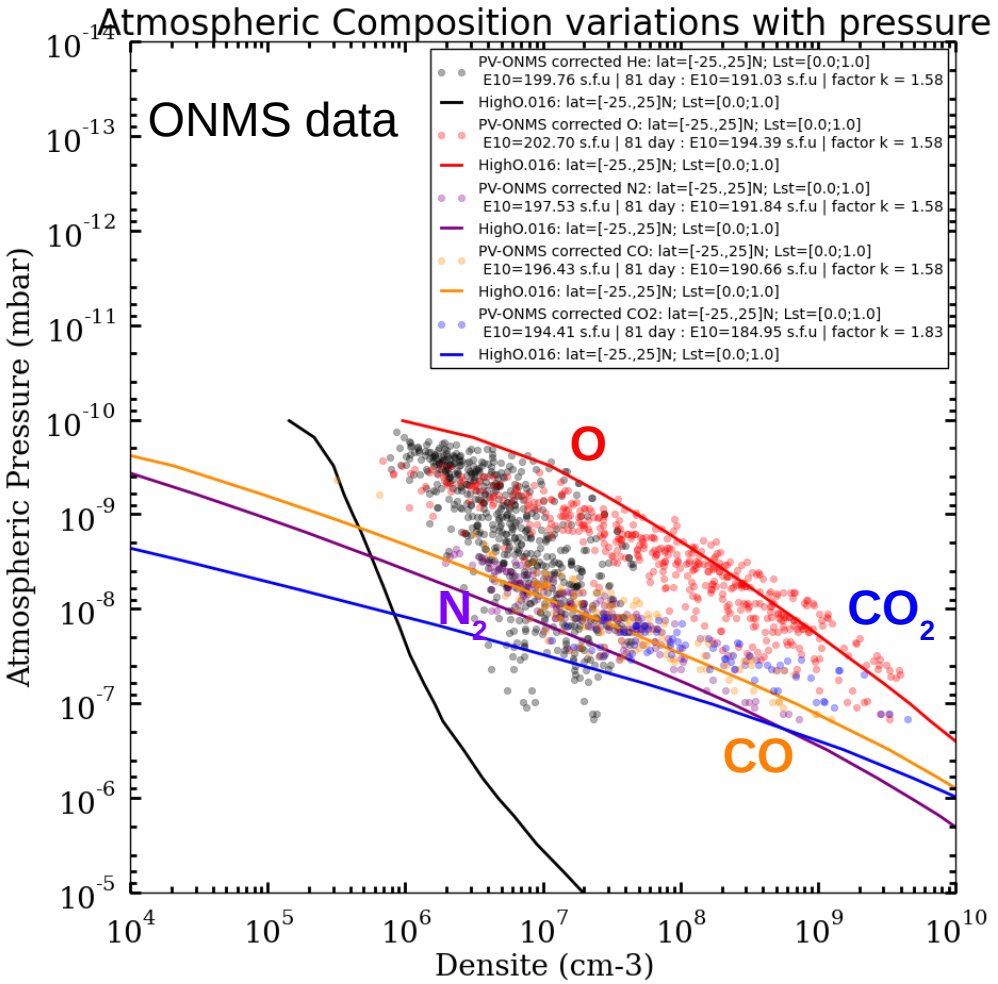
Composition : O and CO

Increasing CO_2 photodissociation improves O and CO…
Investigations ongoing

Noon



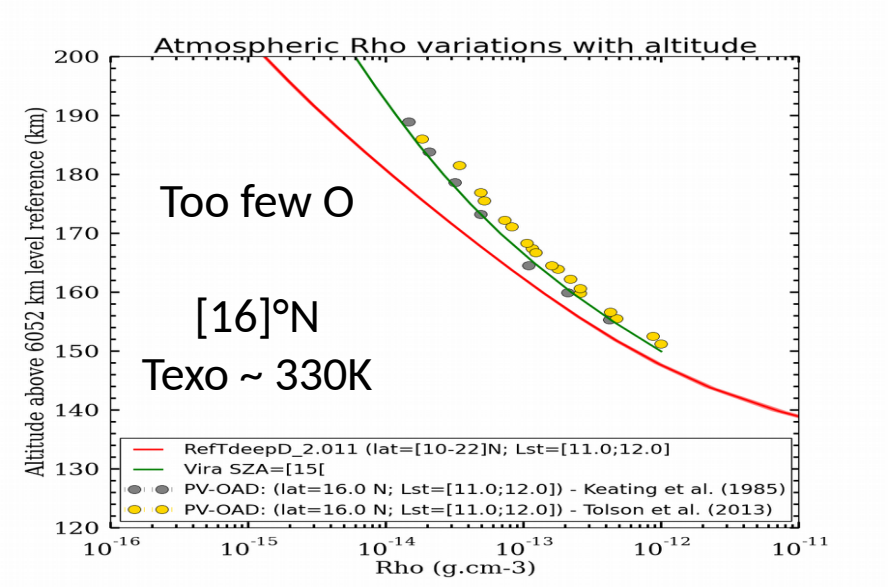
Midnight

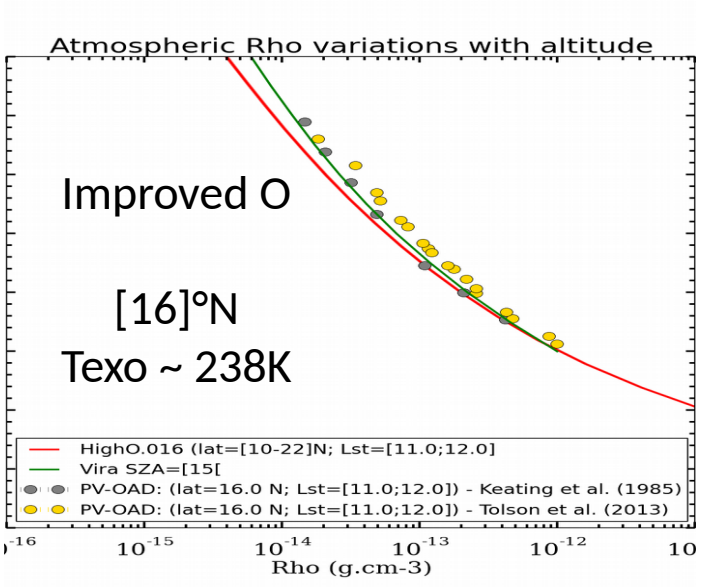


Total density

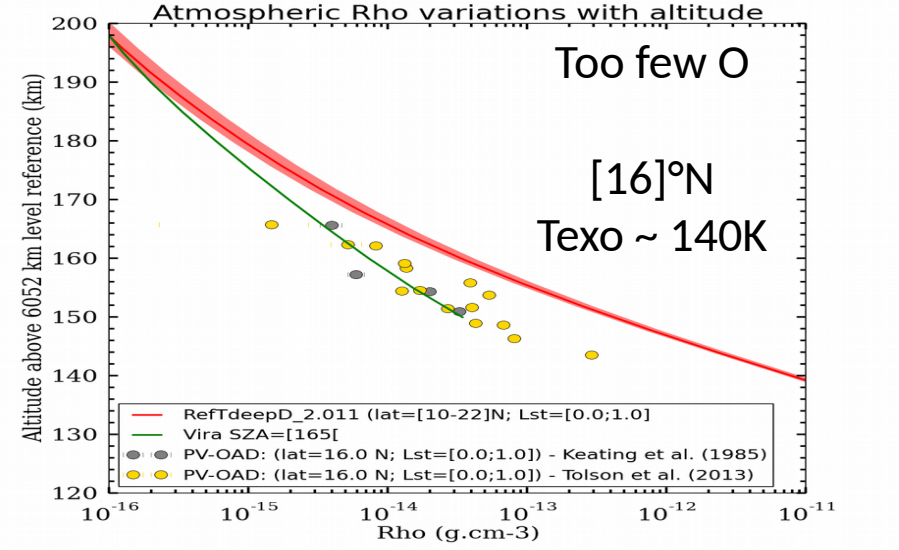
Increasing CO_2 photodissociation improves also total density, especially on dayside.
On nightside, the warm bias in the 90-120 km altitudes makes altitude wrong...

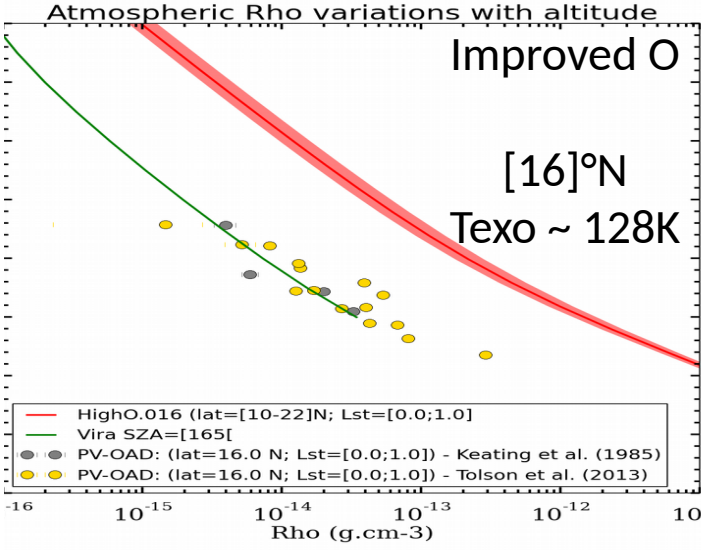
Noon





Midnight

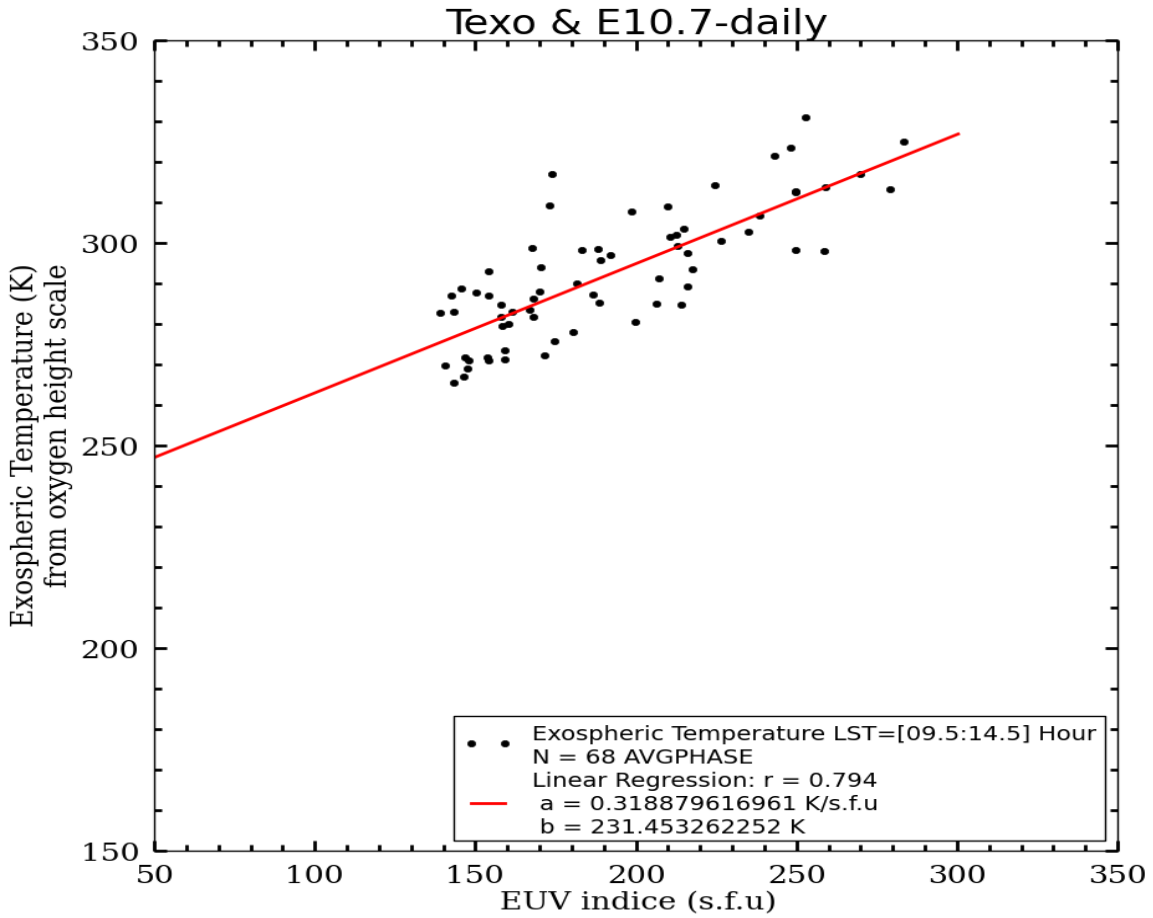




Sensitivity to E10.7

Exospheric temperature as a function of E10.7

Retrieved from O profiles in PV-ONMS datasets



We will investigate the sensitivity of our simulations to E10.7

The Venus Climate Database

VCD

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.

Public release : September 2021