The Venus Climate Database VCD version 2.3 (and 3.0)

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Workshop on Venus Atmosphere, Kobe, 25-29 March 2024
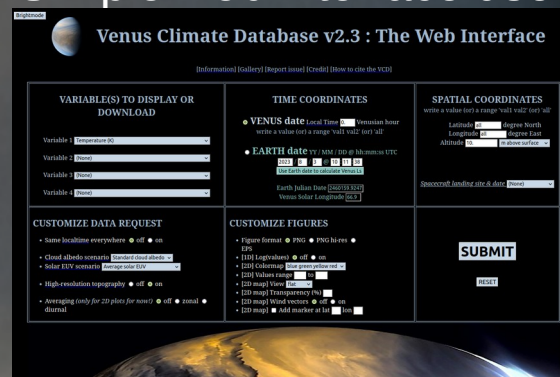
Venus PCM

From surface to 250 km

VCD
routine suite

call_vcd(*z_key,z,lon,lat,…,*
T,p,dens,zonwind,...)

Direct use in users' codes
Various langage interfaces

Simple web interface use

Venus Climate Database v2.3 : The Web Interface

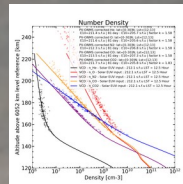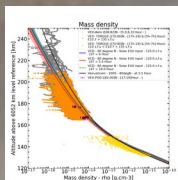[Information] [Gallery] [Report issue] [Credit] [How to cite the VCD]

VARIABLE(S) TO DISPLAY OR DOWNLOAD

TIME COORDINATES

SPATIAL COORDINATES

SUBMIT

RESET

Validation with
observational datasets
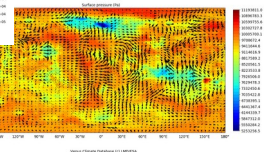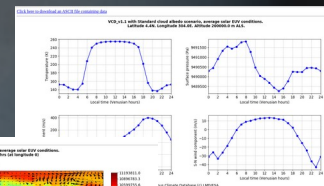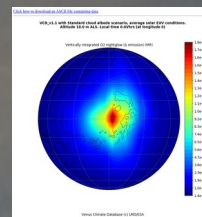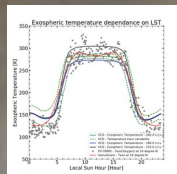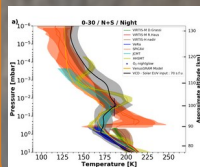
The Venus PCM

- 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
  - Parameterizations of sub-grid processes:
        boundary layer (Mellor&Yamada 1982), convection
        non-orographic gravity waves
        orographic gravity waves
  - Topography

- Includes photochemistry
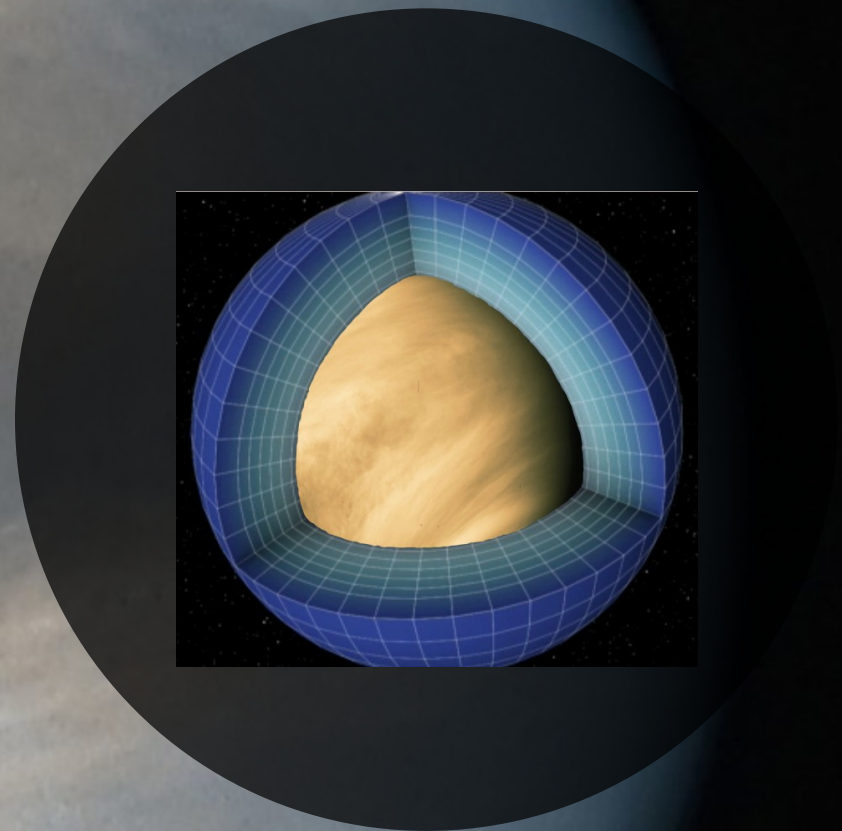
Gilli et al (2017, 2021) ; Garate & Lebonnois (2018) ;
Navarro et al (2018, 2021) ;
Martinez et al (2023, 2024) ; Stolzenbach et al (2023)

The Venus Climate Database

- ESA is funding our Venus Climate Database in the context of the EnVision mission

- The VCD is intended to be useful for engineering applications (aerobraking ; Entry, Descent & Landing) and scientific work which requires accurate knowledge of the Venusian atmosphere (e.g. analysis of observations)

- The VCD is freely available, either via light online access for moderate use (web interface) or full version including advanced post-processing software

    https://www-venus.lmd.jussieu.fr

    VCD 2.2 was released in April 2023
    VCD 2.3 was released in September 2023

Software

Scenarios

High resolution mode

Variability and perturbations

Examples of validation

Examples of applications

Various interfaces

VCD Software

The main access software (call_vcd) :

Primarily composed of a Fortran routine designed to provide access, with adequate interpolations, to fields and variables as a result of a **point-wise (in location and time) query**.

Enabling the user to query along the time dimension either by specifying an **Earth date** or a **Venus Local Time**.

The VCD dataset includes a **full climatological Venus day**, built using 10 days of GCM simulations, sampled at 1/24th of a Venusian day to accurately represent the diurnal cycle.
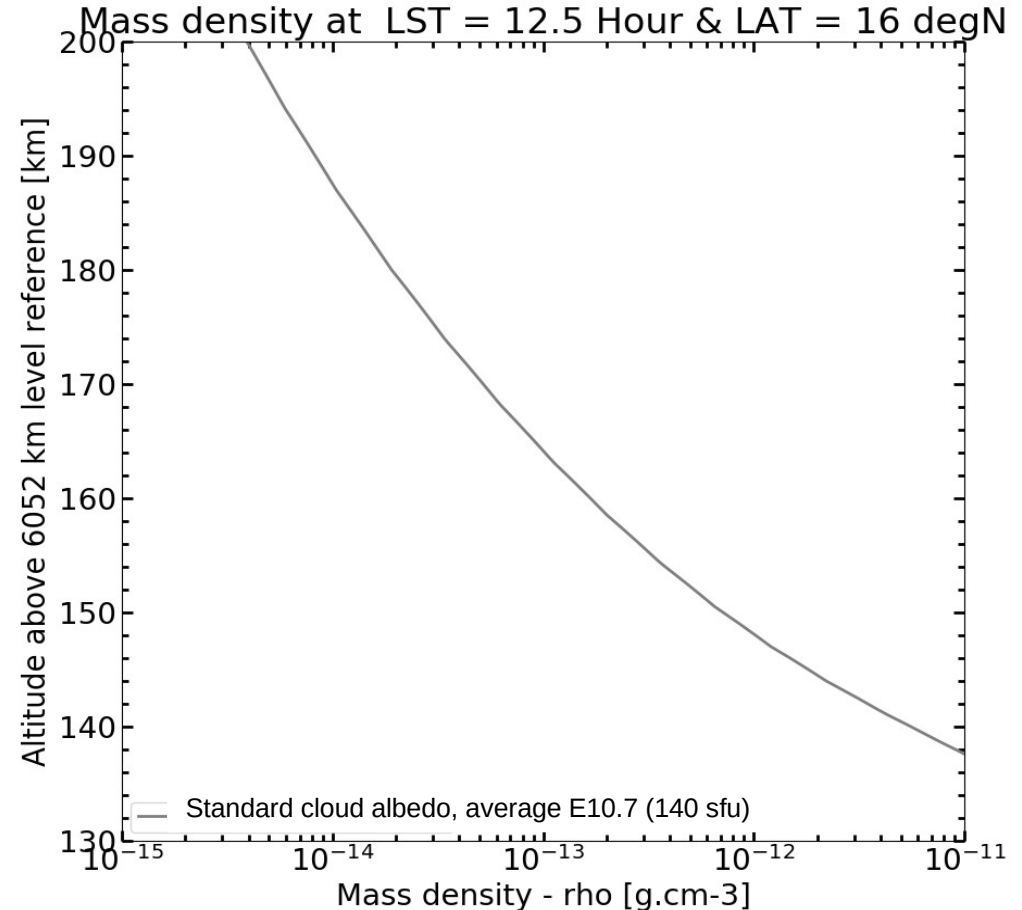
VCD Scenarios

Scenarios

- **Cloud UV albedo** (standard, min or max)
- **EUV E10.7 index** (average, min, max, Earth date or user chosen value)

Example

VCD vs density measurements

- The **EUV scenarios** of the VCD allow to bracket reality
- The comparison can be more accurate using a **specific EUV** (interpolation)

Mass density at LST = 12.5 Hour & LAT = 16 degN

Y-axis: Altitude above 6052 km level reference [km]
X-axis: Mass density - rho [g.cm-3]

Standard cloud albedo, average E10.7 (140 sfu)
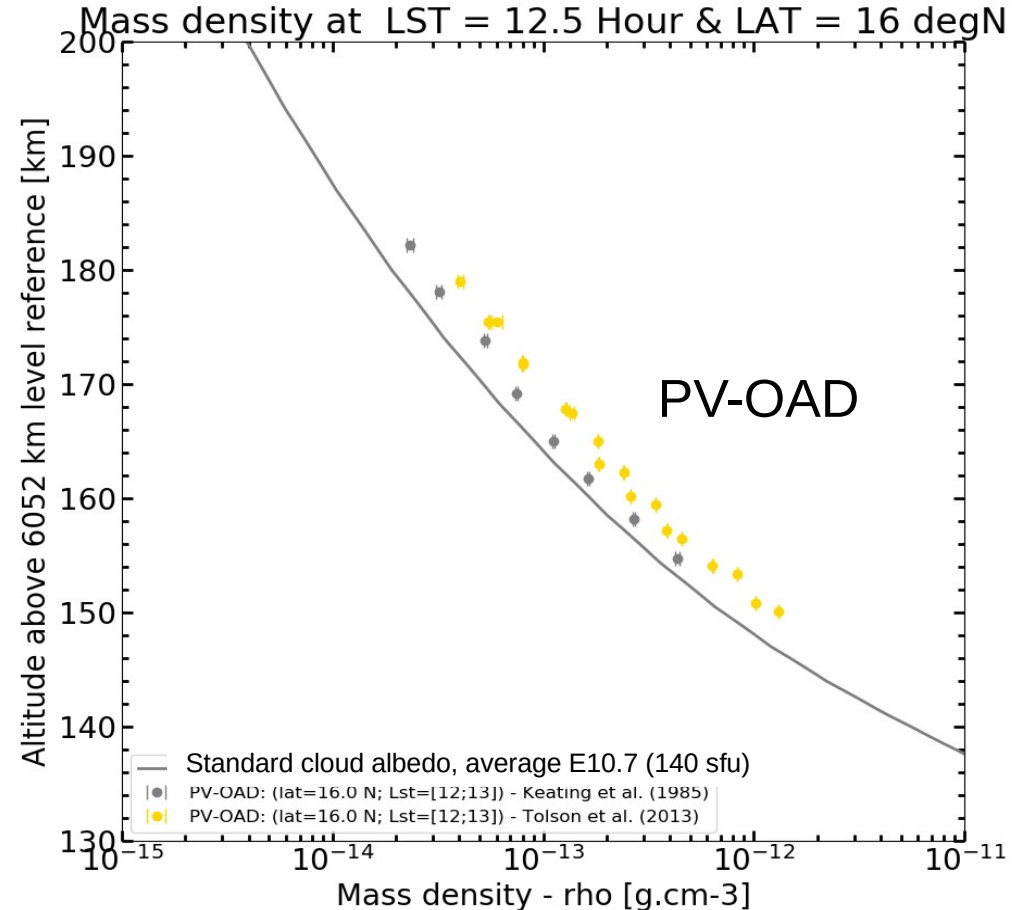
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PV-OAD

Standard cloud albedo, average E10.7 (140 sfu)
PV-OAD: (lat=16.0 N; Lst=[12;13]) - Keating et al. (1985)
PV-OAD: (lat=16.0 N; Lst=[12;13]) - Tolson et al. (2013)

Altitude above 6052 km level reference [km]

Mass density - rho [g.cm-3]
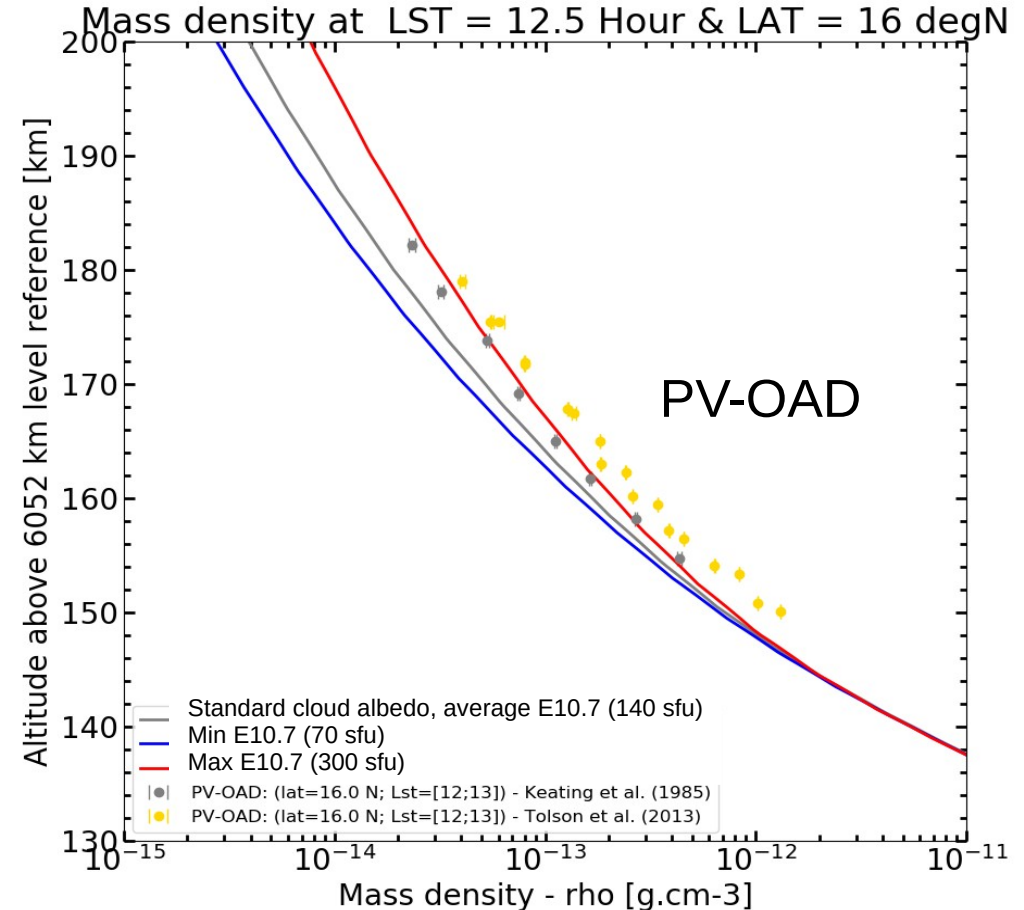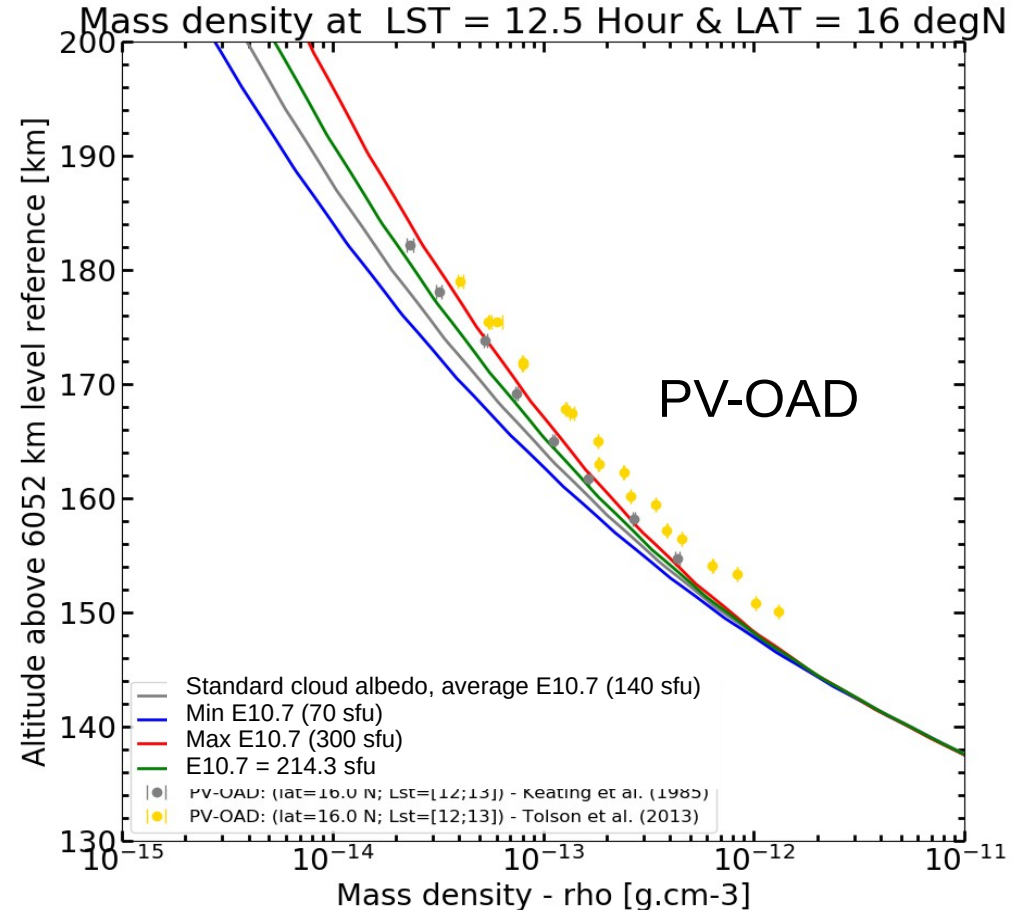
VCD Scenarios

Scenarios

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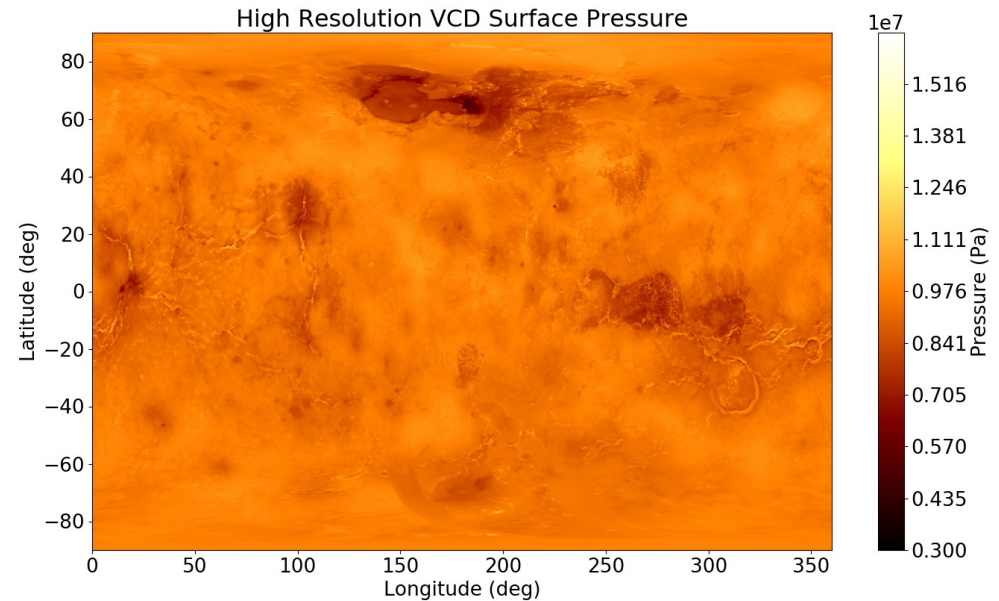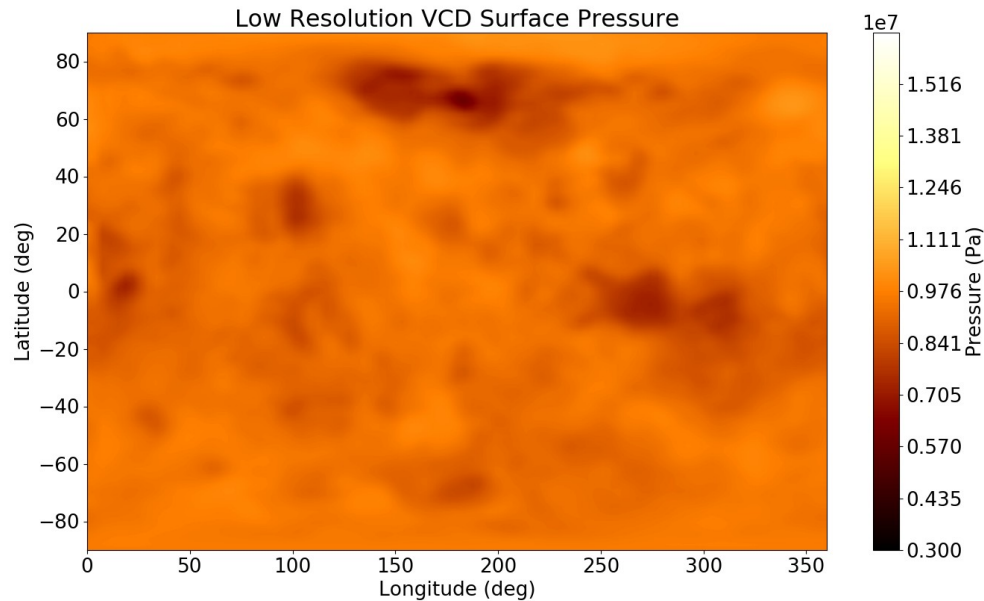- **EUV E10.7 index** (average, min, max, Earth date or user chosen value)

Example

VCD vs density measurements

- The **EUV scenarios** of the VCD allow to bracket reality

- The comparison can be more accurate using a **specific EUV** (interpolation)

Mass density at LST = 12.5 Hour & LAT = 16 degN

PV-OAD

Legend:
- Standard cloud albedo, average E10.7 (140 sfu)
- Min E10.7 (70 sfu)
- Max E10.7 (300 sfu)
- PV-OAD: (lat=16.0 N; Lst=[12;13]) - Keating et al. (1985)
- PV-OAD: (lat=16.0 N; Lst=[12;13]) - Tolson et al. (2013)

Altitude above 6052 km level reference [km] vs Mass density - rho [g.cm-3]

VCD Scenarios

Scenarios

- **Cloud UV albedo** (standard, min or max)
- **EUV E10.7 index** (average, min, max, Earth date or user chosen value)

Example

VCD vs density measurements

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PV-OAD

Legend:
- Standard cloud albedo, average E10.7 (140 sfu)
- Min E10.7 (70 sfu)
- Max E10.7 (300 sfu)
- E10.7 = 214.3 sfu
- PV-OAD: (lat=16.0 N; Lst=[12;13]) - Keating et al. (1985)
- PV-OAD: (lat=16.0 N; Lst=[12;13]) - Tolson et al. (2013)

Altitude above 6052 km level reference [km]

Mass density - rho [g.cm-3]

VCD High resolution mode

The VCD software include a "high resolution" mode using Magellan (23 pixels/degree map) topography combined to re-derived surface pressure and near-surface temperatures (scheme based on hydrostatic equilibrium and known lapse rate)
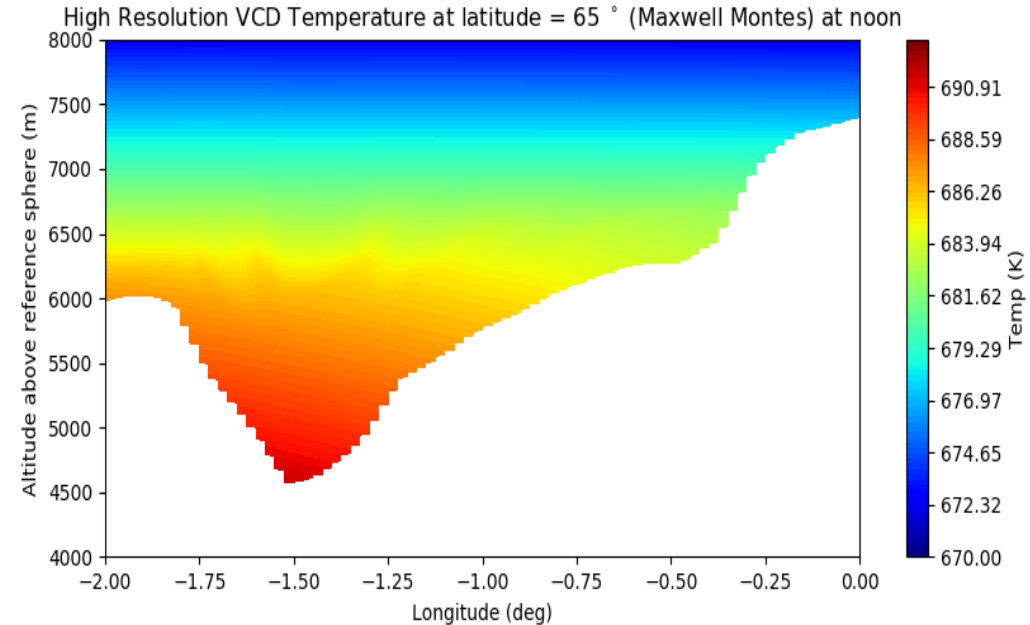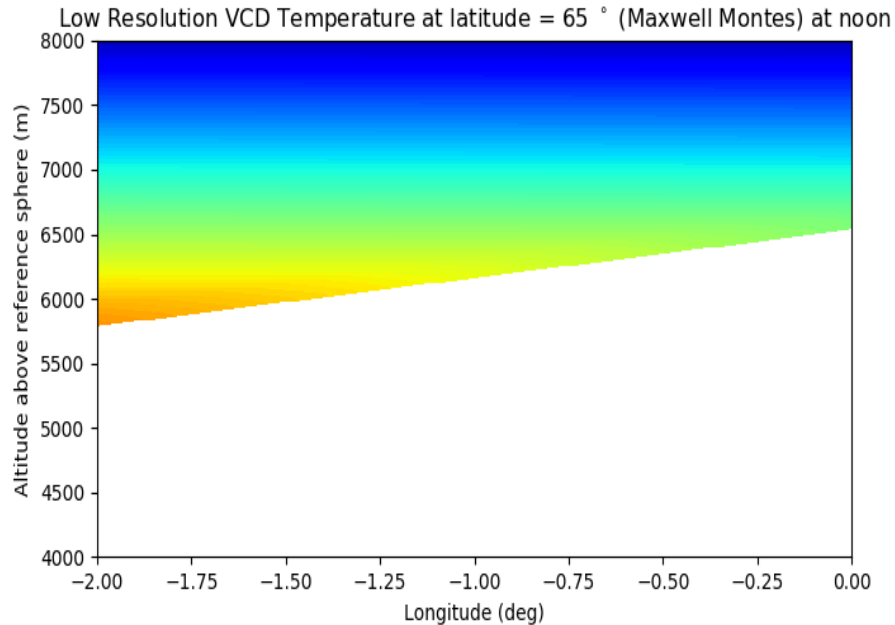

GCM resolution (PCM 96x96 grid) : Longitude x latitude : 3.75° x 1.875°
High resolution (Magellan map & PV measurements to fill gaps) : Longitude x latitude : 0.04° x 0.04°

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VCD Variability and perturbations schemes

Day-to-day and V-hourly RMS

Gravity waves

Reconstruction of the meteorology using EOFs

The VCD provides three types of variability

- **RMS variability from GCM simulations** for mean atmospheric fields (V-hourly and day-to-day)

- Possibility to add random **small-scale perturbations** as gravity waves (of user-specified wavelength)

- Possibility to add random **large-scale perturbations** (extracted from EOFs of individual GCM runs)

Variability:
V-hourly and day-to-day RMS

Example

VCD vs density measurements

V-hourly RMS is shown as green area around the (E10.7=214.3 sfu) climatological mean density

Mass density at LST = 12.5 Hour & LAT = 16 degN

PV-OAD

Legend:
- Standard cloud albedo, average E10.7 (140 sfu)
- Min E10.7 (70 sfu)
- Max E10.7 (300 sfu)
- E10.7 = 214.3 sfu
- PV-OAD: (lat=16.0 N; Lst=[12;13]) - Keating et al. (1985)
- PV-OAD: (lat=16.0 N; Lst=[12;13]) - Tolson et al. (2013)

Altitude above 6052 km level reference [km]

Mass density - rho [g.cm-3]
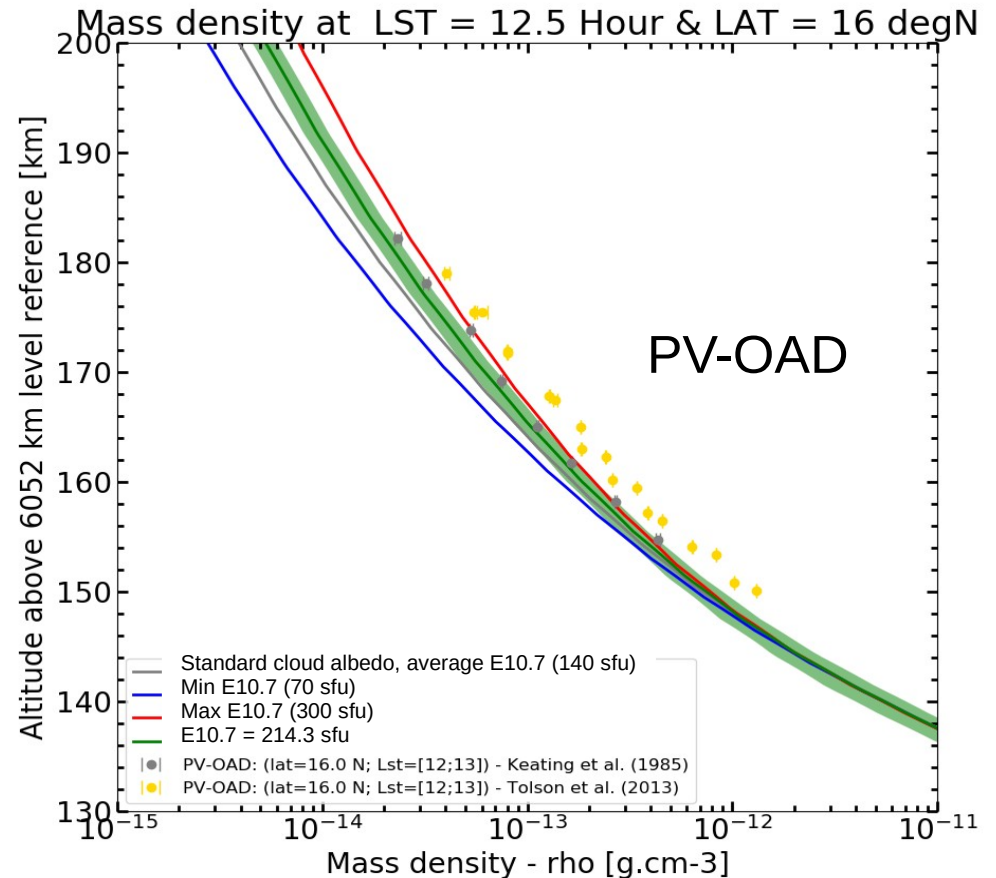
Perturbations:
Small-scale gravity waves

Example

In addition to the climatology, the VCD allow to add **small-scale perturbations** (gravity waves generated at the top of the cloud convective layer).

The vertical wavelength is specified by the user. The horizontal wavelength is set to be $\lambda_h = 100\ \lambda_z$

VCD Density profile with VEX-Torque trajectory

Altitude above 6052 km level reference (km)

Venus-Express Torque experiment

- VEX- TORQUE - Observation: 6
  Phase : INBOUND Date: 2010 OCT 15 06:57:59.340
- E10.7 = 102 sfu / gravity wave lz = 3 km
- E10.7 = 102 sfu / unperturbed
- E10.7 = 102 sfu / gravity wave lz = 5 km

Rho (g.cm-3)
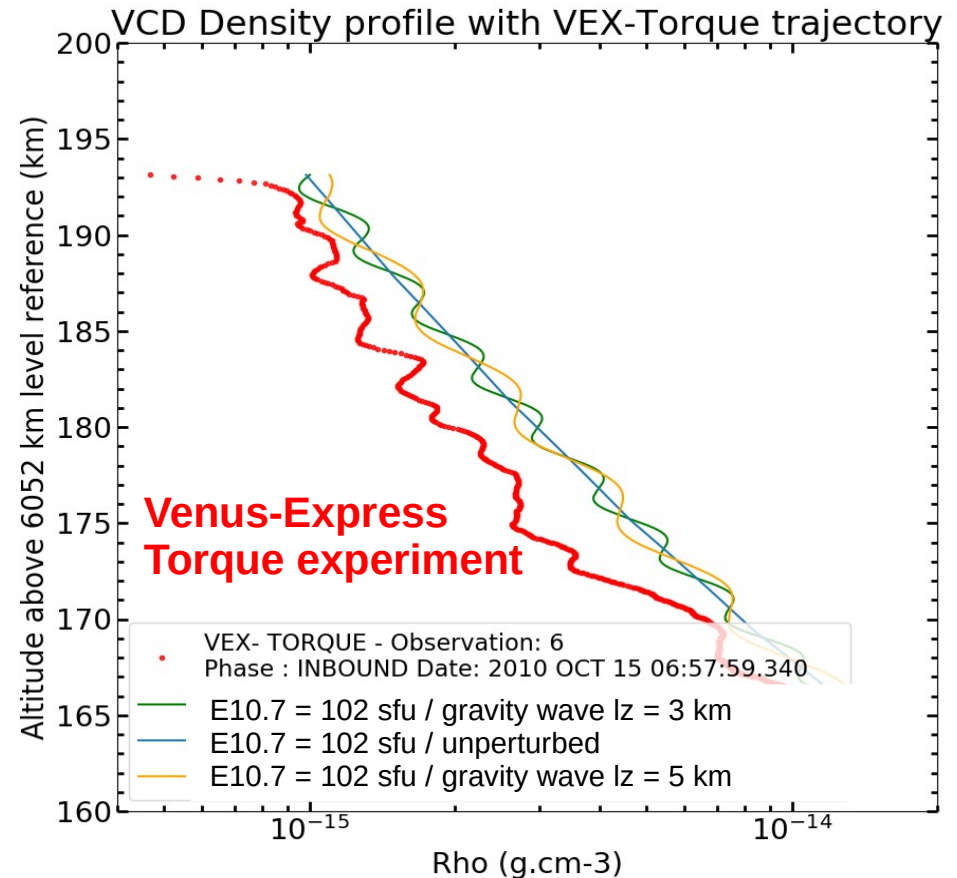
Perturbations:
Large-scale, using EOF reconstruction

Example

In addition to the climatology (red dots), the VCD allow to add **large-scale perturbations** to reconstruct meteorology, using **EOFs of high-temporal resolution GCM simulations** (purple dots).

(orange area is previously mentioned RMS)
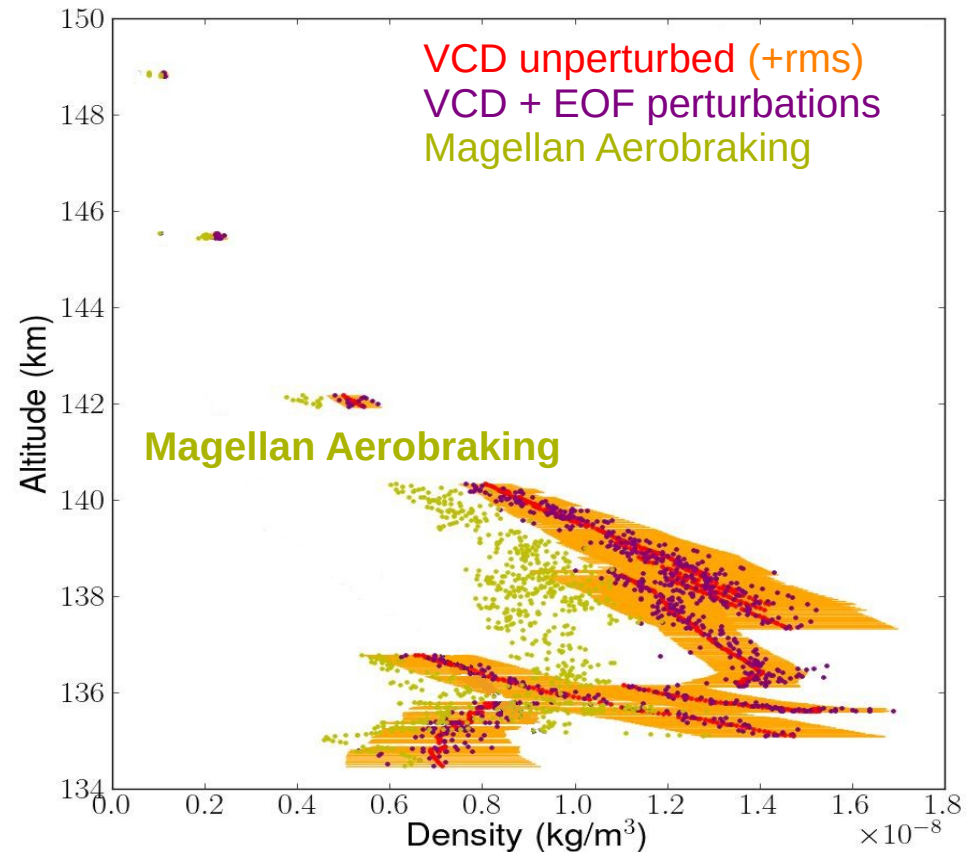
Examples of VCD validation

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

we can investigate temperature, density and composition above 150 km.
=> check the VCD Validation Document

Note that the PCM tuning includes :
    - EUV efficiency and CO_2-O quenching coefficient
    - non-orographic gravity waves
    - O number density => major scientific question

Parameter to be taken into account for thermospheric cases : E10.7

Temperature in the deep atmosphere

Potential Temperature at (-31.2 degN ; 6:46 Hour)

Potential Temperature at (-28.7 degN ; 0:07 Hour)

Potential Temperature at (59.3 degN ; 3:35 Hour)
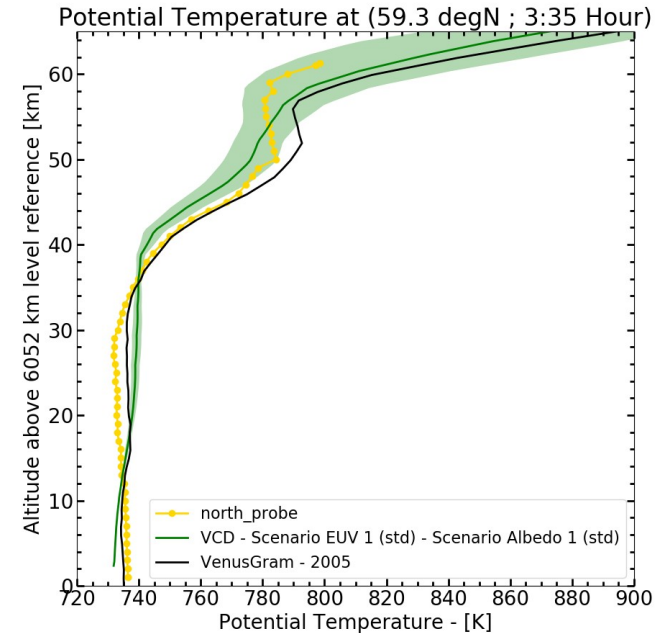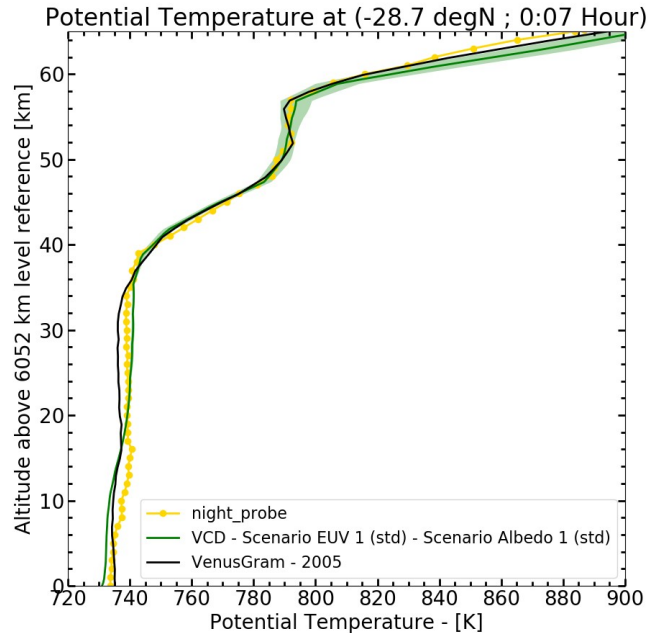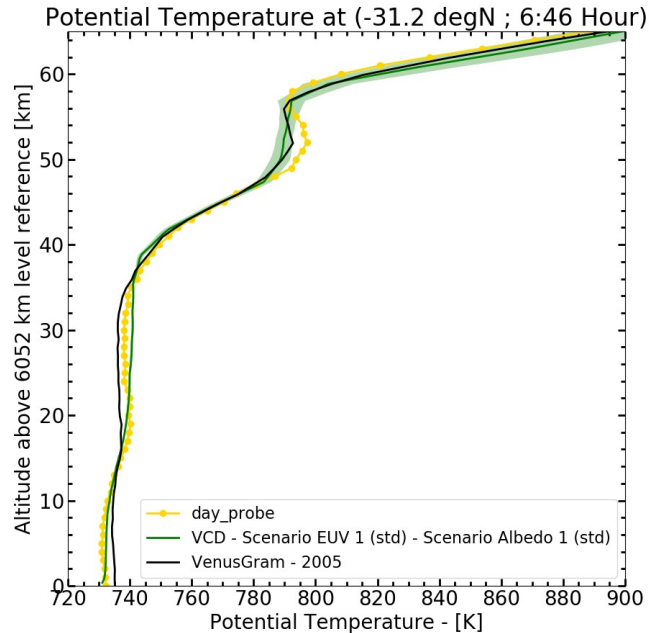
Comparison of potential temperature profiles between some Pioneer-Venus probes (day/night/North), the VCD (standard albedo scenario +RMS) and VenusGram2005

Exospheric temperature retrieved from O profiles in PV-ONMS datasets

Exospheric temperature dependance on LST

Legend:
- VCD - Exospheric Temperature - 200.0 s.f.u
- VCD - Temperature Hour variability
- VCD - Exospheric Temperature - 180.0 s.f.u
- VCD - Exospheric Temperature - 250.0 s.f.u
- PV-ONMS - Texo(Oxygen) at 16 degree N
- VenusGram - Texo at 16 degree N
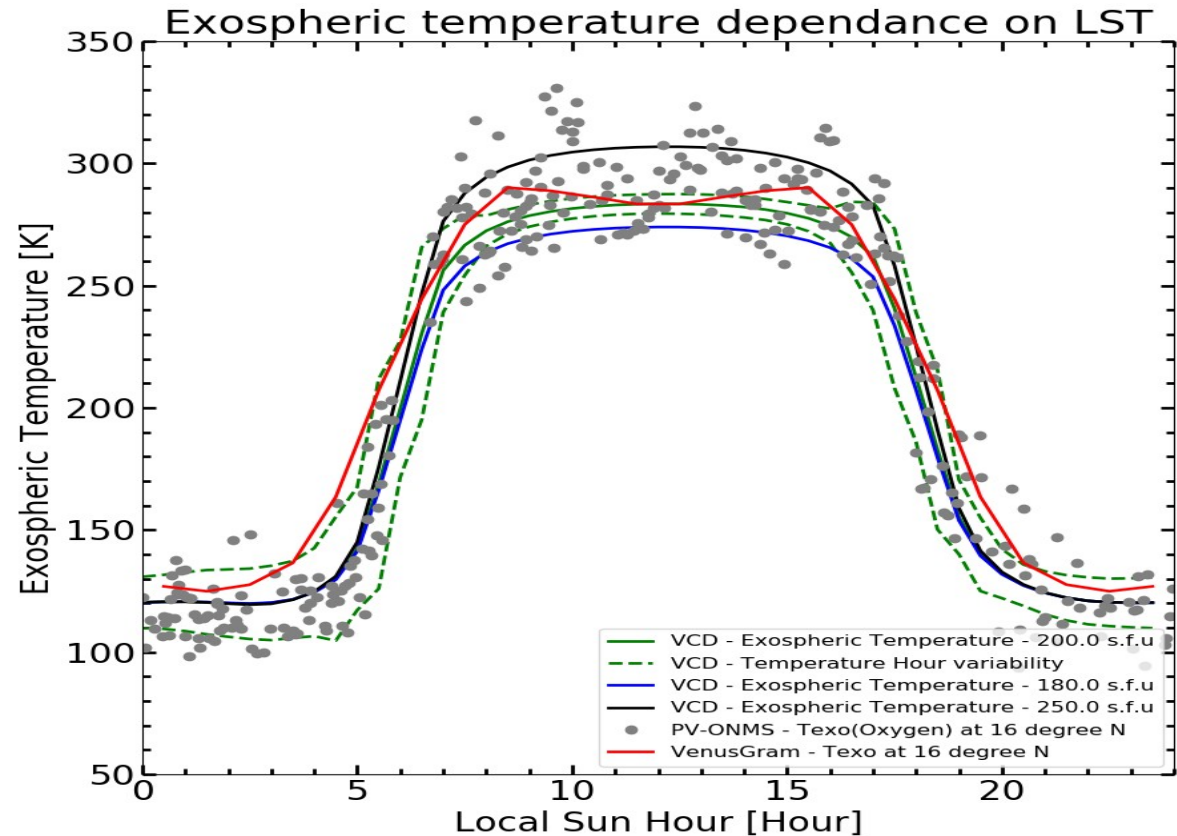
Composition: O and CO

O plays a significant role on temperature !

Increasing CO_2 photodissociation improves O and CO...

Investigations ongoing

Noon
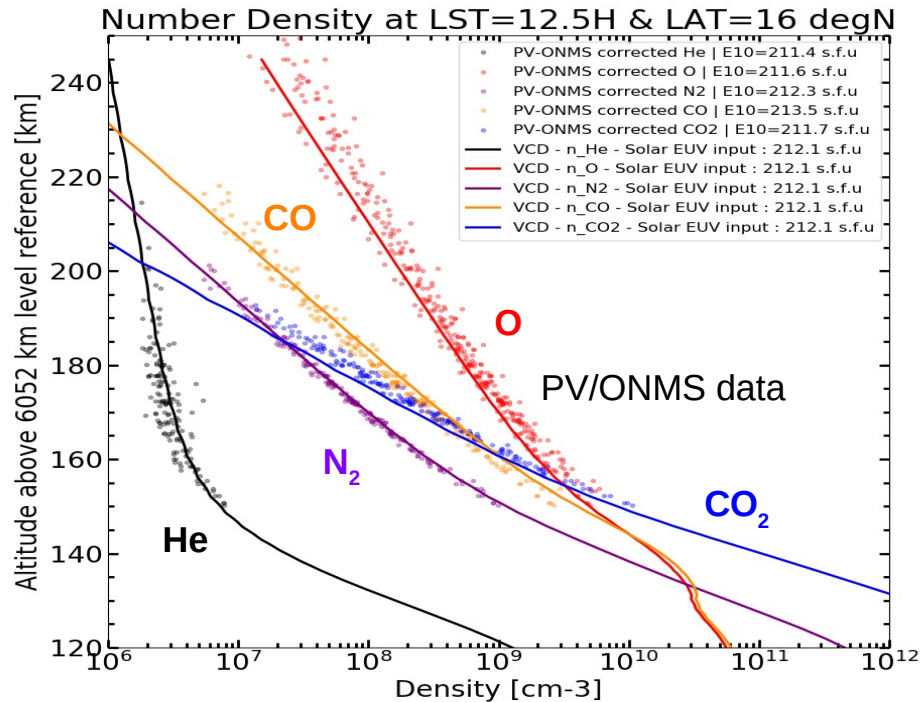
Midnight
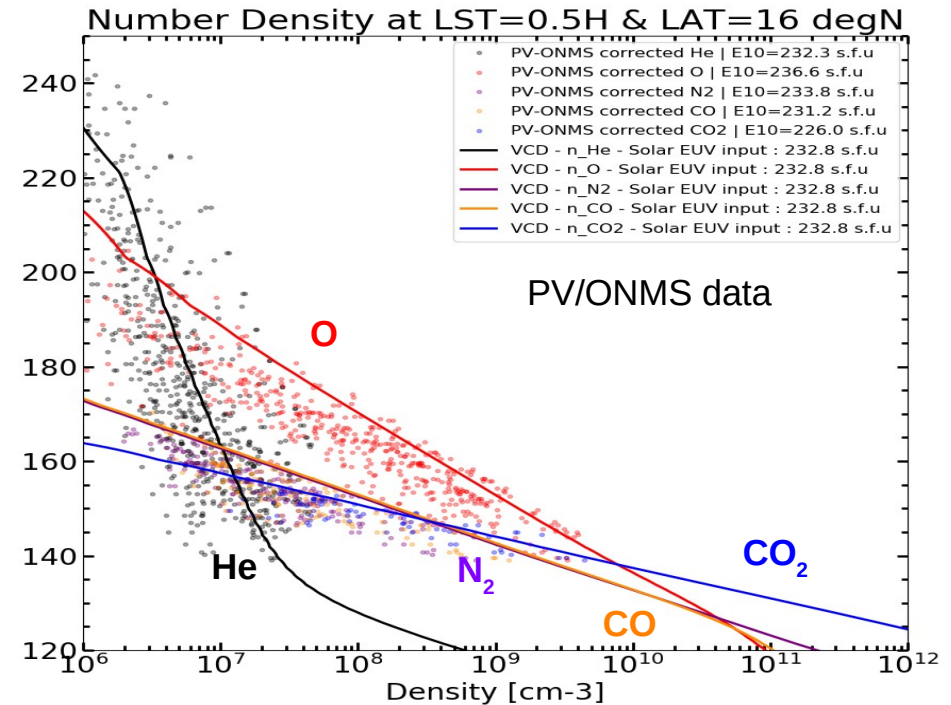
Examples of applications

Illustrative aerobraking example

VCD mass density, mean cloud albedo, VEX-Torque measurement trajectory 50, 2011 MAY 26
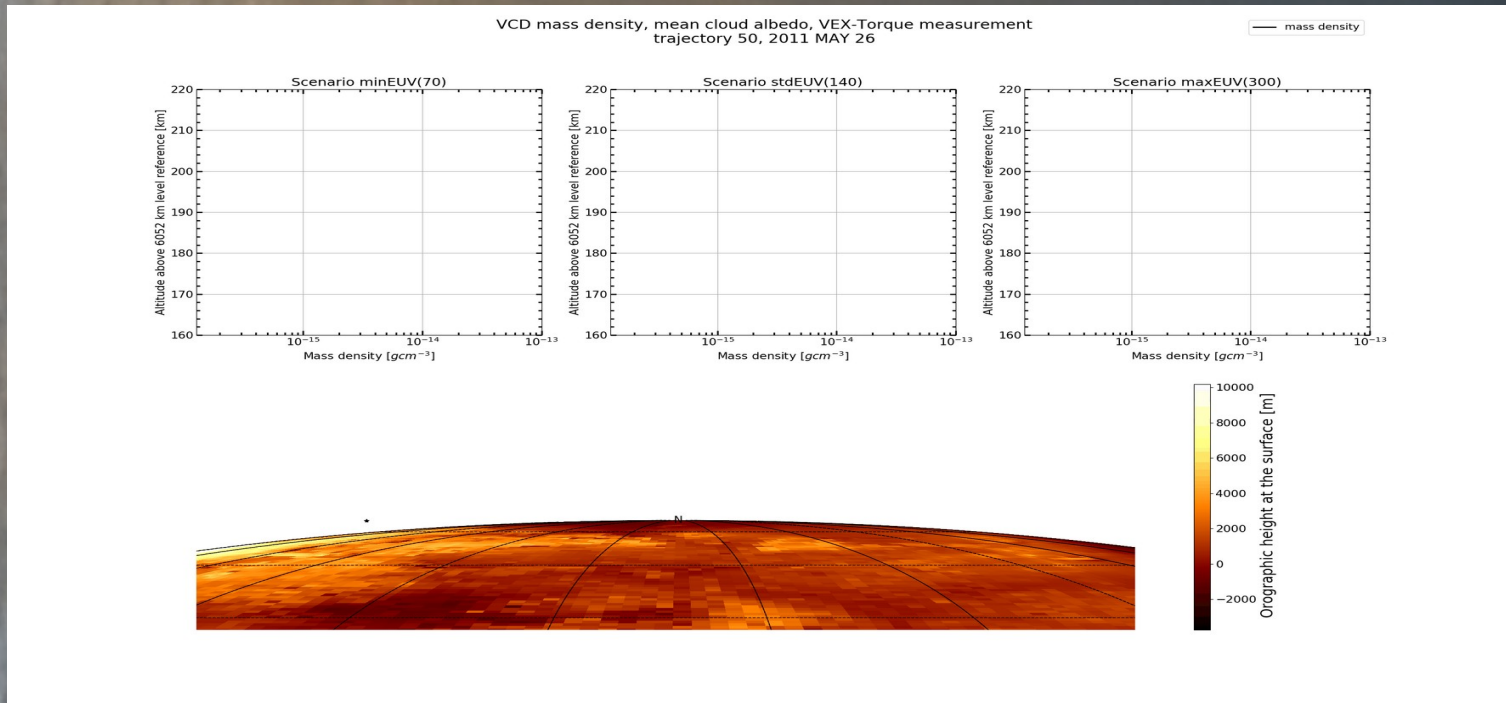
Examples of applications

Aerobraking example

VCD density, stdEUV(140), mean cloud albedo, VEX-Torque measurement
trajectory 50 from (75 N,9 W) to (87 N,170 E), 2011 MAY 26
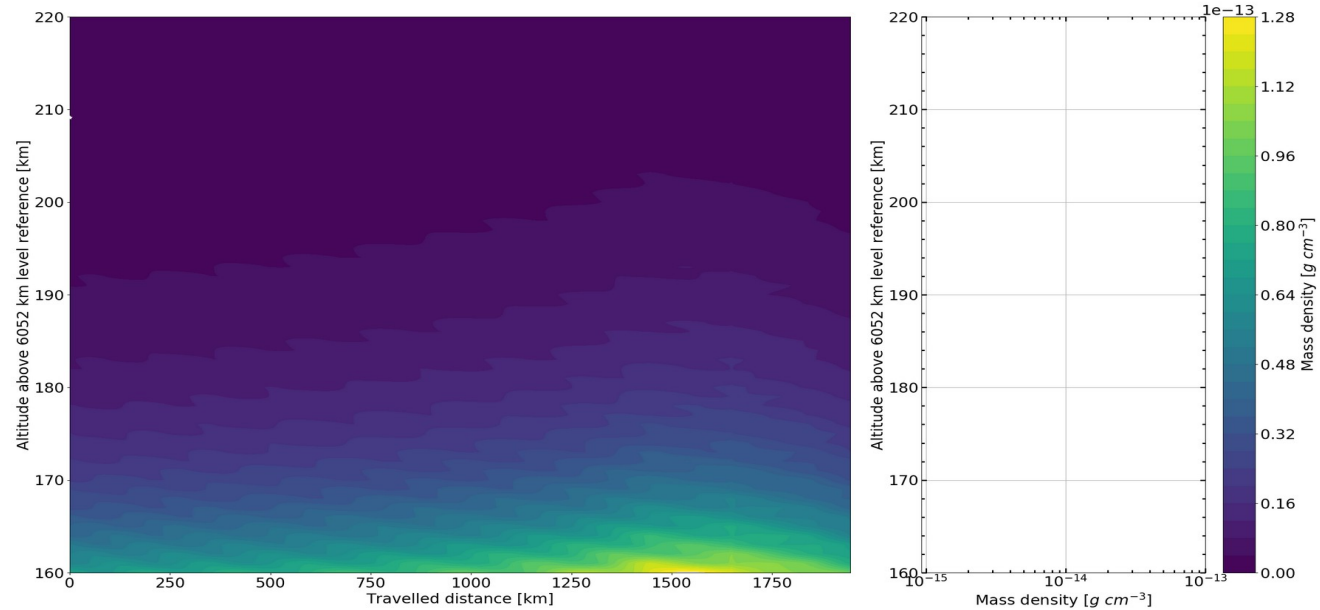
Examples of applications

Descent probe example

VCD wind speed, small and large scale perturbations, stdEUV(140), mean cloud albedo, DAVINCI trajectory 0
from (13 S,1 E) to (24 S,2 E), 2028 APR 10
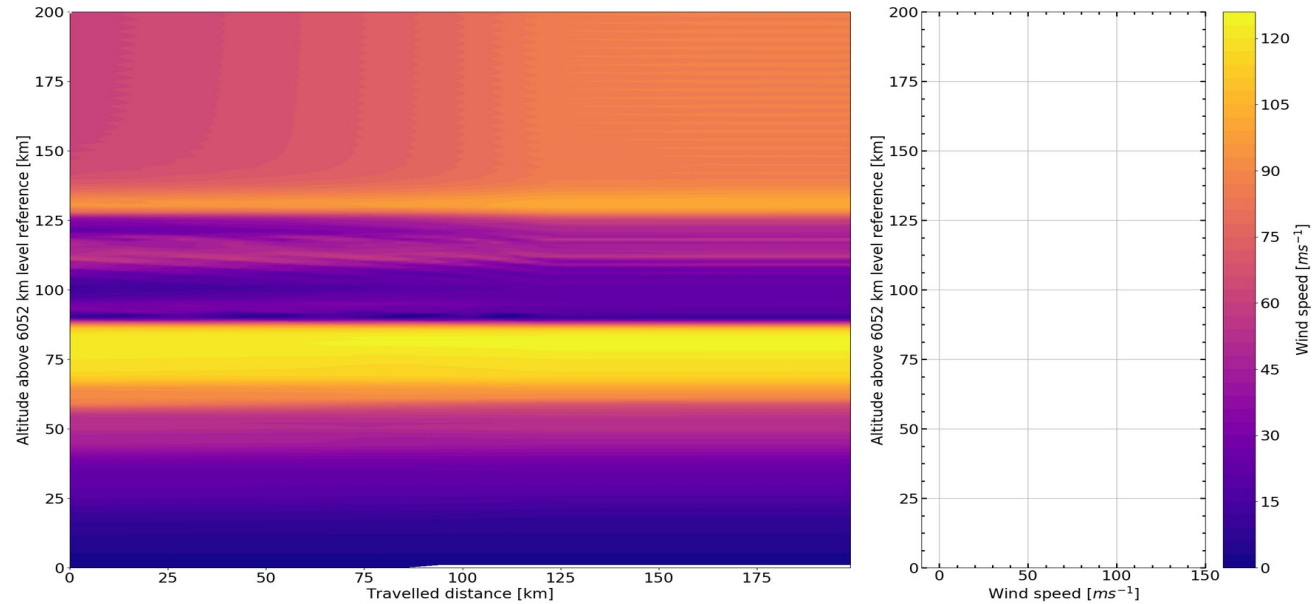
Using the VCD

The VCD access software is provided as a Fortran subroutine call_vcd which provides point-wise query that one should use in their own home-made codes

```
call call_vcd(z_key,z,lon,lat,hires_key,      &
              date_key,juliandate,            &
              localtime,dset,EUV_scena,       &
              albedo_scena,varE107,           &
              perturb_key,perturb_seed,        &
              perturb_gw_length,extvar_keys,  &
              zon_wind,mer_wind,vert_wind,     &
              temp,pres,dens,extvar,           &
              seed_out,ier)
```

INPUTS

OUTPUTS

See the VCD User Manual for a very detailed description of all inputs and output arguments

Various interfaces for the VCD

A full version with various interfaces: Fortran, C, C++, IDL, Matlab, Python...

A web interface for quick-look and plots: **http://www-venus.lmd.jussieu.fr/**

Future plans: Moving on to VCD 3.0

- A request by ESA (and some VCD users) : to have the possibility of obtain from the VCD, a "multi-GCM variability" evaluation (based on the range of predictions variation due to the difference in the climate models themselves).

- We have thus proposed to the community to gather "reference simulations" to integrate in the next version of the VCD, along a pre-defined protocol, with some positive responses from:
  - AFES GCM Team (including some ALEDAS-V assimilation), Japan
  - VTGCM Team, USA
  - TUGCM Team, Tohoku University, Japan
  - …

- To this day, only AFES & ALEDAS-V data has been obtained and processed, enabling the generation of a beta-version of VCD3.0. To be continued...

Illustrative example of VCD 3.0

Some profiles from VCD3.0 at same location and time but from the different models:

Illustrative example of VCD 3.0

Some profiles from VCD3.0 at same location and time but from the different models: